FRONTIERS IN SCIENCE EDUCATION RESEARCH

Proceedings of the Frontiers in Science Education Research Conference
22 – 24 March 2009, Famagusta, North Cyprus

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Edited by
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preface

This volume is the outcome of an international conference on science and mathematics education research held in Famagusta, North Cyprus, in 22-24 March 2009. It embodies the work of 130 scholars from 25 different countries, covering a wide area of education research in science and mathematics.

When we first started organizing this conference, we had three aims. The first was to provide a scholarly environment for promoting discussions in contemporary topics of undergraduate science and mathematics education research amongst professional science and mathematics education researchers, educators, students and all other interested parties. The second was to draw the attention of our colleagues at the Eastern Mediterranean University to the legitimacy of researching the teaching and learning processes within their own classes and disciplines. And third, to document, disseminate and share the outcomes of this endeavour. That we have succeeded in our aims may be seen from the varied and rich collection of participants and their articles presented in this book.

We also believe this book will prove to be a useful resource for practitioners and newcomers to the field; providing a wide selection of recent examples on methodology and theory. What we teach, why we teach and how we teach are questions inexorably tied up with what the learners should learn, why the learners should learn and how do the learners learn. We hope that this volume will illustrate how these issues are being handled in different disciplines and provide inspiration and guidance to others interested in the field.

We hope you will enjoy and derive as much benefit from reading this book as we have done preparing it.

Ayhan Bilsel
Mehmet U. Garip
Editors

Distinguished Keynote Speakers, Speakers, Academics, Students and Guests,

It is a great pleasure to welcome you all to the conference titled 'Frontiers in Science Education Research'. Eastern Mediterranean University EMU is honored to host yet another outstanding conference.

As I read the proceedings, I saw a wide range of topics ranging from Teaching and Learning Strategies, Technology in Teaching and Learning, Faculty Development, Teacher Training, to Contemporary Issues. The Keynote Papers on 'Remodeling science education, Teaching and Learning Science, Improving the teaching of science' are accompanied by numerous quality research papers that will draw attention to the frontiers, the latest developments and findings, cause invaluable discussions and enlighten what lies ahead.

With its accreditations and institutional memberships, students from 68 different countries, and faculty members from 36 different countries, EMU is an international institution that has Quality Education and Research at the top of her agenda. Intercultural dialogue is an everyday life here on campus. This is where we are strong. Moving from value to continual improvement, every effort we have is for considerable contributions to European Higher Education Area EHEA, European Research Area ERA, the harmonization of EHEA and ERA, World Higher Education and Research. This conference is one of several in this year to contribute to EMU efforts, efforts of the institutions of the participants, and the Higher Education Policies of world countries.

As a Mathematics Professor I am a member of science education discussion groups like Stanford and Cambridge. Looking at the topics here, I see that concerns and realizations are to contribute to latest research findings. I am sure that each and every one of the participants, the readers of the conference proceedings will contribute to and benefit a great deal from the conference.

I wish you all a fulfilling conference.

Once again, welcome to Famagusta, the Town of Science!

Best Regards,

Prof. Dr. Ufuk Taneri
President
Eastern Mediterranean University

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keynote papers

Proceedings of the Frontiers in Science Education Research Conference, 22 – 24 March 2009, Eastern Mediterranean University, Famagusta, North Cyprus.

Remodeling science education

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Abstract

Radical reform in science and mathematics education is needed to prepare citizens for challenges of the emerging knowledge-based global economy. We consider definite proposals to establish: (1) *Standards of science and math literacy* for all students. (2) *Integration of the science curriculum* with structure of matter, energy, models and modeling as unifying themes. (3) Pedagogy promoting *scientific inquiry* and argumentation. (4) Sustained *professional development* and support for teachers. (5) *Institutional support from local universities* for continuous upgrades in curriculum and teaching practices. Physics plays a central role in all these reforms.

Introduction

Rapid emergence of a global economy driven by science and technology has precipitated a crisis in the education systems of all nations. Radical education reform is needed to produce (1) *science literate citizens* and consumers, provide (2) w*orkplace readiness* (the technical foundation for an effective workforce), and maintain (3) a *technology pipeline* (educating scientists and engineers to sustain economic growth). However, the problems of systemic education reform are complex and must be understood before effective action can be taken. That understanding is what we seek here.

STEM Education has recently become a code word for the education crisis in the U.S. The acronym STEM for Science, Technology, Engineering and Mathematics was created within the National Science Foundation (NSF) as policy makers struggled to coordinate funding for comprehensive education reform. Unfortunately, planning and policy has lagged far behind the invention of acronyms. My purpose here is to describe the design and implementation of effective STEM education reform derived from decades of physics education R&D in the United States. Most of its components have been successfully tested, but full implementation still awaits adequate funding. Even so, I hope you find elements of the plan convincing and adaptable to STEM education in your own country.

Though problems of STEM education exist at all grades levels, they are most critical in the middle grades of the K-12 system, because that is where the personal orientation toward science and technology for most students is set for life. Accordingly, the first problem of STEM education is to establish standards for science and math literacy for all students; thus to provide them with functional knowledge and skills for active participation in society. Happily, appropriate literacy standards are already available, so the problem reduces to implementation and assessment to assure that the standards are met.

The STEM acronym reflects belated recognition of breakdown in the rigid separation of traditional academic disciplines driven by accelerating advances in science and engineering. Accordingly, the second problem of STEM education is to remodel the science and math curriculum in accordance with current science and technology. If students are to grasp the significance of advances in molecular biology and nanotechnology by grade 12, the traditional biology, chemistry, physics course sequence must be reversed. Physics must come first to introduce students to quantitative methods along with concepts of energy and the atomic-molecular structure of matter that run through the entire curriculum. Throughout the curriculum students must be engaged in scientific inquiry and explanation so they learn how to form and justify rational opinions on their own.

Ultimately, all reform takes place in the classroom, so the teacher is the critical component in implementation. Accordingly, the third problem of STEM education is developing and maintaining teacher expertise in science content and pedagogy. This is where educational systems fail most miserably. For development of genuine expertise requires continuous effort over a decade or more with stimulation from a professional community of peers.

This brings up the ultimate problem in educational reform: Establishing institutional mechanisms to promote high-quality educational change. Teachers and their schools lack the necessary *expertise* in science and technology as well as the *institutional resources* to keep up-to-date with advances in science content, curriculum materials and pedagogy. Those resources reside primarily in universities, especially in the math, science and engineering faculties. **As an *ENGINE to drive rapid, continuous and comprehensive K-12 STEM education reform*** in its region, each public university is advised to establish an Institute for sustained professional development and support of local STEM teachers.

Science and Math Literacy in Curriculum and Assessment

To set baseline goals for STEM curriculum design and assessment, developers are well advised to follow the internationally recognized *PISA framework for science and mathematics literacy* (2006).

In a landmark publication, *Science for All Americans* (Rutherford and Almgren, 1990), AAAS Project 2061 defined scientific literacy as the central goal of public STEM education. This was followed by a more detailed framework in *Benchmarks for Scientific Literacy* (AAAS 1993). Now, nearly two decades later, it is hard to detect a trace of this framework in the textbook-driven public education or the policies of the U.S. Department of Education.

Fortunately, the goals of scientific and mathematical literacy have been taken up with renewed vigor at the international level in creation of the *Programme for International Student Assessment* (PISA) by the Organisation for Economic Cooperation and Development (OECD). To date, PISA has assessed well over a million students in 60 countries. The 30 member nations of the OECD along with 27 partner nations that participated in the most recent testing cycle account for roughly 90% of the world economy.

PISA assessment is directed at students of age 15, because that is near the end of compulsory schooling in most OECD states. The goal is to assess student progress in acquiring *and applying* the skills and knowledge necessary to participate fully in the society of today. Analysis of the extensive results is available on the Web. Two of the most significant conclusions are: First, results of the highest performing nation, Finland, can in large part be attributed to its greater *equity* in educational opportunity. Second, in the best performing countries teachers are regarded as professionals; revered by society, the teaching profession is competitive, and governments in these countries ensure that the best and the brightest enter the profession through subsidies and intensive teacher training programs.

The point of greatest interest here is that design of the PISA assessment instruments is guided by a well-crafted *PISA Framework for Scientific, Reading and Mathematical Literacy* (Cresswell and Vassayettes, 2006) developed by outstanding international teams of domain experts. This framework is simpler and more practical than the Benchmarks, though it captures all the essential aspects of science and math literacy, and it has the great advantage of intimate ties to an internationally credible education assessment program. Accordingly, it can be recommended as a core component of a middle school curriculum framework and professional development program. PISA test questions are freely available to evaluate middle school programs, and the large PISA data base can be used to assess the significance of results.

The AAAS Benchmarks will remain a valuable resource for curriculum design, but we are mindful that it has a serious weakness (Thompson, 1994). In extolling the virtues of mathematical abstraction and rigor, Benchmarks has inadvertently promoted the unhealthy separation between math and science that exists in our schools today. In consequence, most math teachers have only the vaguest concept of science literacy and its intimate connection with math literacy. This flaw is corrected in the PISA literacy framework.

PISA as a framework for instructional design: "What is it important for citizens to know, value, and be able to do in situations involving science and technology?" (Cresswell et al, 2006, p. 20) This is the question that guided PISA scientific literacy framework writers. The competencies that they outline call upon students to demonstrate both cognitive and affective aspects of scientific literacy—the focus of the 2006 PISA assessment. The guiding principle in the development of the mathematical literacy framework is a need for the "capacity to identify and understand the role that mathematics plays in the world, to make well-founded judgments and to use and engage with mathematics in ways that meet the needs of that individual's life as a constructive, concerned and reflective citizen." (p. 72) The upshot for curriculum design is that the PISA math-science assessment items are situated in real world contexts.

Of particular note is the PISA emphasis on modeling as a means of framing both science and mathematics thinking and learning. That is illustrated by many excellent examples. Both mathematics and science items begin with problems that are situated in reality. To solve these problems the student must abstract relevant contextual information and arrange it into a conceptual structure (a model) that can then be manipulated to find answers to a series of questions. As seen below, this closely parallels the design tenets of modeling instruction for both mathematics and science. The PISA scientific and mathematical literacy frameworks provide an excellent source for development of *transdisciplinary* mathematics and science modeling materials for middle school students.

Quantitative Models: the core of scientific knowledge

A thorough analysis of the introductory physics course (Hestenes, 1997) reveals that a handful of basic mathematical models provides the essential structure for the entire subject. Here is the list along with a few hints of applications.

Basic Mathematical Models:

1. **Constant rate** (linear change): graphs and equations for straight lines (proportional reasoning, constant velocity, acceleration, force, momentum, energy, etc.)
2. **Constant change in rate** (quadratic change) graphs and equations for parabolas (constant acceleration, kinetic and elastic potential energy, etc.)
3. **Rate proportional to amount**: doubling time, graphs and equations of exponential growth and decay (monetary interest, population growth, radioactive decay, etc.)
4. **Change in rate proportional to amount:** graphs and equations of trigonometric functions (waves and vibrations, harmonic oscillators, etc.)
5. **Sudden change**: stepwise graphs and inflection points (Impulsive force, etc.)

These models characterize basic quantitative structures that are ubiquitous not only in physics but throughout the rest of science. Their applications to science and modern life are rich and unlimited. Accordingly, skill in using these models in a variety of situations is an essential component of math and science literacy. That skill should be cultivated deliberately and systematically with repeated activities throughout the STEM curriculum.

Integration of mathematics with physics should be strongly emphasized in the middle grades 7 through 9, and implicit throughout the curriculum. In modeling instruction, abstract mathematical concepts such as *variable*, *function* and *rate* can be explored within the context of mathematical models with concrete applications in physics and deployed to other subjects (i.e. chemistry, biology, economics).

By direct experience, students learn there is much more to a scientific model than the abstract structure of a mathematical model. In a scientific model variables must be related to observable experience and quantified with measurement procedures. Here they see another role for mathematics: statistical concepts such as mean, standard deviation, and error analysis are applied in the process of matching models to data collected by students using calculators, computer interfaces and measurement probes. Technology facilitates measurement and data-gathering, thus shifting the focus to data interpretation, model identification and analysis.

The ideal modeling curriculum begins in middle school with an emphasis on *proportional reasoning* as a first step in developing the concepts of *function* and *graphs* in *modeling motion* and money transactions. This is an ideal prelude to the central mathematical theme of *quantitative reasoning with models*. Quantitative reasoning with number and unit goes hand-in-hand with *modeling and measurement*, which couples the mathematics to the science (Lesh & Doerr, 2003a,b). A middle school workshop for teachers fleshes this out with a hands-on introduction to basic physical variables, including time, position, velocity, mass, density, temperature and energy. Proportional reasoning is an essential component of quantitative reasoning, so evaluation should be designed to compare results of instruction in both.

Modeling Instruction as *Instruction in Modeling*

The name *Modeling Instruction* refers to making and using conceptual models of real systems and processes (both natural and artificial) as central to learning and doing science and engineering. Though adoption of "models and modeling" as a unifying theme for science and mathematics education has been strongly recommended by NSES (1996). NCTM (2000) and AAAS Project 2061 (1993), no other program has implemented that theme so thoroughly as the *Modeling Instruction Project* for physics (See website), which is pioneering its extension to the entire STEM curriculum.

Modeling Instruction has much in common with *Realistic Mathematics Education* (RME), a teaching and learning theory in mathematics education developed by the Freudenthal Institute in the Netherlands (Freudenthal, 1991, 1993).

Modeling Instruction integrates a research-based, student-centered teaching methodology with a model-centered curriculum. It applies *structured inquiry techniques* developed in the Modeling Instruction Project to teaching basic skills in mathematical modeling, proportional reasoning, quantitative estimation, and data analysis. This contributes to development of critical thinking and communication skills, including the ability to formulate well-defined opinions and evaluate or defend them with rational argument and evidence. As found in the case of physics, extension of Modeling Instruction more broadly can be expected to produce significant improvement in student scores on standardized reading, writing and mathematics tests as well as in higher-order thinking.

A synopsis of the **Modeling Method of Instruction** is given in Box 1. Here are a few words to highlight unique features most responsible for its success. Its big difference from other approaches is that *all stages of inquiry are structured by modeling principles.* Typical inquiry activities (or investigations) are organized into ***modeling cycles*** about two weeks long (Wells et al, 1995). The teacher subtly guides students through the activities with **modeling discourse** (Hestenes 1997), which means that the teacher promotes *framing all classroom discourse in terms of models and modeling.* The aim is to sensitize students to the structure of scientific knowledge, in both declarative and procedural aspects. Its effectiveness is well established (Desbien 2002, Megowan 2007).

The culmination of student modeling activities is reporting and discussing outcomes in a whiteboard session (Wells 1995, Hestenes 1997). This may be where the deepest student learning takes place, because it stimulates assessing and consolidating the whole experience in recent modeling activities. *Whiteboard* *sessions have become a signature feature of the Modeling Method*, because they are flexible and easy to implement, and so effective in supporting rich classroom interactions. Each student team summarizes its model and evidence on a small (2ft × 2.5ft) whiteboard that is easily displayed to the entire class. This serves as a focus for the team's report and ensuing discussion. Comparison of whiteboards from different teams is often productively provocative. The main point is that class discussion is centered on visible symbolic student-generated inscriptions that serve as an anchor for shared understanding.

Box 1: Synopsis of the MODELING METHOD

The Modeling Method aims to correct many weaknesses of the traditional lecture-demonstration method, including the fragmentation of knowledge, student passivity, and the persistence of naive beliefs about the physical world.

Coherent Instructional Objectives

- To engage students in understanding the physical world by ***constructing and using scientific models*** to describe, to explain, to predict and to control physical phenomena.
- To provide students with ***basic conceptual tools*** for modeling real objects and processes, especially mathematical, graphical and diagrammatic representations.
- To familiarize students with a small set of basic models as the ***content core*** of science.
- To develop insight into the ***structure*** of scientific knowledge by examining how *models* fit into *theories.*
- To show how scientific knowledge is ***validated*** by engaging students in *evaluating* scientific models through comparison with empirical data.
- To develop skill in all aspects of modeling as the ***procedural core*** of scientific knowledge.

Student-Centered Instructional Design

- Instruction is organized into ***modeling cycles*** which move students through all phases of model development, evaluation and application in concrete situations — thus promoting an integrated understanding of modeling processes and acquisition of coordinated modeling skills.
- The teacher sets the stage for student activities, typically with a demonstration and class discussion to establish common understanding of a question to be asked of nature. Then, in small groups, students ***collaborate*** in planning and conducting experiments to answer or clarify the question.
- Students are required to present and justify their conclusions in oral and/or written form, including a ***formulation*** of models for the phenomena in question and ***evaluation*** of the models by comparison with data.
- Technical terms and concepts are introduced by the teacher only as they are needed to sharpen models, facilitate modeling activities and improve the quality of discourse.
- The teacher is prepared with a definite ***agenda*** for student progress and ***guides*** student inquiry and discuss5ion in that direction with questions and remarks.
- The teacher is equipped with a ***taxonomy*** of typical student misconceptions to be addressed as students are induced to articulate, analyze and justify their personal beliefs.

*Primacy of modeling over problem solving***.** In Modeling Instruction, problem solving is addressed as a special case of modeling and model-based reasoning.

Students are taught that the solution to a problem follows directly from a model of the problem situation. The modeling cycle applies equally well to solving artificial textbook problems and significant real world problems of great complexity. *This approach is readily transferred to mathematics teaching*, as math teachers who attend modeling workshops have learned!

The modeling method, with its emphasis on coherence and self-consistency of the model, is especially-well-suited to detection and correction of ill-posed problems, where the given information is either defective or insufficient. Moreover, students are thrilled when they realize that a single model generates solutions to an unlimited number of problems. A number of studies find that model-centered instruction promotes expert problem solving behavior in students (Malone, 2006, 2008).

Middle School Physical Science and Mathematics

Conceptual underpinnings for physics and chemistry that are important components of scientific literacy even for students who do not continue with the recommended sequence of more advanced courses should be addressed in a middle school *Physical Science* course. A workshop to prepare for teaching such a course is available in the MNS graduate program (PHS 534 in Box 2). The course is designed for grade 8, but can easily be spread out over grades 7 and 8. The course is intended for integration with middle school mathematics so both science and math teachers are encouraged to attend the workshop, especially in teams from the same school.

The course emphasizes *proportional reasoning* as a starting point for developing the concept of *function* and in relationship to *graphing* and *modeling motion* and money contexts. This is an ideal prelude to the central mathematical theme of *quantitative reasoning with models*. Quantitative reasoning with number and unit goes hand-in-hand with *modeling and measurement*, which couples the mathematics to the science (Lesh & Doerr, 2003a,b).

The workshop fleshes this out with a hands-on introduction to basic physical variables, including time, position, velocity, mass, density, temperature and energy. All essential concepts are introduced and developed through specific activities that are ready for immediate use with students.

We have space here only for an outline of topics addressed in the physical science course:

1. Modeling geometric properties of matter: size, shape and place.
    a. Measurement of length (rulers, units, congruence, accuracy)
    b. Measurement of area (dimension, size, shape and symmetry)
    c. Measurement of volume (units, irregular shapes, graphical relations of dimensions)
    d. Maps as models of place, size and shape (position vs. distance, scaling)
2. Physical properties of matter
    a. How much stuff? mass (measurement by balancing, conservation under change)
    b. Kinds of stuff: density (material kinds and states; smallest parts)

   c. Systems: boundaries and environments (open and closed, matter exchange)
3. Models of motion and interaction (mathematics of change, proportional reasoning)
   a. Particle models (displacement and motion maps)
   b. Measurement of time (clocks; position-time graphs: slope as velocity)
   c. Constant and variable velocity (measurement with motion sensors, acceleration)
   d. Kinetic energy (energy conservation and transfer in collisions)
4. Agents and interactions
   a. Forces (long and short range; gravitational, electric, magnetic)
   b. Interaction (potential) energy to hold bodies together
   c. Energy & change (change of state; thermal and chemical processes)
   d. Newton's Laws

Energy Thread for Physics First.

Although *energy* is a conceptual thread running through the entire science curriculum, it should be addressed most intensively in the ninth grade physics course focused on *Energy and Structure of Matter*.

A workshop on teaching such a course will be attractive to both physics and chemistry teachers at any level, whether or not they are interested in broader curriculum reform. Some course topics could be included in either physics or chemistry courses, so the importance of integrating those courses is obvious. The workshop is also recommended for teachers of ninth grade math, as they will include explicit designs for coordinating (if not integrating) math with physics.

Design of the *energy thread* should be guided by the need to teach physics as a foundation for chemistry. In particular, the usual Newtonian emphasis on force and motion should be reduced (but not omitted) in favor of internal energy and energy transfer, which play much greater roles in chemistry. The course design should incorporate innovations from physics education research over the last two decades. For example, the general energy conservation law (First Law of Thermodynamics) can be introduced from the beginning by modeling particles with internal energy. This decouples energy and momentum laws (which are inextricably linked in Newtonian mechanics). Among other things, it greatly facilitates the treatment of thermodynamics and the transition by analogical reasoning from macroscopic to microscopic (atomic and molecular) models of matter. Indeed, the ubiquitous role of energy conservation has led Alonso and Finn (1995) to coin the phrase "The Equation of Everything" for the First Law of Thermodynamics. This figurative expression nonetheless captures students' imagination and is a bit less imposing than the "First Law of Thermodynamics." By the way, this approach also corrects serious conceptual mistakes in energy arguments that are common in college as well as high school textbooks (Sherwood 1983, Arons 1987).

Energy storage and transfer serves as a unifying theme that binds the various topics into a coherent conceptual system. The emphasis should be on *qualitative reasoning* with models and diagrammatic tools such as *energy bar* *charts, pie charts and flow diagrams* to establish a solid foundation for energy arguments throughout the high school science curriculum, as well as for quantitative reasoning that follows.

In fashioning the energy strand, strong emphasis should be placed on *potential energy diagrams* as well as the concept of *potential*. Physics education research shows that exposure to and practice with the idea of potential in a mechanical context significantly improves subsequent student learning and understanding of electrical potential (Brewe, 2003). As students move on to chemistry, a solid understanding of electrical potential and potential energy changes will provide the foundation on which conceptual understanding of bonding and electrochemical phenomena can be built.

Finally, the physics course should develop at length the concept of electrical potential to explain binding of atoms and molecules as well as interaction of matter with light. But that is a well-known story so it need not be elaborated here.

Remodeling Chemistry.

Sad to say, the standard high school chemistry course begins with a whirlwind tour of internal structure of the atom, without providing either a rationale for the need to know this structure, or more than a cursory treatment of the evidence used to support the current view. As a result, the chemistry course relies heavily on rote learning, because the atomic theory needed for conceptual understanding requires a physics course. A physics course before chemistry is helpful but not sufficient to solve this problem. It is equally important to clarify the structure of chemistry by defining the models needed to explain particular chemical properties. Only from well-defined models can precise inferences be made. *Models that explain structure of the periodic table of the elements and mechanisms for chemical change are of central importance*. Pedagogically acceptable models will appeal to empirical evidence for a progressively more refined model of matter without resorting to quantum mechanical explanations that students are not prepared to understand. For example, empirical evidence is sufficient to infer the existence of quantized energy levels, so a model of the atom that accounts for the interaction of light and electrons can be developed without quantum mechanical justification. At the same time, a modeling chemistry course cultivates math literacy by stressing proportional reasoning over rote use of algorithms to solve a wide variety of problems (stoichiometry and gas laws).

A Modeling Model of Professional Development.

As forcefully argued in a landmark report by the *National Research Council* (1999), significant STEM education reform requires curriculum coordination across all grades. It cannot be achieved piecemeal, one course at a time.

Reforms of the K-12 STEM curriculum discussed above are as radical as they are necessary! Consequently, they cannot be achieved without intensive training and sustained support for inservice teachers. A model for this kind of professional development has been created and thoroughly tested by the Modeling Instruction Project (See website). It has been institutionalized at

Arizona State University as an integrated system of summer courses in a graduate program for inservice teachers (Box 2).

Box 2: ASU Catalog description of the MNS program

<http://modeling.asu.edu/MNS/MNS.html>

Master of Natural Science (MNS) in Physics for inservice teachers

- **Eligibility.** The program is open to inservice high school teachers who have completed college-level physics and one semester of introductory calculus. Under-prepared teachers can make up deficiencies in regularly scheduled courses.
- **Requirements.** A total of 30 graduate credits is required, selected from the *Courses in physics and physical science for teachers* listed below. A minimum of 15 credits must be taken in the "Teaching Methods" and "Integrated Science" categories listed there. This must include
- Six credits in "Methods of Physics Teaching," unless courses with an equivalent emphasis on physics pedagogy have been taken as an undergraduate.
- An Action Research Project for two or three credits.
- A minimum of six credits must be taken in the "Contemporary Physics" category. Graduate courses in physics or other natural sciences can apply toward the remaining credits if approved by the student's supervisory committee.

Master of Natural Science in Physics with High School Certification

This option is open to graduate students with a BS/BA in physics or a comparable background in engineering. Requirements are the same as for the inservice option, except that the following must be included for certification:

- EDP 510 Essentials of Classroom Learning, 3 credits from College of Education.
- RDG 507 Content Area Literacy, 3 credits from the College of Education.
- PHS 584 Student Teaching in High School, 8 credits to cover the state-mandated 8 weeks of high school teaching.

Including these 14 credits, a total of 36 credits is required for the degree with certification.

Courses in physics and physical science for teachers

Category I: Teaching Methods

PHS 530: Methods of Physics Teaching I (3)
PHS 531: Methods of Physics Teaching II (3)
PHS 534: Methods of teaching physical science (3)
PHS 593: Action Research in Physical Science (1-3)
PHS 598: Leadership Workshop (1)

Category II: Integrated Science

PHS 505: Energy and the Environment (3)
PHS 540: Integrated Physics and Chemistry (3)
PHS 542: Integrated Mathematics and Physics (3)
PHS 550: Physics and Astronomy (3)
PHS 556: Astrophysics (3)
CHM 594: Modeling Instruction in High School Chemistry I & II (3. 3)

Category III: Contemporary Physics

PHS 560: Matter and Light (3)
PHS 564: Light and Electron Optics (3)
PHS 581: Structure of Matter and its Properties (3)
PHS 570: Spacetime Physics (3)
PHS 593: Advanced Projects in Physical Science (1-4)

One of the most important lessons learned in the Modeling Instruction Project is that the student-centered, inquiry-oriented *modeling pedagogy* (Box1) cannot be transmitted through a book, even to teachers. It is a complex system of social practices that can be learned only from direct interaction with other teachers coupled to classroom practice with students. Even talented teachers cannot make fully effective use of Modeling curriculum materials without being introduced to them in a workshop of three weeks or more. Consequently, Modeling curriculum modules are distributed only in connection with workshops, though they are freely available for inspection on the Web by parties who are interested enough to ask for the password.

Ideally, universities should partner with local schools and school districts to organize STEM teachers into learning communities that support continued professional development for successful implementation of the new curriculum. Teachers should be introduced to the curriculum in workshops that promote collaboration in teams as they practice teaching it. Collaboration continues through the school year when, under leadership of a teacher who is proficient in modeling pedagogy, they meet regularly to resolve problems and discuss improvements in their implementation with students. This process can be continued to sustain reforms against inevitable teacher turnover. Induction of new teachers begins with the summer workshop that introduces them to the curriculum and continues in the supportive learning community with guidance from an experienced mentor. Indeed, it would be surprising if this arrangement does not improve job satisfaction and thereby reduce teacher turnover significantly

This ideal has yet to be fully implemented even in Arizona, owing to the profound inertia of school and university administrations.

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Teaching and learning science: Disciplinary knowledge and representation

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Abstract

This presentation forms part of the continually expanding research work that is aimed at improving learning outcomes in science and science related disciplines, and which is directed at informing the development of curriculum and its associated teaching and learning environment. Here, new insights are proposed through an exploration of how a scientific community crafts its particular ways of sharing knowledge and through a related theoretical modelling of the relations between a disciplinary way of knowing, disciplinary discourse, and the modality that identifies the parts of the discipline's semiotic resources. This modelling is then used to suggest implications that arise for teacher craft-knowledge.

Introduction

Taking semiotics to be about the production, interpretation and sharing of meaning that is enabled through discipline-created modes of representation (see Figure 1.), what does it mean to think about science teaching and learning from a semiotic perspective? It means coming to understand the experience of learning in terms of the "cultural communication system" of a particular science discipline, such as physics. This cultural representation system makes up the "language" of the discipline that is used to formulate, share, explore and evaluate knowledge, and to solve problems. From such a perspective, the learning of science may be regarded as the process of "coming to know" through the discursive representations that make up a discipline's "semiotic collection" (cf. characterizations by, for example, Kuhn 1962, Northedge 2002, 2003, and Östman 1998). In other words, physics, chemistry, biology etc. can be seen as having their own "semiotic domains" with each domain having its own specific "order of discourse" that is made up of "a structured set of conventions associated with semiotic activity (including use of language) in a given social space" (New London Group 2000, p. 20).

Taking teaching as being about making learning possible, I would argue that new and powerful insights await an exploration of teaching and learning of science, particularly in higher education environments, having such a semiotic appreciation. This is partially because for a long time now leading science educators have portrayed much of the learning challenge found in science education to be rooted in difficulties that learners have with constituting learning through what arguably can be seen as manifestations of personal and scientific "semiotic mismatches" (for example, see Driver & Ericksson 1983, Solomon 1983, Säljö 2000, and diSessa & Sherin 2000). It is also partially because learning is increasingly being explored in discourse terms in what I consider to be most interesting ways (for example, see diSessa 2004, Florence & Yore 2004, Lemke 1990, 1995, 1998, Northedge 2002, 2003, Roth, McGinn, & Bowen 1996, Swales 1990, Säljö 1999, Wickman & Östman 2002).

Using the background just outlined and by drawing extensively on work such as that done by Lemke (1990, 1995, 1998), Kress et al. (2001), Duval (2002; 2006), and diSessa (2004), John Airey and I have been exploring a constitution of a theoretical modelling of the relations between a disciplinary way of knowing, disciplinary discourse, and the modality that identifies the parts of the discipline's semiotic resources (for example, Airey & Linder 2009, Airey 2009). I will use the remainder of this presentation to expand upon what I see as new and interesting ideas for further informing the teaching and learning of physics, particularly in university physics, which is my work is situated.

Defining disciplinary discourse

Discourse, as a synonym for dialogue, conversation, communication and speech, has led to the notion of "disciplinary discourse" being taken to be synonymous with the specialized *language* that is used in a particular discipline. John and I see this view as being as unintentionally limiting. A way of overcoming this can be found in, for example, Hall's (1997), description of discourse. Hall describes discourse in terms of "ways of referring to or constructing knowledge about a particular topic of practice: a cluster (or formation) of ideas, images and practices, which provide ways of talking about, forms of knowledge and conduct associated with, a particular topic, social activity or institutional site in society" (p. 6). I also see Kress et al. (2001) notion of "affordances" (also, cf. Gibson 1979) as providing a powerful "generative metaphor" (Schön 1979) for our modelling of the modal relationship between disciplinary ways of knowing and the semiotic resources of disciplinary discourse and its implications for teaching and learning science (see Figure 1.):

> Several issues open out from this starting-point: if there are a number of distinct modes in operation at the same time (in our description and analysis we focus on speech, image, gesture, action with models, writing, etc.), then the first question is: "Do they offer differing possibilities for representing?" For ourselves we put that question in these terms: "What are the affordances of each mode used in the science classroom; what are the potentials and limitations for representing of each mode?"; and, "Are the modes specialized to function in particular ways. Is speech say, best for this, and image best for that?" (Kress et al. 2001, p. 1)

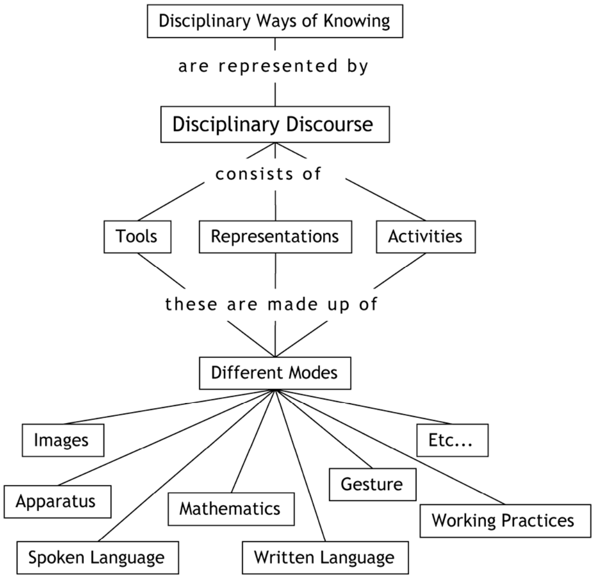


Figure 1. The modal relationship between disciplinary ways of knowing and the semiotic resources of disciplinary discourse (Airey and Linder 2009, p.29).

Figure 1. illustrates how I wish to unpack "disciplinary discourse" vis-à-vis such a collection of Kress et al's notion of "modes". Using the modelling in Figure 1. John and I have constituted a "semiotic resources" based definition of "disciplinary discourse" as *the complex of representations, tools and activities of a discipline* (Airey & Linder 2009, p. 27). I now expand on this definition by clarifying how I understand these terms.

(1) Representations. What is meant here are those semiotic resources that have been designed specifically to convey the ways of knowing of science. For example, oral and written language, images (e.g. graphs and diagrams), mathematics, gesture and so on. (cf. Ainsworth 2006; Givry & Roth 2006; Kress & van Leeuwen 2001; Roth, Tobin, & Shaw 1997; Roth & Welzel 2001).

(2) Tools. By tools what is mean are those abstract and concrete artifacts of science that authentically facilitate the doing of experimental work, problem solving and the framing of theory building (cf. Lemke 2003, Kuhn 1962, Roth & Lawless 2002).

(3) Activities. What is meant here are the activities that form an integral part of scientific activity that need to be assimilated and learnt by both new and established discipline members. This is a highly iterative process as new activities are continually evolving (cf. Crawford, Kelly, & Brown 2000, Kuhn 1962, Roth & Lawless 2002, and Wells 2000).

Using our definition of disciplinary discourse and its associated modelling that is represented in Figure 1., the modes of disciplinary discourse include not only the words, symbols, gestures, diagrams, formulae, etc. used by a discipline, but also the artefacts, pieces of apparatus, measuring devices, etc. and the actions, praxes, practices and methods that underpin a scientific discipline. Using this perspective, John and I argue that good teaching and the experience of good learning involves becoming "discursively fluent" in a complex myriad of semiotic resources. By discursive fluency I mean a process through which handling a mode of disciplinary discourse with respect to a given disciplinary way of knowing in a given context becomes unproblematic, almost second-nature (cf. Fairclough's 1995, "order of discourse"). So, if a person is said to be discursively fluent in a particular mode, then they have successfully come to understand the ways that the discipline generally uses that mode when representing a particular way of knowing. From this perspective, I would argue that science educators need to know much more about the relations between modes of representation, tools and activities, and the associated experience of learning to provide the best opportunity for intended learning to occur. However, this is not an area that has been well researched. Given that, in our model, John and I have the modes of disciplinary discourse having different possibilities for representing different facets of given disciplinary ways of knowing, we argue that the notion of mode-related "facets of knowledge" (cf. diSessa & Sherin 2000, Ainsworth 1999, 2006) should be an essential starting point for such research (see Tang & Yeo in review, Brookes & Etkina 2007, Van Heuvelen & Zou 2001).

Facets of knowledge

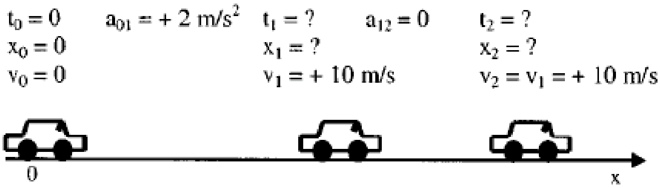
To illustrate what is mean by "facets of knowledge", the kind of diversity that may be involved, and its relevance for teaching and learning in science, I present three modes-of-representation examples, which I have drawn from physics. The first is a more or less standard set of representations that Van Heuvelen & Etkina (2006) have shown to be highly relevant for introductory physics. This example is illustrated for kinematics in Figure 2. in such a way that it requires no further explanation (extracted from Van Heuvelen & Zou 2001, p. 185). The second example is purposefully abstract; the differential geometry operators divergence and curl, which form an integral part of any intermediate introduction to electrodynamics. The third example is purposefully concrete; the application of a rule-bound procedure to enhance understanding by simplifying the analysis of complex electrical circuits; Kirchoffs circuit laws.

For the abstract example that is linked to differential geometry, we get the mathematics-mode representations of divergence and curl as given in Figure 3. When introduced to these concepts many learners in physics can successfully solve the mathematics for the problem-solving, but struggle to understand the meaning that underpins the mathematical procedure that they follow, and hence the associated physics and problem solutions being described by these equations.

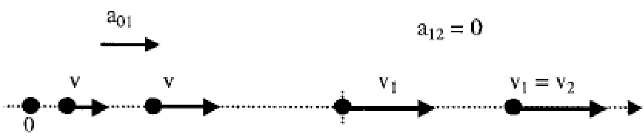
Verbal Representation

A car at a stop sign initially at rest starts to move forward with an acceleration of 2 m/s^2. After the car reaches a speed of 10 m/s, it continues to move with constant velocity.

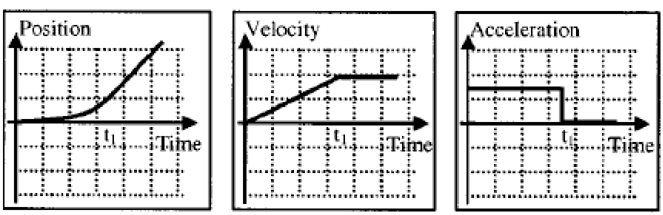
Pictorial Representation



Physical Representation (Motion Diagram)



Physical Representation (Kinematic Graphs)



Mathematical Representation

For $0 < x < x_1$ and $0 < t < t_1$	For $x_1 < x$ and $t_1 < t$
$x = 0 + 0 \bullet t + (1/2)(2\text{ m/s}^2)\,t^2$	$x = x_1 + (10\text{ m/s})\,t$
$v = 0 + (2\text{ m/s}^2)\,t$	$v = +10$ m/s

Figure 2. A basics set of representation modes for introductory kinematics (Van Heuvelen & Zou 2001, p. 185)

$$div\ \mathbf{F} = \nabla \cdot \mathbf{F} = \frac{\partial F_x}{\partial x} + \frac{\partial F_y}{\partial y} + \frac{\partial F_z}{\partial z}$$

$$curl\ \mathbf{F} = \nabla \times \mathbf{F} = \left(\frac{\partial F_z}{\partial y} - \frac{\partial F_y}{\partial z}\right)\hat{\mathbf{i}} + \left(\frac{\partial F_x}{\partial z} - \frac{\partial F_z}{\partial x}\right)\hat{\mathbf{j}} + \left(\frac{\partial F_y}{\partial x} - \frac{\partial F_x}{\partial y}\right)\hat{\mathbf{k}}$$

Figure 3. A mathematics-mode representation of divergence and curl.

Griffiths (1981) offers the following facet of knowledge of divergence and curl through a geometric-language-mode:

> Imagine you are standing at the edge of a pond. Sprinkle some sawdust or pine needles or something on the surface. If the material spreads out, then you dropped it on a point of positive *divergence*. Now float a small paddlewheel (a cork with toothpicks pointing out radially would do). If it starts to turn, then you placed it in a nonzero *curl*. A point of large curl is a whirlpool: a point of large positive divergence is a source (or Faucet); a point of large negative divergence is a sink (or drain). The vector function [**F**] in this model is the velocity of the surface water. As in the example for gradients, this function really depends only on *two* coordinates and has only *two* components – but I am trying to give a "feel" for what the divergence and curl are, **and it's a bit easier to do this in two dimensions**." (p 23, italics in original, bold emphasis added)

For the concrete example we look at Kirchhoff's voltage law (also known as Kirchhoff's loop rule). In a written-language-mode it could be represented as follows, "Since electric fields are conservative the total work performed in moving a test charge around a closed path is zero". In an oral language-mode it could be represented as follows, "The track-directed sum of the electrical potential differences around any closed circuit must be zero". And in the image-mode, in a very simplified form for this example, it could be represented as in Figure 4. (for, say, 4 circuit components).

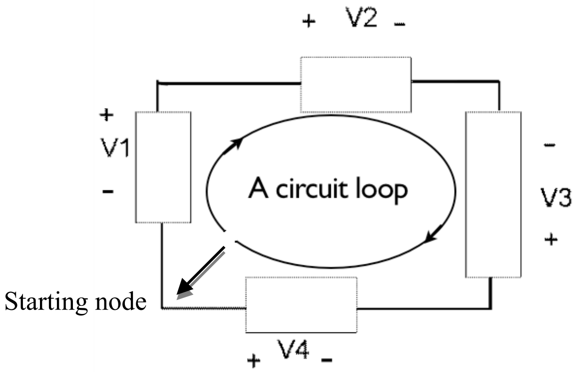


Figure 4. An image-mode representation of Kirchoff's voltage law (also known as the loop law). A closed loop means starting at any node in the circuit, trace a path through the circuit that returns you to your origin starting-point node. In writing KVL equations, the following convention is used: for a loss in potential across a particular element (i.e., + to -) give the voltage for that particular element a minus sign and vice-versa.

Then, a mathematics-mode representation would be as follows:

$$V_1 - V_2 + V_3 + V_4 = 0$$
$$V_2 = V_1 + V_3 + V_4$$
$$\sum_{n=1}^{N} V_n = 0$$

These are just four of the possible ways that a student could experience facets of Kirchoff's voltage law. Other experiences could feasibly involve circuit diagrams, demonstrations, hands-on activities (with batteries, wires, resistors, bulbs, voltmeters and ammeters), a table of voltages and currents for a given circuit, and graphical illustrations.

In their own ways, each of these modes used in the three examples provide access to facets of knowledge, which collectively bring a special kind of understanding, insight or application to the fore. Modes that were not included would probably have other facets that would, for a new learner, remain in the background or simply not be present. From this modelling we argue that it is thus only through an appropriate combination of a particular array of these modes that a holistic learning experience can be made possible (in a way, analogous to viewing a physical object from different angles). John and I illustrate this in an idealized manner (Airey and Linder 2009, p. 31-33) as in Figures 5. through 9.

In Figure 5. our hypothetical disciplinary way of knowing is taken to have an illustrative six separate facets (typically there could be less or many more facets), which are metaphorically shown as the sides of a hexagon. Figure 6. illustrates how a mode such as mathematics may open access to three of these facets, and Figure 7. how an experimental-mode may enable access to two further facets. Figure 8. illustrates a missing access to a facet of knowing, which is denoted by a question mark to illustratively reflect a lack of teacher craft-knowledge about the constellation of modes needed to enable access to a holistically complete representation of the given disciplinary concepts. In this spirit, Figure 9. illustrates how the addition of an image-mode (a diagram) may fail to represent this missing facet, but could provide a link between the mathematical and experimental modes.

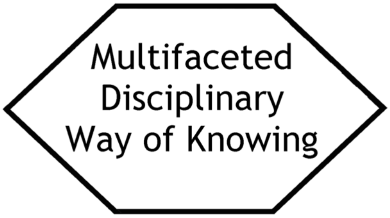


Figure 5. Disciplinary ways of knowing have multiple aspects or as we term them facets. Here we have an idealized representation of a disciplinary way of knowing using a hexagon. Each side of the hexagon represents one facet of the disciplinary way of knowing.

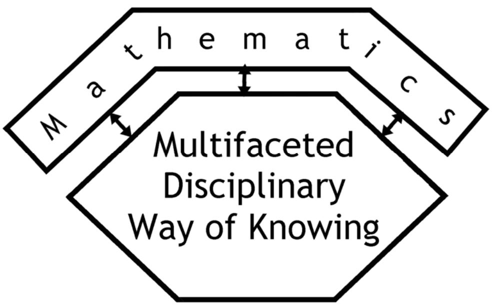


Figure 6. A representation using the mathematical mode of disciplinary discourse allows access to three facets of the disciplinary way of knowing.

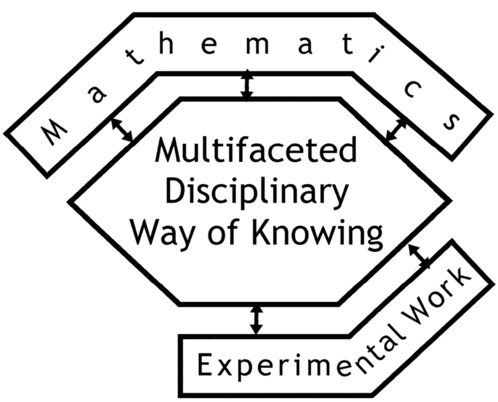


Figure 7. Experimental work allows access to two further facets of the disciplinary way of knowing.

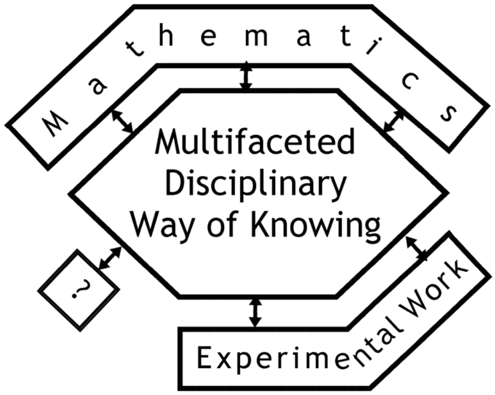


Figure 8. To complete constitution of the disciplinary way of knowing access to the sixth facet is still needed. Here we have chosen to label the mode which gives access to this final facet with a question mark, highlighting what we believe is the present situation in much science teaching: there is little teacher craft-knowledge about the particular constellation of modes that may be required to provide a holistically complete possibility for the learning of a given disciplinary way of knowing.

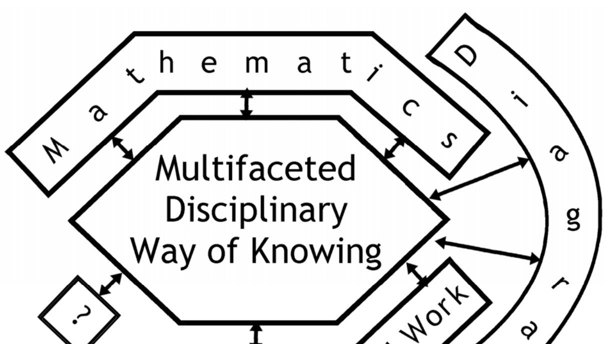


Figure 9. In this final figure, the visual mode is added in the form of a diagram. In this particular case, the addition of the diagram provides a link between the mathematical and the experimental modes, but complete holistic constitution of the disciplinary way of knowing is still impossible.

Modes and appresentation

The relationship between modes of disciplinary discourse and disciplinary ways of knowing can be characterized in terms of the phenomenological concept of *appresentation*, which is illustrated Marton and Booth (1997) as follows:

> …. in addition to what is "presented" to us—that is what we see, hear, smell—we experience other things as well. If we look at a tabletop from above, for instance, we hardly experience it as a two-dimensional surface floating in the air, in spite of the fact that what we see is, strictly speaking, a two-dimensional surface separated in some mysterious way from the ground. But in looking down on a tabletop we experience the legs that support it as well, because the experience is not of a two-dimensional surface, but of a table… That which is not seen, is not even visible is appresented … We wish to apply the concept of appresentation to experiences of abstract entities as well as concrete ones. If we think of the gravitational constant, g, for instance, then the highly abstract formulation made by Newton of how bodies affect one another at a distance is appresented, given that we have acquired sufficient education in and experience of classical physics (pp. 99-100).

In the modelling illustrated in Figures 5. Through 9. the idea of appresentation can be depicted as the ability to spontaneously infer the presence of further abstract and concrete facets of a disciplinary way of knowing, over and above those made available through the mode a learner has been presented with. Put in another way, while a single mode of disciplinary discourse can open up the possibility to experience a particular number of facets of a disciplinary way of knowing, in order to holistically experience this way of knowing, there are most likely to also be other facets of the way of knowing that need to be appresent. From here John and I argue that learners of a particular discipline may be unable to fully experience a disciplinary way of knowing *unless* two important criteria are met.

Firstly, at some stage they must have experienced each of the various facets of the way of knowing. This we argue entails multimodal representation, and we hypothesize that a degree of discursive fluency in a mode may be necessary before some of the facets of knowing that are made available by the mode can be appropriately related to the whole.

Secondly, they need to be able to experience these facets simultaneously (cf. the role of variation in learning, Marton and Tsui 2004); that is, when one facet or group of facets is presented to them through a particular mode of disciplinary discourse, the other necessary facets need to be appresent. We suggest this second criterion can only be met after a person has familiarized themselves with each of the relevant modes of disciplinary discourse sufficiently well that experiencing the various facets simultaneously becomes "second nature", or as we characterize it, when they have become *discursively fluent* in a *critical constellation of modes*. An important corollary is that in order to appropriately come to know and understand an intended object of learning, the object of learning must be experienced within an essential configuration of modes of representation.

Concluding thoughts

From the modelling and associated positing that I have presented it should seem unlikely that a limited number of modes can ever represent a holistic experience of an intended object of learning. Therefore, teacher craft-knowledge needs to include an appreciation of what modes are necessary to open up possible access to all the different facets of knowing needed for an intended object of learning. Also, drawing on a particular set of modes of representation in teaching could never be sufficient in itself. The possibility for learners to become discursively fluent in these modes is also critical.

At the same time I need to clarify that, although there are definitive parts of the semiotic and cognitive views of learning that in fundamental epistemological terms form essentially distinct series of "quantized" parts, I am not suggesting that the argued-for additional teacher craft-knowledge *replace* any of the other powerful learning insights that our science education community has brought to the fore. Instead, I am thinking much more in both supplementary and complementary terms. For example, I can see the possibility for good links to be made with applications of interactive teaching (such as, Mazur 1997) the phenomenographic based "Variation Theory of Learning" (Marton & Trigwell, 2000, Marton & Booth 1997), which posits that there are particular patterns of variation that are necessary for particular forms of learning (such as, Linder et al. 2006), and conceptual learning that is linked to reasoning in problem solving (such as, MacDermott et al. 2003) and the "modeling methodology" for enhancing teaching and learning (such as Hestenes 1997). Thus, I close by complementing the idea of a critical constellation of modes that are needed to further open up the *possibility* of intended learning with the idea that there is a critical constellation of *learning experiences* needed, one of which I have just shared with you.

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Improving the teaching of science through discipline-based education research: An example from physics

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Abstract

Research on the learning and teaching of science is an important field for scholarly inquiry by faculty in science departments. Such research has proved to be an efficient means for improving the effectiveness of instruction in physics. A basic topic in introductory physics is used to illustrate how discipline-based education research has helped identify certain conceptual and reasoning difficulties that are common among university students and pre-university teachers. The results have been used to guide the design of instruction that has brought about a significant improvement in learning. The type of research illustrated requires a deep knowledge of physics and ready accessibility to students as they study that subject. Both of these conditions are usually present only in physics departments, not in departments in which the primary focus is on educational theory and methodology. Although the context of this paper is physics, analogies can readily be made to other sciences.

Introduction

The Physics Education Group at the University of Washington (UW) has demonstrated that the learning and teaching of physics can be investigated in a scientifically rigorous manner. We have drawn on the results to guide the development of two sets of research-based curricula, which are widely distributed. Both are also research-validated, in that they have led to documented improvement in student learning. Our experience suggests that discipline-based education research can be an efficient means for achieving cumulative improvement in the effectiveness of instruction. Our emphasis has been on university students and on elementary and secondary school teachers, but we have evidence that this approach is also useful at other levels of education.

Many university science faculty view teaching solely as an art and maintain that it can never be a science. They seem to regard discipline-based education research only as a means for instructors to improve their own lectures. The goal of this paper is to demonstrate that this field of research can be an efficient means for achieving widespread and ongoing cumulative improvement in the effectiveness of instruction. The context is physics but analogies can readily be made to other sciences. In the discussion that follows, the examples used as illustrations are from a basic topic in physics that most science faculty have studied at some time during their secondary or university education.

Brief History

The Physics Education Group at the University of Washington consists of faculty, postdoctoral research associates, pre-university teachers, and graduate students. It is an integral part of the Physics Department. The group has welcomed many visiting faculty and graduate students, some of whom have joined us for an extended period of time. We conduct a coordinated program of research on student understanding, curriculum development, and instruction. Our graduate students earn a Ph.D. in physics (not in physics education). They meet all of the same requirements as all other graduate students in the Department. Since 1979, 22 have earned a Ph.D. through their research with our group.

Our group is unusual among physicists who conduct research in physics education in the U.S. because our involvement grew out of our work with prospective (preservice) and practicing (inservice) teachers. For more than 35 years, we have been teaching special courses in physics for preservice elementary and secondary school teachers during the academic year and conducting intensive six-week Summer Institutes for inservice teachers. (These have been supported by the U.S. National Science Foundation through a series of competitive grants.) We also offer a special weekly course during the entire academic year for all teachers who have participated in our Summer Institutes or in our academic-year courses for teachers. The development of our curriculum for the preparation of teachers has taken place in all of these instructional environments. In 1991 our research and curriculum development expanded to a major involvement in the introductory calculus-based physics course. We have since extended our research and development of curriculum to include more advanced physics courses.

Our two published curricula are *Physics by Inquiry (PbI)* and *Tutorials in Introductory Physics* (McDermott, 1996; McDermott and Shaffer, 2002). The first is a self-contained, laboratory-centered curriculum especially appropriate for the preparation of elementary and secondary school teachers that has also been used successfully with other students; the second is a supplementary curriculum consisting of tutorials that are intended for use with university students in conjunction with any standard introductory text. Both have been developed through an iterative cycle of research, curriculum development, and instruction. *PbI* has been translated into Greek, Polish, and Spanish. There are German, Greek, Korean, and Spanish translations of the tutorials.

The results from our research and curriculum development have been published in many articles. The context for the present discussion is geometrical optics. The reason for this choice is that almost everyone who has ever studied physics has had some experience in using a ray model to account for the reflection and refraction of light. This paper draws on papers in *AJP* (Goldberg and McDermott, 1987) and in *Optics and Photonics News* (Heron and McDermott, 1998).

Research perspective

The focus of research by the Physics Education Group is on the student as a learner, rather than on the instructor as a teacher. We try to identify specific difficulties that students encounter in the study of various topics. Several different populations were included in the research discussed in this paper: university students in introductory physics courses, elementary and secondary school teachers of physics and physical science, and graduate students whose research interests covered a wide range of subfields in experimental and theoretical physics.

The type of discipline-based education research that is conducted by our group is motivated by our interest in determining student understanding of physics content. Although the emphasis in this paper is on students in introductory university physics courses, we have found that elementary and secondary school teachers, and even physics graduate students, often have similar conceptual and reasoning difficulties. Our analysis of these findings guides our design of instructional strategies to address specific difficulties. Ongoing assessment is an integral part of this process. We have found that both the difficulties that we have identified and the instructional strategies that we have developed are often generalizable beyond a particular course, instructor, or institution. We work toward cumulative improvement in student learning through an iterative process of research, curriculum development, and instruction. We assess the effectiveness of our instructional materials through rigorous pre- and post-testing, document our methods so that they can be replicated, and report the results at meetings and in peer-reviewed papers. These procedures are characteristic of an empirical applied science.

Although experienced instructors know that there is a gap between what is said in lectures and what students learn, most do not recognize how large the gap can be. We have examined student understanding of many topics and have found that on certain types of qualitative questions, student performance is essentially the same: before and after instruction by lecture, laboratory, and textbook; irrespective of the level of mathematics; whether or not there is a standard laboratory; whether or not demonstrations are used; whether classes are large or small; and regardless of the proficiency of the lecturer. There is ample evidence that teaching by telling is ineffective for most students. Meaningful learning requires active mental engagement. The challenge, especially in large courses, is achieving the necessary degree of intellectual involvement. Much of our research has been directed toward responding to this challenge.

We use two general research methods: individual demonstration interviews (which allow deep probing into the nature of student difficulties) and written tests (which yield information on prevalence). Both methods provide a means for assessing student learning before and after instruction. Observations and interactions with students in the classroom lead to additional insights into how students learn best. The results inform the design of carefully sequenced questions in our curricula that are intended to address specific difficulties and to guide students through the process of constructing and applying a coherent conceptual framework in a variety of topics in physics.

Instruction through guided inquiry

Both *Physics by Inquiry (PbI)* and *Tutorials in Introductory Physics* engage students actively in the process of learning physics. In both curricula, teaching is by questioning, rather than by telling. The purpose of the questions that are asked is to force students to do the required reasoning for themselves. The ability to do, and to be able to articulate, the reasoning involved in applying a concept is emphasized. Our characterization of this mode of instruction is *guided inquiry*.

PbI is much more thorough than the tutorials. It is particularly important that teachers develop a deeper understanding of the material than most introductory physics students. There are no lectures in our special courses for teachers. We began developing *PbI* more than 30 years ago expressly for the preparation of elementary and secondary school teachers to teach physics and physical science. We have often found that elementary school teachers who have worked through *PbI* perform better on certain kinds of questions than physics and engineering students in introductory university physics courses. The tutorials are a "band-aid" approach, which is a compromise that satisfies the demands of a standard introductory physics course in which there is a great deal of coverage in very little time. Students are expected to work through all or most of a tutorial in 50 minutes. The same topic in *PbI* takes students several hours to complete.

Assessment of the effectiveness of both curricula is through pre-testing and post-testing that take place on a continuous basis. To ensure applicability beyond our own university, our instructional materials are tested at pilot sites that range from large universities to small colleges

Identification of student difficulties with geometrical optics.

In teaching geometrical optics, most instructors begin with the premise that students taking introductory physics at a university have a functional understanding of the rectilinear propagation of light. Most students can readily articulate that light travels in a straight line. They also seem to accept the idea that light rays travel outward from every point on an object and are converged by a convex lens to a corresponding point on an image. Moreover, almost all can use the thin lens formula ($1/s + 1/s' = 1/f$) to find the distance of an image from a lens, given the object distance and focal length. The two examples that follow show what many university students and pre-university teachers often cannot do.

Research Task: Real image formed by a converging lens While Fred Goldberg (now at San Diego State) was a visitor with our group during the 1980s, we examined how introductory students interpret the real image formed by a converging lens (Goldberg and McDermott, 1987). Fred conducted about 20 individual demonstration interviews with volunteers from the top half of their respective classes. Each interview lasted from 45 to 60 minutes. The questions posed were based on the apparatus shown in Fig. 1, which consists of a clear, brightly lit bulb, a converging lens, and the inverted real image of the filament of the bulb on a screen. The students were asked if anything would change on the screen if certain specified changes were made to the apparatus.

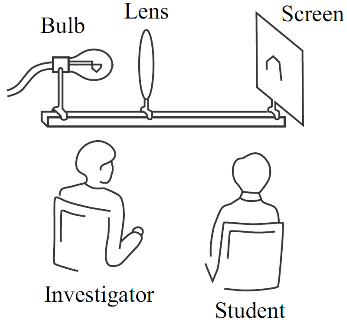

Figure 1. Individual demonstration interview.

The students were first asked what change would occur on the screen if the lens were removed. About half said that it would be right side up, apparently not recognizing the necessity of the lens to form the image. They seemed to think that the function of the lens was to invert the image. The students were also asked what would happen if the top half of the lens were blocked. Only about one-third seemed to recognize that even a very small part of a lens is sufficient to produce an image. The most popular response was "half a lens, half an image." When asked to draw a ray diagram, many of the students did not seem to understand that tracing the principal rays through a lens is an algorithm, or rule, for locating the image. The special rays are sufficient, but not necessary. In another task, the students were asked if anything would change on the screen if it were moved toward the lens. Fewer than half recognized that, if the screen were moved very far in either direction, no image would appear.

A multiple-choice version of these questions that was given to many students led to a similar outcome. The results were essentially the same whether or not students were enrolled in the accompanying laboratory course. Even more disturbing was the fact that the results did not depend on whether or not the students had studied this material in high school or whether or not they had just completed this topic in the university course in which they were enrolled.

Research Task: Geometric image formed by an aperture An investigation conducted several years later indicated that the difficulties that the introductory students had with the questions above were much more fundamental than a lack of understanding of the function of a lens (Wosilait et al, 1998). To determine whether they could apply a correct ray model in a situation not involving a lens, we asked more than 2000 students in the introductory calculus-based course to sketch the images produced on a screen when light from a single point source, two point sources, and a line source passes through a small triangular hole (~1 cm) in a mask. This question was also given to more than 100 graduate students in our Physics Department and to many pre-university teachers.

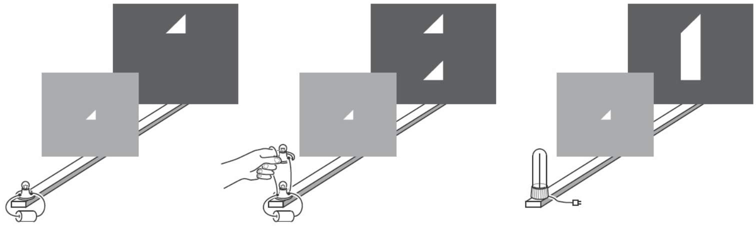

Figure 2. Pretest (with correct responses).

As in the tasks based on the converging lens shown in Fig. 1, memorized formulas do not help. A correct response depends on the ability to apply a correct ray model. To draw an appropriate diagram in the third case, students could treat the line source as a series of point sources, each of which produces a triangular image on the screen. Since the points are closely spaced, the images overlap and produce a vertical rectangle terminated at the top by a triangle.

Although the amount of prior instruction varied, the results did not. The percentages of correct responses for the three light sources by the introductory students were 90%, 60%, and 20%, respectively. The performance of the elementary and secondary school teachers who were asked this question was similar. The graduate students did better on the first two questions, but only about 65% gave a correct (or nearly correct) answer for the line source. The most common incorrect response in all three groups was that the image would be a stretched triangle.

Tutorials: an instructional approach for addressing student difficulties

The motivation for developing *Tutorials in Introductory Physics* was our desire to provide for introductory students at least some of the intellectual experience that *PbI* provides for teachers. We were faced with the challenge of trying to secure the mental engagement of students in large classes. Our one-year introductory calculus-based physics course has about 1000 students. There is the additional complication that all three academic quarters of this course (which at that time ranged from mechanics to physical optics) are taught concurrently. A great deal of material is covered very rapidly in lectures attended by 100-200 students. There are eight lecture sections with eight different instructors. Faculty rotate through the course on a cycle that varies from one academic quarter to three years. A weekly three-hour laboratory is part of the course. There are 45 laboratory sections. Although our faculty are conscientious in fulfilling their instructional responsibilities, the Department is strongly research-oriented. It would be unrealistic to ask the faculty to spend more time in teaching. We needed a system that would be practical, flexible, and sustainable. Our response to the challenge was the development of *Tutorials in Introductory Physics*, which is the core of the tutorial system that we have implemented in the course. We chose the word "tutorial" to distinguish the small-group sessions that are based on our curriculum from the recitation, discussion, or quiz sections traditionally associated with small-group science instruction in the U.S. The usual way of conducting such small-group sessions in physics is for a faculty member, or Teaching Assistant (TA), to work problems for the students, ask them to solve problems, or respond to questions (often with a mini-lecture). The tutorials that we have developed are very different in purpose and in structure.

Nature of the tutorials

The tutorials respond to the research questions: Is the standard presentation in textbook and lecture adequate to develop a functional understanding? If not, what can be done? The tutorials are intended to supplement, not replace, instruction by lecture, laboratory, and textbook. They are designed to target critical ideas and skills that are known through research and teaching experience to present difficulty to students. The emphasis in the tutorials is on constructing concepts, on developing reasoning skills, and on relating the formalism of physics to the real world, not on transmitting information and solving standard problems.

Description of the tutorial system

The tutorial system provides the context in which much of our research and curriculum development take place. Each tutorial sequence consists of a pretest, worksheet, homework assignment, and one or more post-test questions. The sequence begins with a 10-minute pretest (so named because it precedes the tutorial, although the material may have already been covered in lecture). The pretests, which are administered either in lecture or on the internet, have several purposes: to alert students to what they need to know and be able to do, to set the stage for the associated tutorial, and to inform the course lecturers and tutorial instructors about the intellectual state of their students. Most pretests have been designed to elicit known difficulties. During the weekly 50-minute tutorial sessions, about 20-24 students work collaboratively in groups of 3 or 4. The structure is provided by tutorial worksheets that have been designed to help students confront and resolve specific difficulties. The worksheets contain questions that try to break the reasoning process into steps of just the right size for students to become actively involved. If the steps are too small, little thinking may be necessary. If the steps are too large, the students may become lost unless an instructor is by their side. The tutorial homework assignments help students reinforce and extend what they have learned.

To secure the level of intellectual commitment necessary to bring about a significant conceptual change, the tutorials employ a variety of instructional strategies. One that has proved particularly effective can be summarized as a sequence of steps: *elicit, confront,* and *resolve.* The first step is to elicit a known difficulty by contriving a situation in which students are likely to make an error that exposes that particular difficulty. They then need to recognize the source of the error. Many students are willing to tolerate inconsistency. It is the responsibility of the instructor to insist that students confront and resolve underlying difficulties. If these are sufficiently serious and not addressed, they may remain latent and arise in other contexts. Tutorial homework provides additional practice that helps reinforce the ideas developed in the tutorials. The students are given the opportunity to *apply* the relevant concepts in related but different contexts, to *reflect*, and to *generalize.*

At least one-fourth of every course examination requires qualitative reasoning and verbal explanations. The students quickly learn that attending lectures and reading the textbook are not sufficient preparation. Questions based on the tutorials are included on every course examination and serve as post-tests.

Development of a tutorial: *Light and shadow*

We developed the tutorial *Light and Shadow* to help students apply two basic principles from geometrical optics: light travels in straight lines and light rays from every point on an object travel outward in all directions. The tutorial sequence begins with a pretest based on the apparatus shown in Fig.2 and described earlier. Guided by the results from the pretest, we designed a tutorial *Light and Shadow* (McDermott and Shaffer, 2002). It begins by asking students to predict the images formed by point and line sources with apertures of various sizes and shapes. After the students have made predictions and explained their reasoning to one another, they observe what actually happens and try to resolve any discrepancies with their predictions. They are then asked to predict and explain up-down and left-right inversions of images produced by asymmetric sources. These and other exercises help students recognize that the size and shape of the source, the size and shape of the aperture, and the distances involved can all affect the image. The students note that whether a light source can be treated as a point, a line, or an extended source depends on a variety of factors.

Systematic monitoring in the classroom helped improve the tutorial. One exercise was added that has had a pronounced effect. The students are asked to predict what they would see on the screen when a large frosted bulb is used as the light source. Many predict a triangular image and are surprised to see the inverted image of the bulb on the screen. They eventually realize that the entire bulb can be considered as a collection of point sources. Superposition of the images from the continuum of point sources produces an image that closely resembles the shape of the extended source, but is affected by the shape of the aperture at the edges, where fewer images of the aperture overlap with one another.

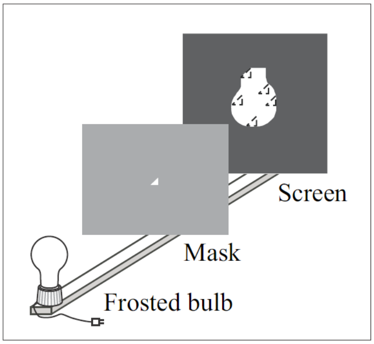

Figure 3. Image of frosted bulb resulting from superposition of images of triangular hole.

Assessment of the tutorial: *Light and shadow*

Throughout development of the tutorial, assessment played a critical role. Post-test questions were administered on different course examinations to about 360 students who had worked through the tutorial. Since the post-tests are always administered on course examinations, they provide accurate feedback on whether students have understood what they were expected to learn from the tutorial. Several of the post-test questions (with correct responses) are shown in Fig. 4.

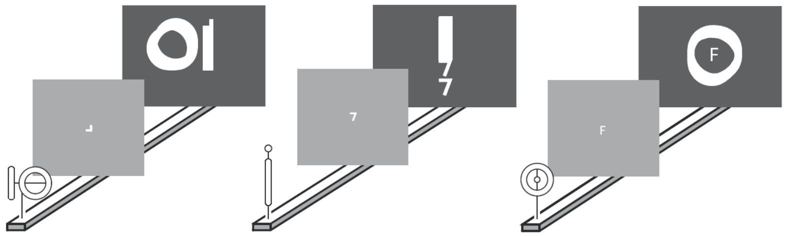

Figure 4. Post-tests (with correct responses)

We counted as correct, or nearly correct, all responses that indicated either that the extended source was composed of point sources or that the image was basically the same shape as the source. About 80% of the introductory students gave correct (or nearly correct) answers on the post-tests, as did about 85% of the prospective secondary school teachers who had worked through similar material in *PbI* (McDermott et al, 2006). This result represented a substantial increase over the 20% on the pretest. Only 10% drew images the same shape as the aperture, in sharp contrast to the 70% who made this error on the pretest.

Pretest scores on the long-filament bulb from 110 TA's and post-docs showed that about 65% gave a correct, or nearly correct, response. About 30% drew a triangular image. Comparison of their average scores with the post-test performance of the introductory students indicates that the undergraduates achieved a better functional understanding of this material than the graduate students initially had.

About 200 participants in our faculty development workshops have taken a pretest slightly more difficult than the one in Fig. 2. About 45% have given a correct, or nearly correct, response for the long-filament bulb. A few participants in our faculty development workshops have predicted a triangular image. After working through the tutorial, some have remembered that during a solar eclipse they had seen multiple images on the ground of the partially eclipsed sun beneath a canopy of leaves.

We have found, both from our own experience and that of other faculty, that even those with a Ph.D. in physics can deepen their understanding by doing simple experiments and carefully reflecting on the outcome. Our experience has been that voluntary time spent in working through a tutorial often varies inversely with the background one has had in physics. Faculty, post-docs, and graduate students frequently spend more time on a tutorial than undergraduates.

Requirements for successful implementation of the tutorials

There are two very important conditions that must be met for successful implementation of the tutorials in an introductory physics course. Students must understand the importance of the type of reasoning that they are expected to learn and the tutorial instructors must recognize that teaching by questioning demands more careful preparation than teaching by telling.

Importance of examinations. If students are to be expected to do the reasoning required for the development and application of concepts, they must be held accountable for developing the required skills. The most effective (and probably the only) way is to insist that they explain their reasoning on course examinations. Requiring students to give explanations challenges a common tendency to think of physics as a collection of facts and formulas. The tutorials would not have been nearly as successful in improving student learning at UW if post-tests had not been part of all examinations and, hence, a significant component of the course grade.

Preparation of tutorial instructors. The tutorial system would not work without ongoing preparation of the tutorial instructors in both the subject matter and the instructional method. Most of us teach as we were taught. It is unrealistic to expect peer instructors, graduate TA's, or faculty to be able, without preparation, to teach by questioning in a way that promotes development of reasoning skills. The instructors who conduct the tutorial sessions are Teaching Assistants (TAs). Most are physics Ph.D. students. Our research has shown that they often have the same conceptual and reasoning difficulties as undergraduates. However, knowing the answer to the questions on the tutorial worksheet is not adequate. It is much easier to give answers and explain why they are correct than it is to formulate questions that guide students through the reasoning involved. Instructors in the tutorials need to learn how to teach by questioning (rather than by telling). They develop this skill in a required weekly Graduate Teaching Seminar, which is conducted on the same material and in the same manner as the tutorial instructors are expected to teach. During the Seminar, the TAs examine responses given by students, try to identify their difficulties, and attempt to determine whether they have used correct reasoning.

Because the TAs take the same pretests as the introductory students, we have a measure of their level of understanding. Although they can generally solve the end-of-chapter problems, they often do not have a sufficiently strong command of the material for the type of teaching by questioning that the tutorials require. We have found that advanced study does not necessarily lead to a deeper understanding of introductory physics. We consider a tutorial successful when the performance of the introductory students on post-tests matches (or surpasses) that of the Graduate Teaching Assistants (TAs) on the corresponding pretests.

Efforts to substitute standard lecture-based instruction for tutorials

Some instructors have tried to adapt the instructional strategies in the tutorials to a lecture format. It is interesting to examine what happened when two professors, who were teaching different lecture sections of the same calculus-based course, decided that having students work through the tutorial *Light and shadow* would take too much class time. One of the classes consisted of honors students; the other was a regular section of the same course. Both professors were experienced and popular lecturers who liked our tutorials and were aware of the conceptual difficulties that they have been designed to address. Instead of asking their students to work through the *Light and shadow* tutorial, they showed demonstrations during their lectures and explained the ideas. They required their students to work through modified versions of the tutorial as homework.

On the pretest, the 30 students in the honors section had an average score of 25%, which was slightly higher than the average of 20% achieved by the more than 1000 students in the regular sections. On the post-test, however, the performance of students in the two sections taught by these professors was well below the average of all of the students who had worked through the tutorial. After doing the homework, the students in the honors section had an average score of 45%, while those in the other section had an average score of 35%. Moreover, the prevalence of the mistaken idea that the image mimics the hole in the mask was still quite high (40% in the honors section and 35% in the regular section). These percentages exceeded the 10% who made this error in all of the sections in which the students had worked through the tutorial.

Apparently, teaching by telling is not nearly as effective as teaching by questioning. It is insufficient for the instructor to give clear explanations, show demonstrations, assign problems for homework, and provide solutions. Even if the instructor is well aware of student difficulties, he or she cannot do the students' thinking for them. Their active mental engagement is necessary. For most students, intellectual involvement at a sufficiently deep level does not take place unless they are required to work step-by-step through instructional materials that have been carefully designed and tested.

The tutorials are designed to help make physics meaningful for students, to help them develop scientific reasoning skills, and to help them recognize that *how* we know is as important as *what* we know. Although the implementation of tutorials means that less time is devoted to solving standard textbook problems, success in solving quantitative problems is not diminished and is often increased. Placing a greater emphasis on qualitative reasoning thus raises standards. The tutorial system has proved to be practical, flexible, and sustainable in our research-oriented physics department. We have also been developing tutorials on more difficult material (e.g., special relativity and quantum mechanics) and have observed that students in more advanced courses welcome the opportunity provided by tutorials to deepen their conceptual understanding. We have found, that the same instructional approach also works well for these students.

Need for special courses for the preparation of teachers

Our group has conducted many studies that have included elementary and secondary school teachers. We have identified many of the same intellectual problems in this population as in others (McDermott et al, 2006). However, teachers must have an especially sound command of the material. They not only need to overcome their own conceptual and reasoning difficulties, but must also learn to recognize and be able to address the difficulties that their students are likely to encounter. Moreover, if they are to be expected to teach science as a process of inquiry, rather than as a compendium of facts to be memorized, teachers should have some direct experience in this way of learning. They should be given the opportunity to learn (or relearn) the physics that they are expected to teach in a manner that is consistent with how they are expected to teach. The time usually allotted for tutorials (~ one hour/week) is insufficient for this purpose. Special courses in physics are needed in which the development of a deep functional understanding of basic concepts is emphasized and instructional methods are taught by example (McDermott, 1974, 1990, 2006; McDermott et al, 2006).

Physics by Inquiry, which is more thorough than the tutorials, has been developed for such courses and has also been used with other populations. *PbI* is a self-contained, laboratory-based curriculum that we began to develop in the 1970s. It is the "ancestor" of the tutorials and is designed to help elementary, middle, and high school teachers develop the competence and confidence needed to be able to teach physics and physical science effectively. *PbI* provides the opportunity for teachers to learn (or relearn) science in a way consistent with how they are expected to teach. Two broad principles characterize this curriculum:

- Concepts, reasoning ability, and representational skills are developed together within a coherent body of subject matter.
- Physics is taught as a process of inquiry, not as an inert body of information.

Physics by Inquiry consists of a set of modules, all of which require active participation by the learner. In all of the modules, observations and simple experiments provide the basis on which students construct physical concepts and develop analytical reasoning skills. The development of concepts begins with observations made by students. Starting with a few plausible assumptions, the curriculum guides students through a chain of reasoning that enables them to construct conceptual models that they can apply to predict and explain the behavior of some common physical phenomena (*e.g.,* bulb brightness in electric circuits, geometric images formed by apertures, and phases of the moon). The topics have been chosen to provide K-12 teachers with the experience needed to be able to teach science in the K-12 grades by inquiry, rather than by lecture.

The preparation of teachers should emphasize intellectual development rather than wide coverage of many topics. Courses that provide an overview of contemporary physics can be inspiring, but they should not be considered a substitute for helping teachers develop a deep understanding of the basic concepts that have led to our present knowledge. The claim that one knows how to prepare teachers to teach their students about recent advances in physics should be carefully examined. Such courses may be inspiring for teachers but they are not adequate for preparing them to teach that material. The criterion that should be used in determining the validity of a claim that a teaching sequence has been successful with teachers (or students) should include information about the nature and depth of the assessment questions asked and the form in which the questions were asked. Such considerations are particularly important in determining whether teachers have been sufficiently well prepared to teach what they have been taught.

Research-based and research-validated curriculum

Until fairly recently our group was accustomed to referring to *Physics by Inquiry* and *Tutorials in Introductory Physics* as *research-based*. However, current overuse use of that term is creating a problem. Almost every new text today is promoted as research-based. What seems to be lacking is the recognition that *research-based* is not equivalent to *research-validated.* Just because one is aware of what students cannot do does not mean that one knows what to do about the situation. Unless instructional strategies have been shown to work reproducibly, merely stating that a text is research-based is not a strong recommendation. A higher standard is needed – one that is based on evidence, not on expectation or opinion. Both PbI and the tutorials are *research-based* and *research-validated*

Generalizations about learning and teaching

Several generalizations about learning and teaching that we have inferred from our research have guided the development of both *Physics by Inquiry* and *Tutorials in Introductory Physics.* (McDermott, 2001). Below, some of our generalizations about learning are paired with *italicized* generalizations about teaching.

- Facility in solving standard quantitative problems is not an adequate criterion for functional understanding. Questions that require qualitative reasoning and verbal explanations are essential to assess student learning. *The use of such questions is also an effective strategy to help students learn.*
- A coherent conceptual framework is not typically an outcome of traditional instruction. *Students need to go through the process of constructing models and applying them to predict and explain real-world phenomena.*
- Certain conceptual difficulties are not overcome by traditional instruction. (Advanced study may not increase student understanding of basic concepts.) *Persistent conceptual difficulties must be explicitly addressed.*
- Connections among concepts, formal representations (diagrams, graphs, *etc.*) and the real world are often lacking after traditional instruction. *Students need repeated practice in interpreting physics formalism and relating it to the real world.*
- Growth in reasoning ability does not usually result from traditional instruction. *Scientific reasoning skills must be expressly cultivated.*
- Teaching by telling is an ineffective mode for most students. *Students must be intellectually active to develop a functional understanding.*

Conclusion

There is a need in physics and other sciences for research on the intellectual development of students as they progress through a body of material. We attribute the effectiveness of *Physics by Inquiry* and *Tutorials in Introductory Physics* to the detailed knowledge of student difficulties that informed their development. The depth of understanding that is required for such research is found only among specialists in a field and therefore must be conducted by science faculty in science departments. When reported at professional meetings and in journal articles, the results provide a rich resource for all who teach. Thus, cumulative improvement in the effectiveness of instruction becomes possible.

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undergraduate curriculum

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A Cross-cultural study: Investigating college students' conceptions of the nature of science

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Abstract

The communal aspect of science includes consideration to the multicultural science as a meritorious enterprise that emphasizes discovery learning. This study attempted to gather information related to major aspects of what constituted the nature of science in a cross-cultural sample of 600 students from the United States, Cyprus, and Sudan. Students' conceptions of science were identified by using the Science Nature Survey (SNS) which is developed to assess college students' conceptions of science (Forawi, 2001). The study investigated three main questions. Analysis of variance, central tendency, and item analysis were measured used. Major results indicated 1) moderate conceptions of the nature of science exhibited by students in the three countries, 2) a statistical difference was found for the level of study, and 3) there were not any statistical differences found for country of origin and gender among participants in the three countries.

Introduction

Ortiz de Montellano (2001) indicated the importance of the communal aspect of science to its essential character. This communal aspect of science includes consideration to the multicultural science as a meritorious enterprise and the movement toward the discovery approaches to learning. This study attempted to gather information related to major aspects of what constituted the nature of science in a cross cultural sample of 600 students in the United States, Cyprus, and Sudan. Students' conception of science was identified using a Science Nature Survey (SNS), a survey developed as part of National Foundation of Science project to assess college students' conceptions of science.

Science educators most often use the phrase nature of science (NOS) to describe the interplay of disciplines informing science education about what science is and how it works. The nature of science, according to Clough (2000), is a fertile hybrid arena including the history, sociology, and philosophy of science combined with research from the cognitive sciences such as psychology into a rich description of what science is, how it works, how scientists operate as a social group and how society itself both directs and reacts to scientific endeavors. The interaction of various social studies of science is where the richest view of science is revealed for those who have but a single opportunity to take in the scenery (Kuhn, 1970).

Several studies have documented student misconceptions of science and how it works (Corder, 2007; Forawi, 2000). The significant misunderstandings that both students and teachers hold regarding the nature of science are particularly damaging to general scientific literacy because they affect students' attitudes toward science. For example, Niaz (2000) interviewed a number of successful science students and reported that they had become disenchanted with science classes and had chosen different majors, in part, because teachers ignored the historical, philosophical, and sociological foundations of science.

As the world becomes increasingly scientifically oriented, individuals need an adequate understanding of science. The expanding global economy demands a populace that is adequately educated in science and knows its nature and its technological implications. The goal of "science for all" in the United States has emphasized this global direction of reforming science education.

Questions of Study

The study investigated four questions: 1) What conceptions of science do college students hold in the study?, 2) are there any statistical differences among the students' conceptions of the nature of science in the three samples, Cyprus, Sudan, and United States?, (3) are there any differences between students' country origin, gender, and college year of study in the three countries?, and (4) what are the most common science conceptions held by students in the three countries?

Participants and Instrument

The Science Nature Survey developed by Sufian Forawi (2001), one of the authors of this study, as part of a National Science Foundation grant project, to measure students' and teachers' conceptions of the nature of science. This instrument consists of 24 discriminating-reliable combinations of items. Six major constructs were identified from the literature and science education practices to best represent contemporary perspectives of the nature of science. These constructs represent scientific knowledge as developmental, parsimonious, testable, culturalistic, tentative, and investigative. Some of the items are positive and others are negative, to account for accuracy and more attention from participants. Three science educators judged the model's soundness and found it to be representative of the nature of scientific knowledge. Participants responded to the items by using a five point Likert scale labeled "strongly agree," "agree," "neutral," "disagree," and "strongly disagree." A maximum score of 120 points for the entire survey is possible. The least score is 24 points. The reliability coefficients for overall Science Nature Survey scores were calculated using Cronbach's alpha internal consistency coefficients (0.80). This reliability indicated that the NSKS scores could objectively and reliably discriminate between groups in this study. These reliability coefficients were similar to reliabilities in previous research with similar sample size (Forawi, 2000; Meichtry, 1992).

Results

The sample size of the study consisted of a total of 600 students from the three countries, Cyprus, Sudan, and the United States. Majority of participants were females (52%). Only Sudan's sample included more male students than female. There were more seniors, juniors, and graduates (180, 167, and 108 students) participated in the study than freshmen and sophomores (52, 93 students). Total participants of samples in the three countries were 204 Cyprus, 190 Sudan, and 204 U.S.

The students in the study administered once the Science Nature Survey (SNS), an instrument aimed to identify the conceptions of the nature of science. Data were analyzed by the use of SPSS to provide tables of ANOVA and central tendencies measures. Table 1 presented means, standard deviations, and ranges of scores of students in the three countries. The means score of the total number of participants on the Science Nature Survey showed a moderate mean (80). This result answered the first question of this study. College students, in this study, held moderate conceptions of the nature of science as measured by the SNS instrument. While most mean scores tended to fall in the contemporary area, students' did not exhibit a clear understanding of the nature of science (Overall Mean = 80). Score of less than 60 points is considered as not exhibiting a contemporary view according to the SNS instrument. This result was found to be consistent with similar research results (Forawi, 2001).

Table 1. Means, Standard deviations, and Ranges of Students SNS scores (n=600)

Country/Item	Mean	SD	Min	Max	Range
Cyprus	80	7.02	68	102	34
Sudan	76	6.71	61	86	31
U.S.	84	8.76	73	108	35

The following section presents the major ANOVA results as presented in Table 2. The data analysis revealed important results that were discussed and summarized as follows. There were no significant differences among the students' Science Nature Survey in the three countries ($p<.11$).

Table 2. ANOVA Results for All Participants' Scores of SNS

Source	Sum of Sq.	DF	Mean Sq.	F	Sig. of F
Country of Origin	1336.39	2	80.10	12.75	.11
Level of Study	851.16	4	170.79	5.16	.001
Gender	1222.36	1	153.51	8.44	.508

Only the factor of level of study has shown a highly significant difference ($F=5.16$; $p< .001$). This result indicated that students' level of study was significantly influential in determining students' conceptions of the nature of science in this study. Unlike the origin of country and gender factors, the level of study factor has shown a significant different among the different college level of study from freshmen, sophomore, junior to senior students' understanding of the nature of science as measured by the Science Nature Survey. As indicated, students' scores have shown an increase from freshmen, sophomore, junior, senior and graduate.

As college students progress in their program from one year to the next, their conceptions of the nature of science seemed to increase. Reform of science education has continuously emphasized educating teachers about the nature of science and scientific enterprise (AAAS, 1993; NRC, 1996; Forawi, 2000; Turner & Sullenger, 1999). However, conceptions of the nature of science held by college students have yet needed to be examined. This study identified conceptions of the nature of science held by college students and their various influential factors. A major question in this study pertained to how these factors influence the conceptions of science of college students. Only the college level of study indicated a positive impact on students' conceptions of the nature of science.

The last questions related to the common conceptions that most students globally hold. By examining the items of the Science Nature Survey that most participants checked, two items were found to be rated as highest. In only two items (# 7 and #13), almost all the students had checked the same responses by a frequency average of over 4 point out of 5. These two items relate to presenting the nature of science as developmental and ever changing process. This result showed that most college students, across the globe, had the same strong conviction of scientific knowledge as ever changing discipline and that the beliefs of science do change over time.

> "Scientific theories may be changed due to new evidence."

> "Scientific facts are changeless."

Another item (#9) was equally found to be identified, at the highest rate, by almost all participating college students. The statement is stated below. It relates to the construct of science as investigative process.

> "Scientific work deals with products and processes where facts, concepts and theories are produced through defined methodologies."

Other items were checked by majority of students to reflect a contemporary notion of the nature of science that influenced their overall scores.

Conclusions

Many efforts have been made by researchers to explain what we mean by the nature of science. History of discussion about the nature of science in the United States has coincided with goals of enhancing science assessment and teaching. Earlier National Science Foundation and other reform initiatives were seen as lacking of promoting true nature of science and concentrating on only what scientists do (Akerson, Hanson, & Cullen 2007; Matthews, 1999; Turner & Sullenger, 1999). Those reform agenda called for understanding the structure of science as synonymous with the nature of science. Mach and Dewey through

Bruner, Schwab and Robinson viewed the understanding of the nature of science as an 'internal' matter for those learning science. They did not see a place to the nature of science for those not majoring in science.

The literature review of science education indicated the importance of promoting adequate conceptions of the nature of science. Extensive research over the past half a century has investigated teachers' and students' conceptions about the nature of science. Many of these studies contradicted their results in identifying factors that determine the nature of science (Rodregis 1998; Forawi, 2001). Despite this conviction, the nature of science has continued to be inadequate. The present study investigated college students' conceptions of science and their country origin, level of study and gender influences. A major result indicated high significance different among different levels of program study. Students' conceptions of the nature of science have found to increase from freshmen to sophomore, junior, senior, and graduate. Finally, a research implication of this study would be to use its methods to collect more data across different nation and ethnic regions to further examine college students' conceptions of the nature of science.

Finally, the twenty first century requires science educators, globally, to accurately measure the nature of science. This study used a new instrument, the Science Nature Survey, which was developed as a result of an NSF grant to assess college students understanding of the nature of science. The use of the Science Nature Survey, in this study, assisted to advance the research efforts in investigating college students' conceptions of science. The use of cross-cultural samples was considered beneficial. Additional research is needed to identify aspects of science classroom experiences that may or may not influence students' conceptions of the nature of science.

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Experiences of causality of attrition: a perspective from former physics undergraduate students

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Abstract

In the natural sciences, particularly in physics, attrition phenomena have a strong international similarity: it is not unusual to find that 40-50% of the students terminate their studies prematurely. Drawing on a discourse analysis perspective developed by James Gee new insights into why students decide to terminate their undergraduate physics study were reached. The data was obtained from interviewing a purposeful sample of seven former Swedish physics students, probing into the experience of learning as rooted in social-identity formation. The 'introspective' discourse model presented here illustrates how decisions to terminate studying can be reflectively considered, across a broad range of student profiles, through the use of a logic of causality that is much less about the experience of the education environment, and much more about personal agency, than previously anticipated or described in the literature. The discourse models are discussed in terms of implications for the informing of evaluation praxis.

Introduction

On average, the fraction of formally qualified people who commence, but do not finish tertiary level physics studies in Europe lies in the area of 50% (European Commission 2004). To address this problem, it is necessary to research into reasons for attrition.

In this paper we report findings concerning the way a group of former students related the logic of causality (i.e. how they appear to make sense of the events) that in their retrospect opinion led them to decide to leave the physics programme at a traditional Swedish research university. Studies of Scandinavian youth cultures make us expect that this way of reasoning can be encountered by anyone engaged with evaluating praxis, and we argue that in order to gain insights into aspects causing attrition, one will benefit from taking into account the finding reported here.

First we describe how the notion of communities of practice can be used in realizing issues of students leaving as processes of exclusion. Secondly we define attrition and thirdly we introduce Gee's construct of *Discourse models* (Gee 2005). Finally we bring out excerpts from student interviews to exemplify and illustrate the way interview participants consistently turned reflections on reasons for leaving inwardly. We suggest that using this realization as an analytical lens, causes and problems inherent to the institutional contexts can be accessed even though they are not explicitly stated by interviewees. Due to page-number limitations we do not, however, bring to the fore considerations on interview method and study setup. For the interested reader we refer to a more elaborate report of the study of attrition (Johannsen 2007).

Student communities of practice

Lave and Wenger (1991) describes the transformation of the successful learner's developing identity as ranging from being one of *legitimate peripheral participation* in a community of practice to becoming that of an experienced member of the community. Later Wenger (2003) elaborated on the membership of a community of practice as conditioned by a *shared repertoire*. This shared repertoire consists of resources for the negotiation of meaning such as routines, words, tools, ways of doing, stories, symbolic gestures and artefacts, and concepts produced or adopted by the community (*ibid*). The shared repertoire of a community, as for instance the community of first-year physics-students, is far from unambiguous or pre-established. A new student will on the day of arrival at the university enter into a community of new physics students, but this community can also be perceived as a community of legitimate peripheral participators in the larger community of physics students. This community, in turn, is to some extent applying for membership in the community of physics practitioners. This membership is not guaranteed by graduation, but will, to significant extent be conditioned by graduation.

In all community-spheres negotiation is taking place. New students are allowed to participate in negotiation at, at least one level (the community-sphere of new students), but at others, they must adapt to pre-established norms. For instance issues concerning the objective of different courses and the decision of whether such objectives are met by the students (i.e. through assessment) are decisions made by teachers. Even though rationales are often explicitly stated in course- and programme-descriptions, much information is implicitly rooted in and carried by modes of teaching conveyed-in-action by the teachers and in the structure of the study programme. Since practice is often different in different courses at different times, these differences give rise to a certain dissonance between ways of seeing the discipline (Rump and Ulriksen 2005, Ulriksen To appear). Each student must figure out ways to either reconcile or dismiss this dissonance, either alone or in the negotiation of membership with different communities – for instance by talking to more experienced students, in discussion with peers or by imitation.

Returning to Wenger's (2003) social theory of learning, the ability to comprehend and navigate among what is considered 'correct' behaviour in a physics education setting is very similar to mastering the 'shared repertoire' of a community of practice. Yet Wenger insists that becoming and being a member of a community is an ongoing negotiation of meaning because the shared repertoire 'reflects a history of mutual engagement and remains inherently ambiguous'. Wenger (2003) continues (p. 83): "ambiguity is not an absence of or a lack of meaning. Rather, it is a condition of negotiability and this is a condition for the very possibility of meaning."

Drawing on Bourdieu's notion of symbolic violence – the unavoidable social reaction to individuals' break with non-negotiable norms of social conduct (cf.

Bourdieu 1990, Jenkins 2002) – we might understand better the processes of attrition as a form of social exclusion leading students to decide to leave their studies. Behaviour of individuals found to be indications of a lack of mastery of the shared repertoire is to some degree rendered 'meaningless' relative to the behaviour of the community. Hence we perceive of exclusion or self-exclusion (because of course norms of social conduct is a matter of perspective) as the consequence of recurring breaks with norms of social conduct of the institutional culture. That this notion is not a mere theoretical construct is plentifully supported in literature. For instance Tobias (1990) who found that young people avoid science subjects, not because they lack in talent, but because they are *different*, Seymour & Hewitt who found that talent notwithstanding, students not of a traditional white male personage had greater chance of leaving than other student-types and Hasse (2002) who found that for physics students to include other physics students into their work, certain behavioural 'codes' had to be shared among the group.

Thus perceiving attrition as the result of a cultural incommensurability (that of the institutional context, and that of the individual student's) we decided that interviewing students who left their studies prematurely was one viable way of gaining insight into what 'breaks' with norms of social conduct drive the exclusion-process of large fractions of new physics students.

Defining attrition

Taking departure in Tinto's (1975) theoretical synthesis of dropout from higher education, we felt an important part was missing. Tinto stresses the necessity for distinguishing between students that leave higher education entirely, and students who merely transfer to other educational programmes within institutions of higher education. If not, he argues, it leads "state planners to overestimate substantially the extent of dropout from higher education" (*ibid,* p. 90). Admittedly, such a perspective might be fruitful at a societal level, but it is also a cause for confusion: Based on OECD (2004) 'survival rate' indicators (output divided by input) Langen and Dekkers (2005) find an inverse relationship between university survival rates (Sweden 48%, Netherlands 69% and the UK 83%) and tuition fees and provisions for student support. Implicitly the authors suggest that the lower the socio-economic consequence of changing education, the greater the tendency of educational 'restlessness' (cf. Hovdhaugen and Aamodt 2005). Conversely OECD (2008) find it difficult to see how increasing the tuition fees can serve as incentives for students to finish their studies quickly. Instead OECD links the low "proportion of students who enter a tertiary programme and leave without at least a first tertiary degree" (*Ibid,* p. 92) in Denmark to no tuition fees and a high level of public subsidies for students. Though be it not the place here to argue that both of the above views might both have justification in their own right, the examples serves to show that Tinto's original concern for 'state planners' might be somewhat misdirected: at any rate we may expect statistics to be used according to political purpose.

Dropout, such as Tinto's (1975) model seeks to explain, will inevitably lead to a notion of attrition between systems inside the institution (i.e. between programmes) as a form of transition. We take on the view that a missing part of

Tinto's model can be introduced by defining attrition as the phenomenon of 'students starting a given programme and then leaving it for something else'. If for no other reason, we take on this view to be able to include in studies of attrition a majority of able and talented students who leave educational programmes anywhere.

Discourse analysis

Our main premise when engaging with interviews was that attrition is a result of an incommensurability of cultures - that of the individual leaver's and that of the institutional context. In the case of retention, for the stayer to become a member of a community of practice, the person will also have to learn to share the values of that community or system of relations. "Learning thus implies becoming a different person with respect to the possibilities enabled by these systems of relations" (Lave and Wenger 1991, p. 53). Becoming a different person is constructing a different identity – a process. So in order for a person to become a member of a community, the person will have to embrace the shared repertoire to be able to participate in the practices of the community – but until values are shared, until the intrinsic process of personal transformation is recognized as adequate, and until an access to the ways of knowing in the community is provided, this participation will be peripheral. In the case of schooling this peripheral participation is legitimate. In other words, even though a student is not a capable physicist, participation in physicist activities is often encouraged, and education is often designed in a way that encourages students to *mimic modes of disciplinary discourse* (Airey and Linder 2006). Thus being a member of a community of legitimate peripheral participators, such as a student body, can in itself be considered a community of practice as previously noted, characterized by distinct sets of shared repertoires.

Mimicking practice, or legitimate peripheral participation, has often been compared to learning a language by including in the language the idea of a shared repertoire. Thus, learning to become 'discursively fluent' (Airey and Linder To appear) might be an appropriate metaphor, also for characterizing and tapping into the process of identity formation and adaptation necessary for legitimizing the membership of the student community.

Gee (2005) has developed a type discourse analysis methodology especially suitable for understanding aspects of legitimate peripheral participation. It provides a coherent analytical framework within which discursive transactions captured in the interview can be analysed. Gee's discourse analysis differs from the more theoretically dogmatic discourse analysis frameworks by also calling for the inclusion of those of the aspects of communication that does not solely relate to the language-in-use (Ibid). To distinguish Gee-like approaches to discourse analysis Gee denotes the situated discourse 'big D' Discourse. Such broader models of discourse analysis is intended to go beyond 'what is said' and purposefully include what is 'known about', thereby revealing a range of issues allowing them to be factored into the interpretation of the ways, for instance, students respond to their circumstances (Case 2007).

When interviewing students about the reasons for leaving, the students will relate how they made sense of their choices. In such sense-making they will draw on their experience and the result will be a personal interpretation that lends logic to the causality of the experience of studying and of deciding to leave. Ways of interpreting the world to make sense of it, is what Gee calls Discourse models. They "are 'theories' (storylines, images, explanatory frameworks) that people hold, often unconsciously, and use to make sense of the world and their experience in it. They are always oversimplified, an attempt to capture some main elements and background subtleties, in order to allow us to act in the world without having to think overtly about everything all at once. In this sense they are like stereotypes […] meant to help us understand complicated realities by focusing on important things" (Gee 2005, p. 61). In this paper we focus on insight into how seven students who left the physics programme at a traditional Swedish research university (henceforward referred to as physics*) model their personal explanation for leaving physics* without graduating.

Students making sense of leaving

The intention with the seven interviews was to document aspects of the experience of studying physics* that led the informants to the decision of leaving. The intention was also to carry the learned experience from one interview to the next and thereby forming ideas of institutionally rooted reasons for attrition that could be tested against the interview participants as a working progress. Most prominent of such experiences however, was that the interviewer had a feeling of being denied insight into those of the interview participants' experiences of studying physics* that were experienced as inherent to the physics* context. This denial took on a form of a kind of 'wall' of introspection. Almost every of the participants' experienced difficulties had to do with *something about themselves*, rather than *something about physics**. For example, one informant told that she stopped because she lacked the interest and the abilities:

> *I just realized that I wasn't interested in physics anymore. I was so bad at physics, I didn't pass that many exams, so I had to leave.*

The student appears to have reached the practical limits for continuing her studies: no interest, no ability. But we would have liked to know why she was 'bad at physics', 'not good enough' and why she lost her initial interest. Her answer seems to lie in the domains of interest and ability. If we take her second statement as explaining the first; her story is somewhat more clear: She was initially interested, but because she lacked the experience of success (she did not pass that many exams) her interest died away – thereby confirming the well established connection between interest and experiencing success (cf. Biggs and Tang 2007).

At another instance the student who was interviewed did not feel she ever started studying physics*:

> *I left physics before I even got there. I took the brush-up course in mathematics, and realized that this was how it was going to be for, well only for like a full year, but it still seemed too much.*

So maybe she was not that interested in physics anyway, but wondering what was so bad about her first impressions that it killed what remained of her interest she explains:

> *I was interested in the subject, but not that much really. Plus there was the competition. Three or four girls in the programme had already been working with meteorology for the military. They got their education paid for, and since I figured there weren't that many jobs in meteorology, and since the pay was really bad – like seriously awful – I lost interest completely.*

Here, the issue of not starting the actual physics* illustrates this 'wall' of introspection. The loss-of-interest decision to leave in terms of competition and job-opportunities illustrates that she in a very concrete sense had commenced the studies but changed her mind due to her experience when starting at the university. Despite possible implications of the external, the logic of causality is pointed inwards and the reason for leaving, she insists, is the 'complete loss of interest'. Thus, we started exploring the notion that maybe this mode of introspection was a way for the students to make sense of their experiences.

The introspective Discourse model. We remember Gee's notion of Discourse models as 'theories that people hold and use to make sense of the world'. They are group constructions "that become a resource that an individual may call on to guide his or her actions" and moreover explanatory models that individuals draw on when making sense of experience (Gee and Green 1998, p. 123-24).

Consequently the 'wall' of introspection might be our way of noticing aspects of an 'introspective' Discourse model, by which the participants attempt to make sense of the logic of causality that led them to decide to leave physics* - leaving out the 'details' of extrovert circumstances. Plus, one might argue that when you invite people to speak about themselves – as we in our interview with a design that focus on past and present experiences – talking about themselves is exactly what they will do.

However, the interviewer actively introduced issues that might turn the conversational response in more extrovert directions. For instance, one student told that he needed a break, during which he worked, because he felt the pace was too high.

> *I just felt that I can't keep up that speed for so long. I needed more time to let it sink in. So it felt kind of pointless at the end I think.*

It was suggested that a hypothetical situation in which the pace had been different, could have made him stay. But this prompted the following response:

> *No, I don't think so because I didn't take the decision that I'm gonna stop studying. If the pace hadn't been so high, it wouldn't have made any difference, because I think it would have been the same anyway. I would have started working and just slowly drifted away.*

It appears that even though he had a problem with the pace, his leaving was still very much embedded in a Discourse model dictating that ‘things just happen as they do’, instead of the notion as we saw previously, that the decision of leaving can be prompted by ‘not being good enough’. In other words, needing ‘more time to let it sink in’, is not translated into action, for example by planning to take longer to complete the studies and thus effectively taking less courses per semester. When asked, studying at a lower pace was decisively not an option for this student.

A Discourse model in two parts. As we explore the notion that the students we interviewed made use of an ‘introspective Discourse model’ to explain why things were as they were, the model appears to have two distinctive parts. Overtly the interviewees make use of an interpretative social language (or a theory) that says that if something goes wrong, it must be because of ‘something within the self’. But further, this ‘something within the self’ is related by students as if it allows for events to ‘just happen that way’, or as if it is an issue of ability resulting in not ‘being good enough’ to stay in physics*.

The ‘not being good enough’ part. To us it appears that the inferences the participants drawn from the introspective Discourse model are very stable and conclusive. At one instance the interviewer suggested that the feelings of inadequacy conveyed by one participant during an interview, could be a cause of frustration; a frustration that could have been directed outwardly in what could be well-deserved criticism of physics*. As is apparent from the excerpt brought underneath, this was not a popular notion:

> *I wasn’t angry because the pace was too high or because I didn’t understand it. Then you just think: ‘maybe I should study something else.’ It’s not some-one else’s fault.*

The ‘it just happens that way’ part. We have already described how this part of the introspective Discourse model can be manifested. But what is really interesting is that it appears that this part can also be used to strengthen the ‘not being good enough’ part. Another leaver explains:

> *Gradually I worked more and more and more and studied less and less. And then it got pointless. When you come over a certain line or boundary, it gets pointless to go [back] to university at all because you are already so far behind that you can’t catch up. So leaving physics was a gradual process for me. But when I did study, I did manage ok*

.

What she says is that she drifted somewhat from the studies (‘it just happens that way’) but whenever she considered taking up the studies, it seemed too big an obstacle (‘not being good enough’) to be worth the effort (‘it just happens that way’). Here it is also suggested that one of the more ‘well-known’ excuses for under-performance (‘I could if I would’) has its root in the introspective Discourse model: ‘I could if I would’ implies that since ‘I do not, it is because I won’t’. The same self-reflection explicitly modelled extrovertly might sound: “I could if I would. But I do not, because the content simply fails to motivate me". Unfortunately such is seldom the case – it might even be naïve to expect of students to have such insights into their own motivational dynamics. Therefore evaluation of reasons for underperformance or attrition will have to be interpreted accordingly. We find it an imperative for the evaluation process that Discourse models used by the students informing the evaluation are allowed for and taken into consideration.

Discussion

Based on our experience with interviewing seven students about their reasons for leaving physics* it appears that young people invoke introspectively modelled reasoning when relating the logic of causalities leading them to take the decision of leaving physics*. However, Seymour & Hewitt (1997) reported from their North American based study of attrition, that a staggering percentage of leavers ascribed their choice, to having experienced *'bad teaching'* – which is obviously an extrovertly modelled reason for leaving. Clearly reasoning by introspection is *not* a universally encountered phenomenon with regards to education evaluation. But it may very well be a Scandinavian phenomenon. Descriptions of youth culture in Scandinavia trace interest-driven reasoning on choice back into the object of Scandinavian subject-centred schooling (cf. Troelsen 2000, Schreiner and Sjøberg 2005, Rødseth and Bungum 2007). For Sweden and Denmark respectively, the object of schooling has been described in essence to be 'making persons out of pupils' instead of 'making pupils out of persons' (Frykman 1998) and by recently changing the old question '*What* do you want to *become* when you grow up?' into '*Who* do you want to *be* when you grow up?' (Illeris, Katznelson et al. 2002). Therefore we find reason to believe that the introspective Discourse model is also put to use outside of the physics* education context – at least in Scandinavia.

Roughly at the same time as this study was performed, another report on attrition was prepared at the same university detailing reasons for leaving with the purpose of understanding and preventing attrition (Appel 2007). The author and her associates had interviewed students who had studied law, social sciences, computer science and education and reached by and large to the same conclusions as did the students we interviewed, when we conclusively asked them if they had any suggestions for ways to make students stay in physics*. However, we found it necessary to use our insight into the introspective Discourse model as an interpretational lens to reach more locally oriented constructive suggestions for understanding and preventing attrition.

The introspective Discourse model as interpretational lens. We strongly recommend that education researchers and teachers involved with evaluation practice take into consideration that young people might make sense of their experiences making use of introspective reasoning, as was found in this study. If this is the case, and if evaluation statements are taken at face value, important and useful feedback may be missed, and the only outcome of individually based interviews on attrition may be related to the youth culture rather than related to external issues that can be addressed by the institution.

We give one last example which elucidate the problem of taking introspectively derived statements at face value:

> *It would have been nice if someone noticed that I had problems at the end of the first semester, but no-one did. But there's no way anyone could have. I mean, you have different teachers in every subject.*

In response to such a claim, you could surely intercede (among so many other things) that it is a (collective) responsibility for teachers to notice students if they do not learn. Introspectively modelled, such a conclusion, that the student was neglected by her teachers, is not viable, why the researcher's conscientious interpretation is necessary.

Conclusion

We have argued for conceiving attrition as the failure of an individual to be admitted into the legitimate peripheral participation of the community of physics learners. Also, that this failure of admittance takes on the form of exclusion, either by the community or by the individual as self-exclusion or rejection. Gaining insights into attrition can thus be done through interviews purposefully probing into each student's experience of the logic of causality that led to the choice of leaving. Based on our experience of interviewing students who left the physics programme at a traditional Swedish research university, we found that for the purpose of interpreting student interviews, one must take into account the two different modes of introspective modelling: attrition *'just happens that way'* or that leaving was necessary because the student was just *'not good enough'*.

We conclude this paper expecting that young people in Scandinavia may invoke introspective Discourse modelling in situations were they are asked in retrospect to relate their impression of the logic of causalities that led them to decide to leave any university education programme.

Consequently we strongly recommend for researchers and teachers involved with any evaluation practice involving student testimonies, to take into consideration that young people might make use of introspective reasoning. Therefore interpretation needs to be performed accordingly if one wishes to gain insight into issues concerning attrition external to the individual student that might be addressed at the institutional level.

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Curriculum Process in Science Education

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Abstract

Science education in the **communicative conception** is defined as the continuous transfer of the knowledge and methods of science into the minds of individuals who have not participated in creating them. This process, called the **educational communication of science**, is performed by various educational agents – teachers, curriculum makers, textbook designers, university teachers and does not mean only a simple transfer of information, but it also involves teaching and instruction at all levels of the school system, the study, learning, and cognition of pupils, students and all other learners, the assessment and evaluation of learning outcomes, curriculum composition and design, the production of textbooks and other means of educational communication and, in addition, university education and the further training of teachers. The educational communication is carried out by the **curriculum process** (CP) of science, which is a sequence of **variant forms of curriculum** mutually interconnected by **curriculum transformations** (CT). The variant forms of curriculum are as follows: conceptual curriculum, intended curriculum, project (written) curriculum, operational curriculum, implemented curriculum, and attained curriculum.

Introduction

During the last three decades, studies forming and then developing the **communicative conception in physics education** were published (Brockmeyer, Kotásek, 1979, Brockmeyer, 1982, Brockmeyer et al, 1984, Tarábek, Záškodný, 2006, Brockmeyer, Tarábek, 2007, Tarábek, 2007, Tarábek, Záškodný et al, 2007, Záškodný, 2007). The four historical conceptions of physics education were distinguished: the methodical, application, integration, and communicative. In 2004 – 2008, the **communicative conception in science education** was formed (Kotásek, 2004, Tarábek, Záškodný et al, 2005, 2007, Adamčíková, Tarábek, 2006, 2007, 2008). Science education in the **communicative conception** was defined as the continuous transfer of the knowledge and methods of science into the minds of individuals who have not participated in creating them. This process, called the **educational communication of science**, is performed by various educational agents and involves teaching and instruction at all levels of the school system, the learning of students, the assessment and evaluation of learning outcomes, curriculum composition and design, the production of textbooks and other means of educational communication and, in addition, university education and the further training of teachers. The theory of science education concerning the process of educational communication deals with the **conceptual knowledge system of science**. This **conceptual knowledge system (CKS[1])** takes several variant forms during the course of educational communication and it passes through several **knowledge transformations** (see figure 1). Science education has to follow the complete path of transformations and forms of scientific knowledge, and, in the process, the variant forms of the conceptual knowledge system of science correspond to qualitatively distinct **phases of educational communication**. In correspondence with knowledge transformations of CKS of science, we can also distinguish **transformations in the educational communication of science**. **Phases** P0 – P6 of the educational communication of science are connected through **didactic[2] transformations** DT1 – DT6 (see figure 1). Phases P0 – P6 and transformations DT1 – DT6 constitute six **stages of educational communication**. Thus, in the **educational communication of science**, a transformation process can be observed that is characterized by the sequence of the **didactic[2] transformations** DT1 – DT6 that go from phase P0 up to phase P6 (the arrows mean transformation process). Starting phase P0 is the **scientific conceptual knowledge system** of science. It is also called the **scientific system**.

Transformation DT1 = scientific system → conceptual model (P1),
Transformation DT2 = conceptual model (P1) → educative model (P2),
Transformation DT3 = educative model (P2) → educational project (P3),
Transformation DT4 = educational project (P3) → realized curriculum (P4),
Transformation DT5 = realized curriculum (P4) → outcomes of education (P5),
Transformation DT6 = outcomes of education (P5) → applicable outcomes of education (P6)

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1. **Conceptual Knowledge Systems (CKS)**

According to the Modeling Theory of Hestenes (2006, 2007) a system is a set of related objects. The structure of a system is defined as the set of relations among objects in the system. Common and scientific concepts and knowledge comprise a system with a structure. We can distinguish two types of conceptual knowledge systems: the internal (mental) and the external (Tarábek, 2007).

The internal (mental) conceptual knowledge system (ICKS) is a result of the individual cognitive process of a human. It is a system of concepts and knowledge which humans acquire and form through the process of education, learning, observation, and empirical experience, as well as in the process of scientific cognition through goal-oriented experimentation and through their own thinking. The internal conceptual knowledge system comprises the elements and relations between them. The basic elements of the ICKS are concepts at various levels of abstraction and formation. The concepts are also systems and involve words, mathematical, physical, chemical, and other symbols, features of denotata (objects, events, phenomena in reality to which the given concept refers), and images at various levels of abstraction. The ICKS also contains experiences and perceptions stored in the memory. Relations between the elements of the ICKS are of various types – connections between components of concepts and among the concepts, declarative knowledge as specific (cognitive) connections between the concepts, intrinsic rules of types of human reasoning and specific procedural knowledge. The term ICKS partially corresponds to the term "mental model" of Hestenes (2006, 2007).

The external conceptual knowledge system (ECKS) is a result of the social cognitive process, i.e. the cognitive processes of human society as a system of cognitive agents, while it is necessary to distinguish which system is being discussed. The scientific conceptual knowledge system (SCKS) is the result of the cognitive process of a scientific community in a given science. It consists of the scientific concepts, terms, empirical facts, laws, principles, theories, their applications and interpretations, and cognitive, modeling, application, and interpretation methods and procedures that the given science makes use of. The term ECKS partially corresponds to the term of the "conceptual model" in the Modeling Theory of Hestenes (2006, 2007).

2. In the American curriculum theory, the term "educational communication" is used.

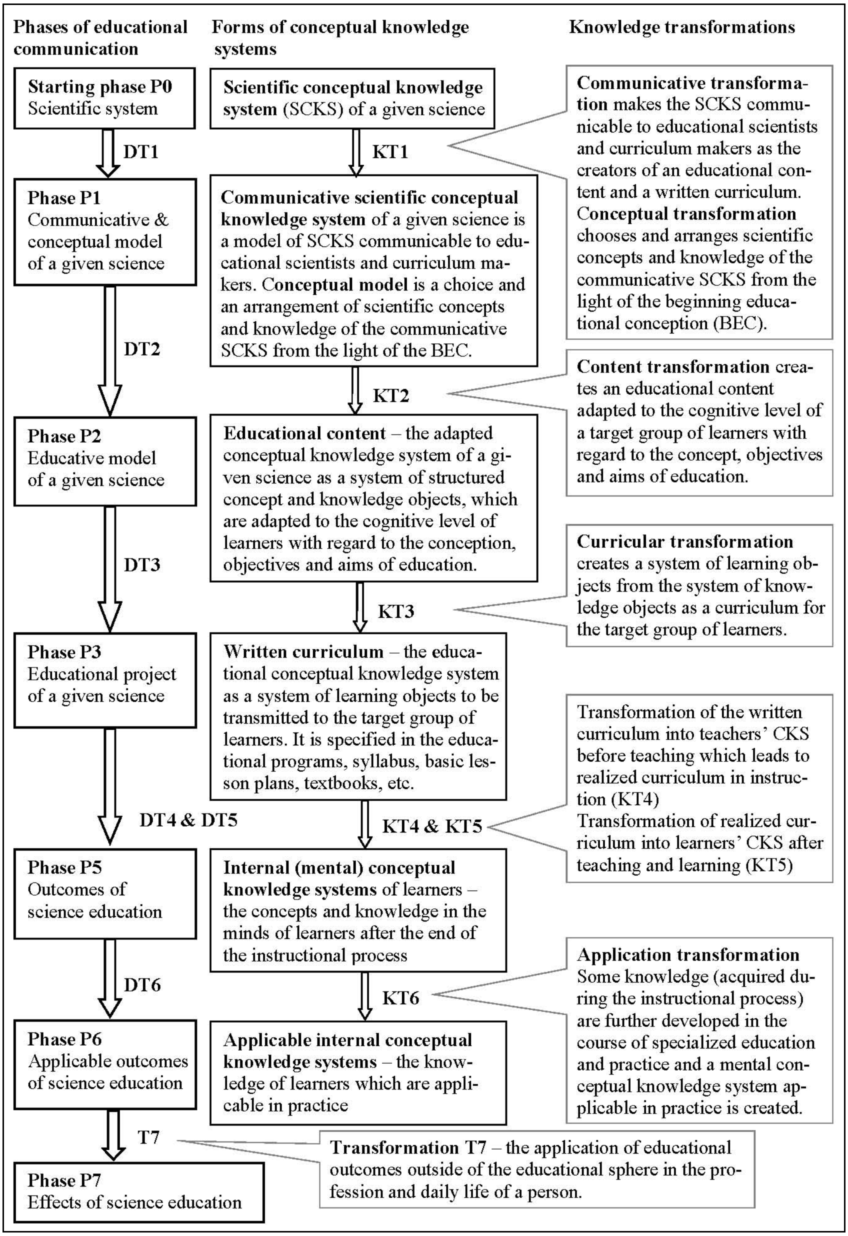

Figure 1: Phases P0 – P6 of educational communication, forms of conceptual knowledge systems and their knowledge transformations KT1 – KT6. The DT1 – DT6 are didactic transformations. The T7 is a "non-educational" member of the sequence DT1 – DT6, T7.

In 2002 and 2006 – 2008, studies developing the conception of **variant forms of curriculum** were published (Průcha, 2002, 2006, Maňák, 2007, Záškodný, 2007, 2008, Tarábek, 2008). In the framework of this conception, the curriculum is not understand as a static phenomenon, but passes through various forms – conceptual, intended, project, operational, implemented, and attained that are connected by curriculum transformations. This conception follows up to the distinguishing of the various aspects of curriculum in TIMSS curriculum model – intended, implemented, and achieved/attained curriculum (TIMSS 1995, TIMSS, 2007), the levels of curriculum described by Akker (2003) – intended ideal, intended formal/written, implemented perceived, implemented operational, attained experiential, attained learned, types of curriculum – planned/official, and actual/received (Kelly, 2004) etc. In this conception, the **curriculum process** is a sequence of variant forms of curriculum mutually interconnected by several curriculum transformations. The first three transformations correspond to the curriculum development and design. The fourth and fifth transformations take place during the education. The sixth transformation takes place in the subsequent practice. In 2007, the correspondence between both of the conceptions was shown (Záškodný, 2007). In 2008, both of the conceptions were integrated in the **communicative conception of science education** (Adamčíková, Tarábek, 2008, Tarábek, 2008, Záškodný, 2008).

Curriculum Process in Science Education

The communicative conception of science education means the continuous transfer of the knowledge and methods of science into the minds of individuals who have not participated in creating them. This process, called the **educational communication of science**, is performed by various educational agents – teachers, curriculum makers, textbook designers, university teachers, educational scientists and does not mean only a simple transfer of information, but it also involves teaching and instruction at all levels of the school system, the study, learning, and cognition of pupils, students and all other learners, the assessment and evaluation of learning outcomes, curriculum composition and design, the production of textbooks and other means of educational communication and, in addition, university education and the further training of teachers. The theory of science education concerning the process of educational communication deals with the **scientific conceptual knowledge system** of a given science. This **conceptual knowledge system (CKS[1])** takes several variant forms during the course of the educational communication of science and it passes through several **knowledge transformations**. Science education has to follow a complete path of transformations and forms of scientific knowledge, and, in the process, the variant forms of the conceptual knowledge system of science correspond to qualitatively distinct phases of curriculum process. The **curriculum process** in science education as the complete continuous transfer of scientific knowledge and methods into the minds of learners is realized by means of the sequence of **variant forms of curriculum** P0 – P6 (as **phases** of the curriculum process) that are mutually interconnected through curriculum transformations CT1 – CT6. The first and only "non-curricular" member (P0) of this sequence is the scientific system of a given science. Two transformation lines move through the curriculum process: the first of these lines is the sequence of the **phases of curriculum process** P0 – P6 (**variant forms of curriculum**) that are interconnected through **curriculum transformations** CT1 – CT6 (see figure 2). The second of these lines is the sequence of **variant forms of conceptual knowledge systems (CKS[1])** that are interconnected through **knowledge transformations** KT1 – KT6 (see also the figure 1). The CKS[1] are also called the **content knowledge (CK)** of a given science/subject in phases 2 – 5.

Phases of Curriculum Process and Curriculum Transformations (CT)

CT1 = scientific system → conceptual curriculum

The scientific conceptual knowledge system (SCKS) of a given science is usually fully comprehensible only to scientists. Therefore the **communicative transformation** adapts the SCKS to ensure its communicability to those who create the next phases of the curriculum process. The communicative transformation creates the **communicative scientific conceptual knowledge system.** The next step is the **conceptual transformation** – the selection and arrangement of knowledge to be transmitted to pupils and students from the light of the beginning educational conception (**BEC**). The conceptual transformation creates **the conceptual curriculum** as the **conceptual model** of the SCKS – the conceptual model of science.

Phase P1: **The conceptual curriculum** for science consists of two components:

- the conceptual model of science which involves the communicative SCKS;
- the conception, aims and objectives of education following from the BEC.

CT2 = conceptual curriculum → intended curriculum

The conceptual model of a given science is the subject of cognitive analysis, synthesis and adaptation to the cognitive level of learners during the **intention transformation** CT2. This transformation creates an **intended curriculum** as the phase P2 of the curriculum process, which consists of three components:

- the **intended form of CKS** (**content knowledge** of a given science or draft educational content) adapted to the cognitive level of learners and with regard to the aims and objectives of education.
- the conception, aims and objectives of education,
- information about the cognitive level of the learners' concepts and knowledge.

CT3 = intended curriculum → project curriculum

During the **project transformation CT3**, the intended form of content knowledge is transformed into a definite educational content (educational form of CKS) with respect to the objectives and goals of education and in the relation to instructional forms and methods. **Phase P3** is the **project curriculum** – the educational project that consists of five components:

- the **educational form of CKS** (**content knowledge** or educational content of a given subject) consists of educational programs, the syllabus, knowledge standards, and basic lesson plans. It is concretized in textbooks and other means of instruction.

- the objectives and aims of education,
- the planned and recommended methods and forms of teaching,
- the planned and recommended methods and tools for detection, assessment, and evaluation of learners' knowledge and skills,
- the competencies and qualifications of teachers,
- the organization and conditions of the entire educational system.

CT4 & CT5 = project curriculum → implemented curriculum

The transformation CT4 & CT5 is the **educational process** which consists of the teaching, learning and assessment of knowledge. The teaching and instruction comprise an **operational transformation** (CT4) which leads to the **realized form of the CKS** (or **content knowledge**). This phase of an actual instructional process is described by the **operational curriculum** (phase P4). The learning of students leads to the **implemented form of CKS** that consists of the internal conceptual knowledge system of learners after the process of education. This stage of curriculum process is called the **implementing transformation** (CT5). **Phase P5** is the **implemented curriculum** – the **outcomes of education** and their assessment which consist of three components:

- the **implemented form of CKS** (or **content knowledge**) – the internal conceptual knowledge systems, competencies, skills, and attitudes of learners after instruction and learning,
- the knowledge standards, and
- the methods for the detection and assessment of knowledge, skills and competencies.

CT6 = implemented curriculum → attained curriculum

CT6 is an **attaining transformation** of the outcomes of education into applicable outcomes of education (knowledge applicable in practice). **Phase P6** is the **attained curriculum** which consists of three components:

- the **attained form of CKS** – learners' knowledge, skills and competencies which are applicable in practice,
- the applicable knowledge, skills and competencies standards, and
- the methods for the detection and assessment of applicable knowledge, skills and competencies.

Curricular components

The variant forms of curriculum consist of multiple components:

- **the conceptual component** comprises the philosophy, conception, aims, objectives, and goals of education,
- **the content knowledge component** comprises the variant forms of conceptual knowledge systems of science that are also called the content knowledge of a given subject in the phases 2 – 5,
- **the methodical component** comprises the methods and forms of teaching and instruction,
- **the efficiency component** comprises the methods and tools of detection, assessment, and evaluation of knowledge, skills, and competencies,

- **the cognitive component** comprises knowledge of cognitive psychology and science used in the curriculum process (concerning the perception and cognition of learners in the instruction process, structure of concepts and knowledge to be taught) and also information about the cognitive level of the learners' concepts and knowledge, methods of adaptation of scientific knowledge to the cognitive level and input knowledge of learners,
- **the pedagogical component** comprises the pedagogical content knowledge of teachers, curriculum makers, textbook creators and designers, and also the pedagogical knowledge concerning the teaching, instruction, learning,
- **the organizational component** comprises an external organization of education (kinds of schools, organizational forms of education, financial and legal components of educational system, etc.).

Conclusion

The creation and development of the communicative conception in science education came from the needs of the knowledge society in the age of the exponentially increasing scientific knowledge. The communicative conception of science education was first described by the didactic/educational communication of physics and science and subsequently by the curriculum process. Thereafter, we can understand the science education in the light of communicative conception as the complete continuous transfer of scientific knowledge and methods into the minds of individuals who have not participated in creating them. This process is called the educational communication of science and it is a two-way communication between science, curriculum makers, teachers and learners involving all components of the curriculum research, development and construction, components of the optimal instruction process (motivation, transfer of information, teaching activities, constant analysis of learner's feedback, assessment, the evaluation of the learner's performance, etc.), and the application of a gained knowledge. This transfer is also called the curriculum process. The curriculum process is realized by way sequencing of the variant forms of curriculum that are mutually interconnected through six curriculum transformations. The first three transformations correspond to the curriculum development and design. The fourth and fifth transformations take place during the education. The sixth transformation takes place in the subsequent practice. In the curriculum theory, this theoretical conception covers many important aspects of the school educational process in its complexity by means of a relatively simple and comprehensible process chain.

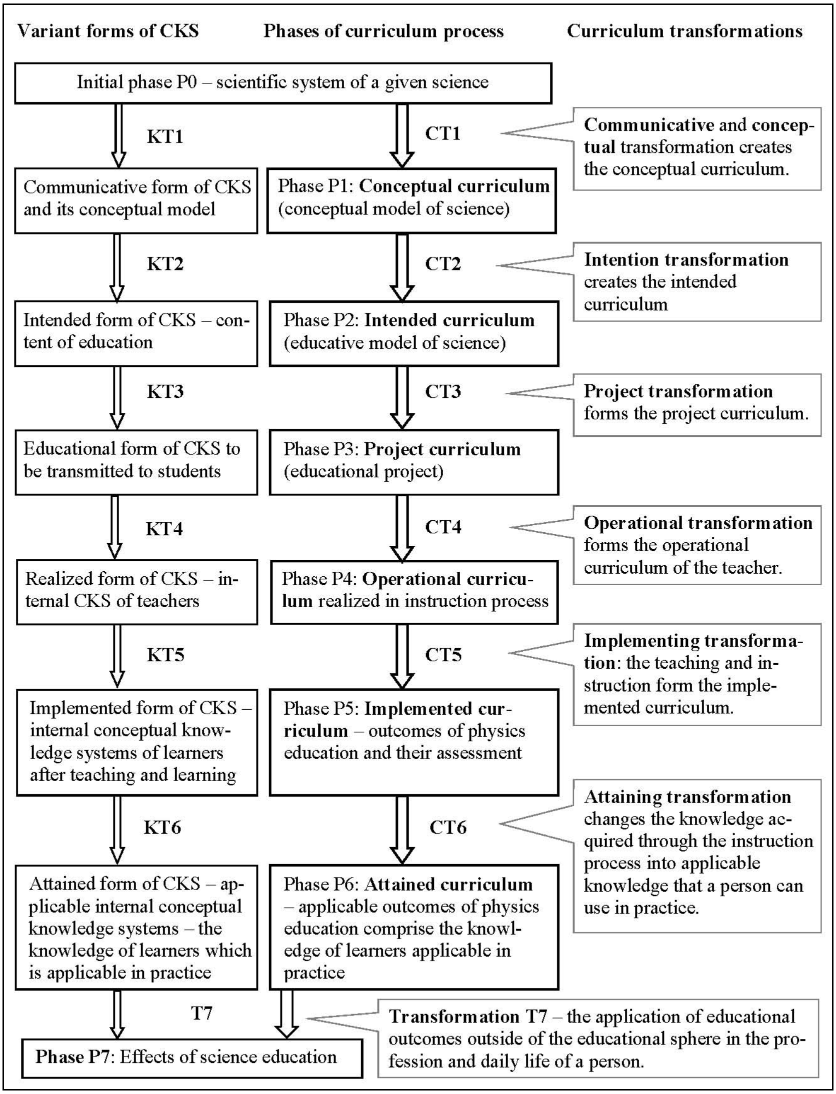

Figure 2: Curriculum process in science education and its phases – variant forms of curriculum and corresponding variant forms of CKS

CKS – conceptual knowledge system of a given science – content knowledge in the phases 2 – 5
KT – knowledge transformations, CT – curriculum transformations
T7 – "non-educational" member of the sequence of the curriculum transformations
P0 – "non-curricular" member of the sequence P0 – P6

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Curricula of the course on modelling behaviour of human and animal-like agents

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Abstract

Intelligent virtual agents (IVAs) are agents imitating behaviour of a human or an animal, graphically embodied in a 2D or 3D virtual world. In our university, we have established a novel interdisciplinary course, including a practical seminar, on modelling behaviour of such agents. The course focuses on action selection from the perspective of artificial intelligence, computer games, and ethology, but covers also various introductory topics from cognitive psychology and neurobiology. This paper details the curriculum of the course.

Introduction

Intelligent virtual agents (IVA) are typically conceived as software agents (Wooldridge, 2002) imitating the behaviour of a human or an animal, embodied in a 2D or 3D virtual world. First true IVAs started to emerge about a decade ago. Today, this field is becoming matured. Various kinds of applications feature IVAs, including commercial videogames games, serious games, industrial applications, cultural heritage applications, virtual reality environments for cognitive science research, and computational ethology simulations (see e.g. Orkin, 2006; Aylett et al., 2005; Magnenat-Thalmann et al., 2006; Burgess, 2002; Bryson et al., 2007, respectively; see also Prendinger and Ishizuka 2004). Consequently, the community is increasingly growing. As this happens, an issue how to educate its new members, in most cases undergraduate students, starts to demand attention (Brom et al, 2008). Educational issues seem to be well addressed by neighbouring disciplines, namely computer graphics, robotics, and software agents; consider e.g. the number of summer schools and introductory books available for these domains, the RoboCup platform, or the special educational track at the Eurographics conference. While the classes directly focused on IVAs have already started to emerge, and some of the class materials are available on-line, e.g. (Aylett, 2008; Dignum and Westra, 2008), the reports on advances in education directly related to IVAs are scarce.

In this paper, we describe the curriculum of a one-term theoretical course on *Modelling Behaviour of Human and Animal-like Agents* (Brom, 2008), highlighting main lessons learned from teaching perspective. The course was created in 2005 primarily for undergraduate computer science students, but it was also adopted for a high-school workshop and for a summer school. While primarily focussing on modelling behaviour of IVAs in the context of interactive entertainment applications such as videogames and virtual storytelling, the course also provides students with limited knowledge of cognitive and behavioural sciences, including theories of emotions, perception, and memory, natural neural networks, and basics of ethology, presenting a starting point for students considering studying these subjects in the future. As far as we know, there is no single book covering the whole curricula.

During 2008, this theoretical course has been augmented with practical seminar, during which students learn to program their own virtual characters. Students develop their characters for Unreal Tournament 2004 (UT04) (Epic, 2004), but instead of using Unreal Script, the native scripting language of the UT04, they use a special purpose toolkit Pogamut 2 we developed (Kadlec et al., 2007). Pogamut 2 was intentionally created to facilitate start with IVAs, both for educational and research purposes, and it is freely available to download[1].

The primary goal of this paper is to discuss the curriculum of the course in order to facilitate either development of a similar course or extending a course that is already running. In this respect, the paper is most similar to the work of de Melo et al. (2006), who reported on augmentation of a course on *Autonomous Agents and Multi-agent Systems* with a practical seminar using Counter Strike 3D game. We depart from this work in that our course is directly focused on *IVAs* behaviour and we use a different toolkit for the practical seminar.

The paper first details the background of the course and then focuses on its curriculum, highlighting the main lessons learned. The description of the teaching methodology and the general discussion follow in the complementary papery (Brom et al., 2008), which also reports on the curriculum of the practical seminar using the toolkit Pogamut 2.

The Course

Background. The course was created at Charles University in Prague at the faculty of Mathematics-Physics, the computer science study program, in 2005. From then, the course was taught every year in the summer term. The theoretical part of the course comprises 13 lesson units, one unit amounts to 90 minutes. In 2008, the practical seminar has been added (6 lessons units) (Brom et al., 2008). At the end, each student must create his/her own IVA, which presents about half of the student's evaluation.

The course is tailored to computer science students at least in their fourth term of bachelor studies, after they attended several courses on programming (10.5[2]), mathematics (17), general IT skills (8.5), and algorithms (5.5). Most of them have only limited knowledge of other topics. Many are recruited from technical high-schools. Every year, the course is attended by about 30 – 50 students (about 15% of the total number of students of one grade).

[1] The toolkit is available for download at http://artemis.ms.mff.cuni.cz/pogamut.

[2] Normalised number of courses on a given topic; "1 course" equals 13 lesson units (i.e. 13 x 90 minutes). The course presented in this paper, with the practical seminar, amounts to 1.5.

Objectives. Objectives of the course are (1) to introduce the field of interactive applications featuring IVAs, (2) to teach students to develop behaviour of IVAs, (3) to boost their interest in related disciplines, namely in artificial intelligence, autonomous agents, and behavioural sciences. At our faculty, there are many other courses where the students can learn about other aspects of IVAs, most importantly courses on computer graphics, computational linguistic, artificial intelligence (AI), autonomous agents (AA), and computer games development (Fig. 1). While there is no given order in which to attend these courses, the questionnaire administered in 2008 showed that our lecture is the entry-level point for the subjects of AI and AA for 60% students (either the first or the only lecture related to AI). Computer graphics, on the other hand, is studied mostly earlier than or in parallel to our course. Note, however, that from the point of view of IVAs, some courses that would give students a broader context are missing; most notably social sciences and human-computer interaction.

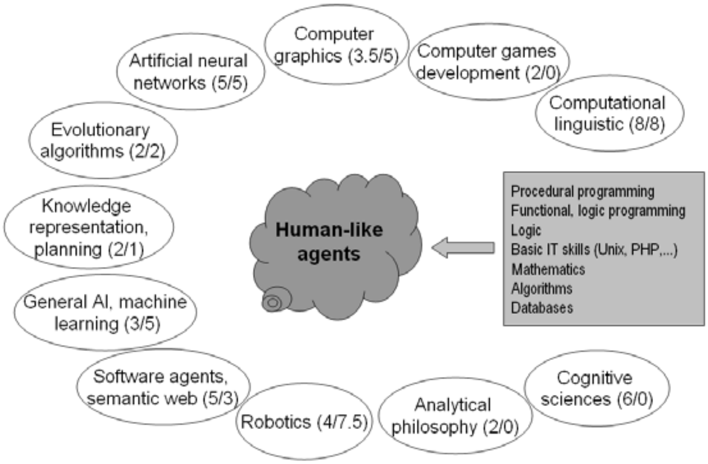

Figure 1. The curricular context of the course. Prerequisites are depicted in grey. The number of introductory courses and advanced courses are given in normalised numbers (see Note (2)).

Curriculum overview. Conceptually, the course comprises an introductory lecture, three theoretical blocks, and the practical seminar. The curriculum of the theoretical part is overviewed in Tab. 1. In general, the course starts with relatively concrete models for controlling behaviour and proceeds to more abstract ones. The course has more possible orderings of lectures, specifically within the block on advanced topics (Fig. 2). We will now discuss each part of the course in turn.

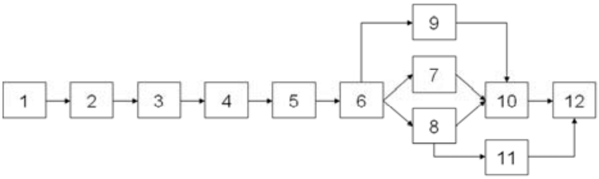

Figure 2. Possible ordering of lecture parts.

Table 1. The curriculum of the course.

Block	Topic	Units
	(1) Introduction	1
Concrete models of action-selection.	(2) Reactive planning: hierarchical if then rules with priorities, hierarchical finite state machines, fuzzy rules, probabilistic finite state machines.	2
	(3) Artificial and natural neural networks, reinforcement learning, evolutionary algorithms.	2
	(4) Behavioural science models: "Psycho-hydraulic" model of Konrad Lorenz, Tyrrell's free-flow hierarchy, classical and operant conditioning, imprinting.	1
	(5) Path-finding, steering, abstract terrain representations.	1
Conceptual notions, architectures, representation.	(6) Architectures: symbolism vs. connectionism, layered architectures, notion of deliberation. BDI, planning.	1
	(7) Multi-agent systems introduction: types of agents, communication.	1
	(8) Representation: logic, deictic representation, Gibson's affordances, smart objects.	0.5
Extras, broader context	(9) Artificial emotions.	1
	(10) Storytelling: emergent narrative, plots representation, level-of detail AI, role-passing.	1
	(11) Perception and memory.	0.5
	(12) Unified theories of cognition.	1

(1) Introduction. The knowledge of many students on IVAs is minimal, they typically think that IVAs belong only to the domain of computer games. Thence, it is crucial to demonstrate the broad scope of the field and to introduce the main technical issues. Most notably, interactive drama (Mateas, 2002), serious games (Aylett, 2005), cultural heritage applications (Magnenat-Thalmann et al., 2006; Burgess, 2002; Bryson et al., 2007), films (Softimage, 2008), cognitive science research (Burgess, 2002), cognitive-behavioural therapy (Herbelin, 2005), technical applications (Badler et al., 2002), and computational ethology (Bryson et al., 2007; Guerin and Kunkle, 2004) are introduced. Students most welcome live state-of-art demonstrations. The last two examples are important for drawing distinction between *plausibility* in the sense of a natural science, e.g. ethology or physics, and *believability* (Loyall, 1997). The Netlogo examples (Wilensky, 1999) help with clarifying the notion of *emergence*. The notion of *autonomy* has to be stressed. The survey of main issues, such as navigation, action selection, knowledge representation, emotional modelling, and story generation, helps to outline the content of the rest of the course.

(2) Reactive planning. Capitalising on the notion of rapid development, this part of the course help students to see how some action selection issues can be promptly solved. Specifically, if-then rules, decision trees, hierarchical finite state machines, and their fuzzy and probabilistic derivatives are introduced – good texts are (Champandard, 2003; Bryson, 2001; Brom, 2005). Students appreciate concrete mechanisms and concrete solutions. Since they are not able to produce counter-examples readily, they tend to regard these special-purpose mechanisms as abstract and general. While it is useful to give the concrete examples in which these methods fail, it is ineffective to try to give students any abstract,

background knowledge, at this moment. From the teaching process perspective, these concrete mechanisms will actually serve as a ground upon which the students will represent in their minds more advanced and/or general knowledge.

(3) Neural networks and evolutionary methods. This part extends the notion of reactive planning introducing neural networks and evolutionary methods. The control architecture of animals from the computer game Creatures (Grand et al., 1997) is an excellent material for this part for several reasons. First, it helps to explain both of the topics. Second, the neural networks used in Creatures are more biologically plausible than typical artificial neural networks, which helps with introducing the distinction between biological and artificial neurons. Third, the game can be demonstrated during the course on-line, including some technicalities (e.g. activity of some neurons). This lecture also helps with making links towards the domains of machine learning and computational neurobiology.

(4) Behavioural sciences models. It is useful to introduce the action selection problem from the perspective of behavioural sciences. This demonstrates rich cross-fertilisation between the disciplines, and reminds students of the believability—plausibility distinction. The excellent material is the Tyrrell's free-flow hierarchy architecture (1993). Not only it presents the bridge between IVAs and ethology, it also helps the students to understand some limitations of Creatures' neural networks. On the other hand, it can be demonstrated that outcome similar to Tyrrell's can be produced by reactive rules (Bryson, 2000).

The basic notions of ethology and behaviourism can be introduced, such as fixed action patterns, appetitive vs. consumatory behaviour, classical and operant conditioning, or imprinting. Other architectures that can be introduced at this point are (Lorenz, 1950; Miller et al., 1960/1986; Blumberg, 1996).

(5) Path-finding. This lecture first stresses the notion of representation, in particular terrain representation (e.g. Hancock, 2002; Isla, 2005; see also Isla and Blumberg, 2002). Also firstly, this lecture introduces the idea that thinking about IVAs at several levels of abstraction is beneficial by drawing the distinction between low-level steering and high-level path-planning (A*). The suggested materials are sections on path-finding in the book series AI Game Programming Wisdom (Rabin, 2002; 2004; 2006; 2008), and of course (Reynolds, 1987). Our experience is that students appreciate an introduction to more advanced path-finding algorithms, e.g. hierarchical versions of A* (Botea et al., 2004), or D* (Stenz, 1995).

(6) Architectures. Technically, so far, the students have been taught special-purpose solutions. Now, their knowledge should be unified within more abstract, conceptual frameworks. This helps them to see the models' individual advantages and disadvantages. Notions of goals and intentions, basically Belief-Desire-Intention (BDI) (Bratman, 1987), should be introduced, reactive approach confronted with planning, symbolism with connectionism. Layered architectures and hybrid approach should be introduced. The notion of behavioural-oriented design can be discussed (Bryson, 2003). A welcomed example demonstrating that BDI can be really implemented in various ways is the hybrid control architecture of Black & White creatures (Evans, 2002), which also reminds the students of reinforcement learning.

(7) Software agents. To frame the notion of IVAs in a broader context and to discuss the topic of communication, it is vital to introduce the concepts of intelligent software agents and multi-agent systems (Wooldridge, 2002; Franklin and Greasser, 1997).

(8) Representation. Capitalising on the lecture on path-finding and the notion of planning, this lecture pushes the topic of representation forward. In particular, the students should become familiar with the notions of affordances (Gibson, 1979; Brom et al., 2006), smart objects (Kallmann and Thalmann, 1998), deictic representation (Agre and Chapman, 1987), and logical representations (Russel and Norvig, 2003; ch. 7, 8). More general representations, such as frames and bayesian networks can be introduced, the notion of semantic web discussed (Dokulil et al., 2007).

Storytelling (10). The high-point of the course is storytelling for many reasons. Most importantly, students start to understand that IVAs cannot exist without virtual worlds and vice versa, in other words that IVAs and virtual worlds constitute an intertwined couple, a sort of marionette theatre in a service of a user. Through this metaphor and the notion of a story manager (e.g. Magerko, 2006; Mateas, 2002) students can understand how to *systematically* abandon the concept of strong autonomy. These notions also help with introducing the concept of role-passing (McNamee et al., 2002; Brom, 2007), a reminiscence of schema (Bartlett, 1932), and level-of-detail AI (Brom et al., 2007). At this moment, it is also possible to introduce the distinction between affordances for IVAs, i.e. representations, and affordances for users and authors (Mateas, 2002), i.e. mediators of users' experiences and author's intentions, respectively. Additionally, the notion of emergent narrative (Aylett, 2000) reminds students of the idea of emergence and the concept of story construction reminds them of planning.

(9, 11, 12) Cognitive Sciences Extras. Every year, many students are surprised that when developing an IVA, despite the IVA is intended to be believable but not psychologically plausible, it might be a good idea to look at what psychologists say about real humans. For example, the students are amazed that mechanisms of attention can really help with limited computational resources. In sum, these lectures help the students to understand that a "mind" of an IVA comprises not only an action selection mechanism, but also various additional "circuits". Concerning literature, these lectures mostly capitalise on state of the art works (e.g. Aylett et al., 2005, 2007; Ho et al., 2008, Mata and Aylett, 2007; Kim et al., 2005) and general cognitive science literature (e.g. Baddley, 1986; Ortony and Collins, 1988; Sternberg, 1996). It is beneficial to at least touch general cognitive architectures, e.g. Soar (Newell, 1990), ACT-R (Anderson, 2007), and LIDA (Franklin et al., 2005). It is also possible to include a bit of social sciences and cultural modelling (e.g. Davis et al., 2008). Our experience is that it is better to give these lectures after the students are already familiar with IVAs architectures and action selection.

Discussion and Conclusion

This paper has described the curricula of a university course on *Modelling Behaviour of Human and Animal-like Agents* and has overviewed the main lessons learned from the educational perspective. As already said, this course also has a practical seminar, in which students extend their theoretical knowledge by building their own virtual characters, a vital experience. The curriculum of this seminar is overviewed in the complementary paper (Brom et al., 2008).

Apart from the main subject of the course, students also learn basics of ethology, cognitive sciences, and artificial intelligence, developing a background knowledge on which they can build during their future education. This point is important given the interdisciplinary nature of the filed of virtual agents. Another important point is that modelling behaviour of IVAs helps to increase general programming skills of students, most importantly, they start to better understand the concepts of agents oriented programming and parallel programming. On the other hand, some issues related to social sciences and human-computer interaction are missing at the curricula of the course. This drawback is due to the limited number of lessons an individual course at our faculty can have.

Generally, the course, including the practical seminar with the toolkit Pogamut 2, is appropriate (with some modifications) for a summer school, or high-school computer science students. This has been actually demonstrated, as detailed in Brom et al. (2008). This paper also discusses the teaching methodology underpinning the course in depth. For space limitations, suffice it to say now that this methodology follows this line: to start with a concrete models and to proceed to more abstract ones, while incrementally immersing students to a broad context of the discipline. We believe that this line should be followed for similar courses as well.

The lecture materials and the Pogamut 2 are freely available for download (Brom, 2008).

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Ethical imperative of teaching ELSI to bioscience majors.

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Abstract

The regulation of biological research and its applications should involve both experts and members of the public. However bioscientists in the U.S. are rarely trained to be socially- and ethically-literate so that they can be cognizant of, sympathetic and anticipatory to, the complex ethical, legal and social implications (ELSI) of advances in bioscience. In a survey of undergraduate genetics instructors, 99% believed students should be exposed to ethical issues resulting from advances in genetics and 55% believed this discussion should occur within the science classroom. However, instructors actually only devoted <5% class time (<7.5 min/week) to ELSI issues. 55% did not believe this is adequate coverage and most cited "lack of time" as the reason they inadequately addressed ELSI issues.
I propose a set of principles for the "Ethics of Teaching Science" similar to those given for the "Ethics of Scientific Research": (Shrader-Frechette, 1994), consisting of Teaching Objectively (current state of knowledge, avoiding bias, grading fairly etc.) and Teaching for the Public Good (an ELSI component to educate scientists to consider the public good as part of their professional identity). Implementation of such a set of principles should increase the time devoted to ELSI either within the science classroom or in specialized ELSI courses required for majors. In this way, instructors' practices would be in closer alignment with their expressed goals.

Introduction

"The curriculum" is generally assumed to be the domain of faculty who, as the experts, regulate the content and composition of curricula with either broad (general education) or narrow (departmental) focus. Science departments may have to construct their curricula with some constraints from outside sources, e.g. requirements for American Chemical Society accreditation, but it is the faculty's responsibility to provide the best education possible to both train future scientists and to educate all students to be scientifically-literate members of society. A large proportion of any curriculum in bioscience is occupied by factual content and training in methodology and techniques. However I argue, as have many others, that method and content alone provide inadequate preparation for life as a 21st century scientist. Scientists should also be familiar with issues in research ethics, public communication of science, and the ethical, legal and social implications ELSI) of advances in bioscience. A curriculum that does not balance all aspects of training a well-rounded professional is inadequate and unethical. As the teachers responsible for the integrity and future of our profession, we should develop and adopt a set of principles for the "Ethics of Teaching Science" similar to those proposed for the "Ethics of Science Research" (Shrader-Frechette, 1994) to guide the process of bioscience curriculum development.

This paper will focus on undergraduate programs in bioscience in the United States with special attention on genetics and related sub-disciplines. The typical

American undergraduate program in bioscience is comprised of courses in the major, supporting sciences, general education or distribution requirements and free electives. The allocation of time spent in these different types of courses differs according to the type of institution. Students in technical schools spend a much higher percentage of their time in required sciences than those at liberal arts colleges who generally devote about a third of their coursework to their major. Given the rapid and continuing expansion of knowledge in all disciplines it is not surprising that all curricula and syllabi are a delicate balance where instructors teach as much of the basics and history of a discipline as possible while simultaneously engaging their students in the 'cutting-edge' of their field. The pressures of maintaining content and currency in rapidly developing areas of bioscience leave instructors little time to broaden the scope of their courses to include 'peripheral' issues like the ethical, legal and social implications (ELSI) of the science. The question to our profession is are we satisfied with the status quo? Do we believe the curriculum we teach is an optimal compromise of all the competing goals of undergraduate science education?

Background Survey

In order to better understand the current situation we conducted a survey of professors responsible for teaching undergraduate genetics at U.S. research universities and liberal arts colleges ranked in the top 25 by U.S. News and Reports (Booth and Garrett, 2004). We were specifically interested to determine the degree to which ELSI issues are taught within genetics courses, and more broadly, to understand the degree to which students are exposed to the ELSI issues that arise from advances in bioscience throughout their entire undergraduate experience. The responses from 151 genetics instructors indicated that faculty are convinced of the importance of including ethical issues as part of their students' experience. Essentially all respondents supported ELSI training somewhere in the undergraduate curriculum and the most do try to incorporate the subject of ethics and policy directly within their own course. However, when asked to specify the amount of class time devoted to ELSI, the vast majority devote <5% (Fig. 1): only 6% of the respondents use more than 5% of class time to consideration of the public consequences of advances in genetics in their courses. While 5% may seem to be a reasonable investment in ELSI discussions, this is only 7.5 minutes of instruction per week of three 50-minute classes. It is also significant that less than a third of the instructors included any assessment of the ELSI course component in the final grade, which probably indicated the status of the discussions as peripheral, unimportant to the students. When asked if they are satisfied with their treatment of ELSI in class, the majority of survey respondents believed their efforts were insufficient and "lack of time" was overwhelmingly the most frequently cited (by 95%) reason for the shortfall (Booth & Garrett, 2004).

The results of our study also indicate that American students are rarely systematically exposed to training in ELSI issues elsewhere in their undergraduate program. While the majority of our respondents supported an ELSI requirement either as a general education course or as a specific 'science and society' course for science majors, only 37% of their schools have even a vague ethics component in the core curriculum. Only 4% of the schools surveyed mandate a course that specifically focuses on the ELSI issues of science. This shows there is a serious disconnect between the stated priorities of members of our profession and the education our students actually receive. We are currently abdicating our professional responsibility of preparing the next generation of scientists to be competent in the consideration of ELSI issues so that they are fully prepared to be 21st century bioscientists and citizens.

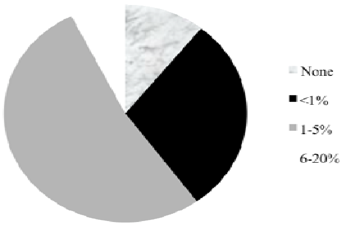

Figure 1. Percentage of class time devoted to ELSI issues in genetics courses.

The Professional Scientist: Ethics of Research.

Scientists are among the group of respected professionals lucky enough to maintain sufficient public trust to self-govern. When considering the ethics of the profession 'bioscientist', most people first concentrate on issues of research ethics. Nearly 20 years ago, an important summary of professional values and behaviors, "On Being a Scientist", was published by the National Academy of Sciences (NAS) USA (Ayala et al, 1989). This document discusses issues such as allocation of credit, plagiarism, and fraud in science, and is extremely useful as a teaching tool when discussing research ethics with students. The ethical principles that should guide research scientists have been elaborated further by philosophers, including a comprehensive set of guidelines published in the book "Ethics of Scientific Research" (Shrader-Frechette, 1994). However, these professional guidelines ignore any responsibility on the scientist as a teacher except in the role of imparting the research ethics to the next generation, i.e. instructing a graduate student in the principles given in "On Being a Scientist". I will argue that teaching is a very important role for every scientist and that we should adopt a clear set of guidelines that embrace the breadth of our responsibility to society instead of remaining narrowly focused on our research interests.

In the "Ethics of Scientific Research", Dr. Shrader-Frechette develops 3 principles of research ethics, which focus on the basic mechanics of completing objective research as well as give an injunction that scientific work should also be aimed at improving social welfare and developed for the public good.

> "To serve members of the public and the profession, researchers must (1) avoid doing biased work themselves (2) promote unbiased use of scholarly results of others, and (3) support the goals of promoting the public good and the welfare of third parties, such as present and future inhabitants of the planet." (Shrader-Frechette, p 51)

The first 2 principles are familiar and obvious. All scientific experimentation should be completed and disseminated as objectively as possible and scientists should be scrupulously fair in acknowledging and utilizing the results of others. These principles cover the injunctions against the three sins of fabrication, falsification and plagiarism in "On Being a Scientist" (Ayala et al, 1989). These are the basic tenets of any research enterprise: if these 'rules' are broken, professional disciplinary action may be taken. The third principle of 'promoting the public good and the welfare of third parties' also seems uncontroversial at first glance but on deeper reflection becomes problematic as 'public good' and 'welfare' are highly contested terms.

First, it is important to realize that many scientists do not believe that principle #3 is necessary. They assert that scientists are well meaning and forward thinking individuals who strive to improve the human condition. Furthermore, some scientists and philosophers believe that there should be no limits on research; that the human mind should be allowed to follow intellectual pursuits wherever they lead and that it is only the application of research in society that should be regulated. They point out that scientists have demonstrated responsibility and leadership by self-regulating new, potentially damaging, avenues of research. A notable, and highly touted, example was the Asilomar conference in 1971(Watson, 2004) where a group of leading molecular biologists and legal experts met to discuss the potential dangers of the new recombinant DNA technologies of cloning foreign DNA into bacterial plasmid vectors. They reached consensus on a set of guidelines for safety and containment procedures that were adopted by the public funding agencies and effectively regulated research in this area for decades. More recently, scientists have spoken out and organized around an international ban on human reproductive cloning (International Bioethics Committee, 2005).

On the other hand, experiments have been conducted (e.g. the twin studies of Joseph Mengele – Posner & Ware, 1986), which were gross violations of human decency and dignity. These may have been unbiased and objective in design but were clearly not acceptable professional conduct. Examples like these have made the formal acceptance of rules for conduct in the laboratory, which provide a framework for disciplinary action, both necessary and desirable.

In order to better understand the basis of principle #3, it is useful to elaborate what would covered under this principle. The 'rules of thumb' to avoid certain types of research suggested by Shrader-Frechette (p.26)

1. Scientists ought not to do research that causes unjustifiable risks to people.
2. Scientists ought not to do research that violates norms of free informed consent.
3. Scientists ought not to do research that unjustly converts public resources to private profits.
4. Scientists ought not to do research that seriously jeopardizes environmental welfare.

seem uncontroversial at face value and, indeed provide the basis for many of the regulatory procedures e.g. human subject use or animal care and use committees.

As with any set of guidelines, problems arise in interpretation and the guidelines should be constantly under review. For example, there have been many cases where experiments that were socially acceptable at the time are deemed unethical later. The now infamous Tuskegee experiments on the progression of syphilis in African Americans in the 1940's are now seen to have violated the first two principles of respect for human subjects listed above (Duster, 2003). The men in the trial were not fully informed of the purpose of the research or the full range of treatments available to them. The concept that poor African Americans should be given the information necessary to give full consent to be part of medical research was outside the worldview of the doctors conducting the experiment. They felt justified because they believed that they were actually helping the men in the study through providing medical care that would not have been available to them at the time.

A more recent example of controversy surrounding the implementation of these guidelines involves the development of genetically modified crops and their introduction in commercial agriculture. Opponents of the genetic modification of plants have argued vigorously that the potential release of genetically modified gametes into the wild seriously jeopardizes environmental welfare (#4) and this research should be banned (Butler & Reichhardt, 1999). Others argue equally vigorously that genetic modification of crops will greatly enhance the abundance, range and nutritional value of these products and thus enhance human nutrition (Dale et al, 2002). Interestingly, public opinion towards GM crops is very different in developed countries with many European countries being extremely wary of introduction, and even testing, of GM plants whereas the majority of people in the United States have a much more indifferent or positive attitude.

These examples show how the implementation of an injunction to do research 'in the public good' is far from a simple rule, but rather is highly subject to historical and social context and interpretation. A research scientist cannot apply a simple code of conduct without engaging the ethical, social and legal implications of his/her research and interacting productively with the public.

The Professional Scientist: Ethics of Teaching.

While the label 'scientist' tends to evoke the picture of someone at a laboratory bench undertaking research, teaching is also a very important role for most scientists. Even researchers who do not have any official teaching role in a classroom are usually leaders of teams of scientists with differing levels of training. Specifically, a principal investigator is responsible for teaching graduate and undergraduate research assistants, mentoring post-docs and junior faculty, training technicians and laboratory staff. Other scientists choose careers in which their primary responsibility is that of teaching science to aspiring scientists and/or teaching science to future citizens as part of their general education. In the American higher education system, professors in science disciplines are trained within their narrow disciplinary focus and are not systematically required to gain expertise in any specialized education theory. The normal structure of the 'pure science' departments and the 'science education' program in US universities results in the graduation of science teachers (for secondary education) who have a reasonable background in the basis of science disciplines (flow of students from introductory science to education). However, there is little or no reciprocal knowledge sharing. Professors and students in the science departments rarely concern themselves with the scholarship of science education. Science students proceed to become scientists, and science teachers in higher education, with no familiarity with the mechanics or ethics of teaching. Their training is entirely through the 'apprenticeship' model of learning by observation of their teachers and mentors.

In the higher education literature there are multiple sets of codes and guidelines for ethical teaching. These focus on topics such as content competence; pedagogical competence; appropriate dealing with sensitive topics; contribution to student development; avoidance of dual-role relationships with students; maintenance of confidentiality; respect for colleagues and institution; and valid assessment of students (e.g. Murray et al, 1996). There are obvious parallels between the published professional codes of ethics for teaching and those for presented by NAS for scientists. The primary focus of these guidelines is on the objectivity and fairness aspects of ethics. They admonish teachers/scientists to behave honorably and fairly. At the first level the 'principle of objectivity' can be applied in teaching as a 'principle of fairness': the unbiased treatment of all students. That this principle has not been strictly adhered to in the past is well known, the "chilly" climate found in many classrooms for women and members of minority groups has been well documented (Hall & Sandler, 1984; Manning, 1991). However, great strides have been made in bringing visibility to this issue and most instructors, depending on their degree of awareness of the complexities of the issue, strive to give all students fair treatment.

The deontological approach of rule setting results in an ethics of 'thou shalt not' do something drastic that breaks the guideline to the degree of precipitating sanction. But does simple adherence to a set of rules constitute ethical behavior for a teacher? As with research ethics, I argue these rules are a great foundation but inadequate by themselves. Teachers should also be committed to the higher "goals of promoting the public good and the welfare of third parties, such as present and future inhabitants of the planet." The guidelines for research and teaching practice, as well as the ethical principles underlying them are given in Table 1.

Under this scheme, what responsibilities fall on an ethical science professor? In order to promote the public good, a professor must be willing to enter into those controversial areas discussed earlier where the uses of science in society are complex and contested. He/she must leave the comfortable areas of subject content and learn to communicate with people with very different backgrounds, priorities and worldviews. A scientist who teaches genetic manipulation in plants, concentrating on technological feats like the vector development and genome transformation, prepares students for life as a research technician; a career of bench work with no social relevance only. How is a young scientist, preparing for a career in biotechnology, going to learn about or understand the issues involved with GMOs if the person responsible for teaching them proceeds as though there is no controversy and does not ensure that the student is exposed to these issues somewhere in their education? How do young geneticists understand resistance to their latest achievements, for example "The Wisdom of Repugnance" (Kass, 1997) if they are never introduced to alternative viewpoints as part of their science education?

One fortunate result of the Human Genome Project (HGP) is that there has been a dramatic increase in resources available to undergraduate science teachers who wish to teach ELSI issues in their courses. ELSI funding out of the HGP budget has supported many pedagogical developments including a series of workshops by the Dartmouth Ethics Institute, which provided faculty training in ELSI issues and pedagogy (Donavon & Green, 2008). There are also many compilations of resources and pedagogies available to the bioscience professor interested in including ELSI and communication studies in their courses for majors or non-majors (Garrett & Triman, 2009; Haga, 2006; McCabe & McCabe, 2008).

Table 1. Three principles for the ethics of research and teaching.

Principle	Research Ethics	Teaching Ethics	Basis
I. Unbiased work, Professional integrity	No falsification, fabrication or plagiarism.	Accurate content. Fair assessment practices. Equal treatment	Objective as possible. Predominantly rule-based.
2. Promote unbiased use of others' work	Prevent or challenge biased use of own or other's work. Whistle-blowing.	Prepare scientists – teach research ethics. Communication	As above but less clearly defined. Duty to community.
3. Promoting the 'public good'.	5 'rules'. Institutional regulatory committees, peer review professional society guidelines.	Prepare informed citizens. Incorporate ELSI of science.	Primarily utilitarian. Promotes greatest (public) good beyond professional rules of conduct.

Finally, the goal of promoting the public good requires that scientists are able to competently engage the public in deliberations about what constitutes a 'public good'. Thus communicating developments and applications in science to the public and effectively engaging with a broad audience becomes a responsibility of practicing scientists. This requires scientists to disengage from their tendency to occupy a privileged position in a discussion (scientific evidence 'proves' a point) and thoroughly consider alternative viewpoints. It also required them to surrender their position as 'expert' and be willing to acknowledge the limits of their training. As many current professors lack training in ELSI and communication pedagogy this can be very hard for them to accept or accomplish. The brilliant physicist Richard Feynman (2001) was aware of the limits of his expertise.

> "From time to time people suggest to me that scientists ought to give more consideration to social problems – especially that they should be more responsible in considering the impact of science in society….It seems to me that we do think about these problems from time to time, but we don't put a full-time effort into them- the reasons being that we know we don't have any magic formula for solving social problems, that social problems are very much harder than scientific ones, and that we don't get anywhere when we do think about them. I believe that a scientist looking at nonscientific problems is just as dumb as the next guy-and when he talks about a nonscientific matter, he sounds just as naïve as anyone untrained in the matter." (Feynman, p.241)

However, in acknowledging the limitations of a scientist's expertise, Feynman also seems to be excusing scientists from participating. I disagree and believe scientists should be taught to be both willing to engage with the public on ELSI issues arising from their research and accept/ acknowledge their position as expert scientist/non-expert ELSI citizen.

Conclusion

A bioscientist's roles as researcher and teacher are both governed by self imposed principles for ethical behavior in the profession. These guidelines cover basic principles of objectivity and fairness and can/should also be expanded to include consideration of the 'public good' in both areas of a bioscientist's professional conduct. The framework and equivalence of these ethical principles is given in Table 1. As I argued in the ethics of research section, our evaluation of whether a scientific development or project is 'in the public good' may be subject to social and historical context. Thus sensitivity to ELSI issues and the impact of scientific developments on society is an extremely important aspect of science education, but one that is systematically undervalued or ignored. As shown by our survey, most professors of genetics devote less than 5% of class time to issues of genetics and society and only 4% of their schools require a course focusing on ELSI issues in science for graduation. If we accept the goal of teaching 'for the public good' we must include ELSI issues and communication training in our teaching for bioscience majors. It is an ethical imperative.

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Examining undergraduate students' ability in transferring their mathematical knowledge to chemistry

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Abstract

This study examines students' ability in transferring their mathematics understanding to chemistry. Four *diagnostic tools* have been designed and implemented to determine 2nd year undergraduate students' competency in mathematics pertinent to kinetics and thermodynamics. The *tools* have been designed on the basis of students having completed a 1st year calculus course. They assess their proficiency, insofar as is possible in *procedural* and *conceptual* understanding of fractions, slopes, differentiation, manipulation of indices and integrals—all deemed absolutely essential in various aspects of courses in chemistry, such as kinetics and thermodynamics. This paper discusses in detail the findings from one of these questions and specifically focuses on the methodological approach employed to deduce these findings. A table will aim to convey the notable features of the results with regards to each of the other *matching questions.*

Introduction

International Context: Roberts et al (2005) articulate how 'transfer' is often described by researchers as the ultimate goal of education. From a chemical education perspective, in describing the 'Nature of Context' in the aforementioned domain, Gilbert (2006) states how students appear to be competent in:

> *Only solving problems presented to them in ways that closely mirror the ways in which they are taught.*

This raises a question pertinent to this study, namely whether students can transfer their mathematical knowledge from a mathematics context to a somewhat 'far-off' chemistry context, where quite frequently the underlying mathematics can seem to be obscured. Gilbert further expresses the necessity for:

> *Further research into the effects of assessing pupils' scientific knowledge & understanding through the use of context-based questions.*

Somewhat analogous, albeit it in a different scientific field, namely Physics, Gill (1999) in his article on *The Physics/Maths Problem Again* stresses the importance of understanding the nature of transfer—and more specifically the flagship variables that affect the extent to which it occurs. In his study, he draws emphasis upon evidence from a pre-test administered to his students; those who performed quite well on the graph-type questions appeared more favourably disposed towards achieving success in their future studies of mathematics. This was deemed to be interesting as there was no requirement for this type of competency in the end-of-semester exams; it in effect spurred Gill to posit the question:

What is the relationship between transfer and graph?

Perhaps on a less positive note, Gill asserts that teaching mathematics as part of a single or a combination of contexts inevitably ties the mathematics to these contexts, thus leaving the students 'no better off' in terms of transferring mathematics knowledge from one context to another.

Irish Context: From an Irish Perspective, Hourigan & O'Donoghue (2006) undertook a study on *The Influence of the Pre-Tertiary Mathematics Experience on Students' Ability to Make a Successful Transition to Tertiary Level Mathematics Courses in Ireland*. They describe how at tertiary level, in courses that are mathematically laden, it is necessary for students to possess conceptual and transferable skills to solve unfamiliar problems.

In addition, they stress that there is local and indeed international evidence to suggest that students entering the Irish Third Level system possess few of the fundamental mathematical skills—skills essential for course success. There is they also state evidence that students rely on rote memory and step-by-step algorithms as opposed to deep conceptual understanding. Poor performance on non-routine formats in mathematical studies such as PISA has also been reported.

Findings such as these could be considered paradoxical as the authors describe the Leaving Certificate (Terminal Irish Second-Level Education Exam) Mathematics Curriculum as predominately abstract. If this is the case, then surely one would expect this to foster conceptual understanding and an ability transfer into unfamiliar contexts.

Perhaps crucially, the authors state that the majority of the course is context free; which leaves one asking the question whether or not this is a reason for students inability to perceive the relevance of their mathematics education at second level & thus be proficient in applying it in a new context. Conversely, one could also conjecture that there may be too much of an emphasis on *procedural questions* in assessment, thus impeding a propensity towards a capability in transferring mathematical knowledge from one context to another.

Previous Research Concerning Students Ability to Transfer from Mathematics to Chemistry: In their study *Transfer of Algebraic & Graphical Thinking between Mathematics and Chemistry*, the authors Potgieter et al (2007) exposed a group of students to a 'chemistry instrument' based on the Nernst Equation in an electrochemistry context & then to a similar 'mathematics instrument' in which the questions were subsequently stripped of the prior chemistry context upon which they were embedded within. Among their research questions was that of attempting to answer:

> *To what extent a lack of conceptual understanding of mathematics or a lack of mathematical skills impacts on students' ability to transfer from a mathematics context to a chemistry context where the mathematics may appear obscured.*

Their findings showed that students cannot effectively use the graphical approach in both a mathematics context & the corresponding chemistry context, leading to the claim that 'algebra without its visual implications' is very much at odds with a competency in demonstrating the practical implications of an equation such as in this instance the Nernst Equation. Interestingly the authors found that students were able to transfer their algebraic mathematical knowledge into a chemistry context—a competency which the authors deemed 'procedural'

Conversely the success of transfer between problem solving tasks in more conceptual thinking (those questions which embodied a graphical approach) was less clear for the authors. Their main finding was that the problem students have in transferring their mathematical knowledge from mathematics to chemistry appears to reside on the mathematics side. Perhaps another reason for the impetus behind this study was their assertion that the extent to which the results of their study are relevant to non-logarithmic functions needs to be investigated.

Research Methodology

In light of current research to date, the purpose of this pilot study was to probe students' mathematical knowledge, essential to both kinetics and thermodynamics in both a mathematics context and chemistry context in tandem with their ability to transfer this mathematical knowledge from a mathematics context to a chemistry context. Researchers from the faculty of Mathematical Sciences & the Faculty of Chemical Sciences were pivotal in the formulation of these *Diagnostic Tools*.

The *Diagnostic Tools* were administered to a group of 2nd year Undergraduate Science Students, who were enrolled on a Thermodynamics and Kinetics module. All of the students had completed and passed a 1st year Undergraduate Calculus Course. The tools comprised of the relevant mathematical skills/concepts being present in both a mathematics context and their corresponding chemistry context. It should be noted that the mathematics side of the relevant tool was administered separately from the chemistry context aspect of the tool (within a timeframe of 5-6 weeks). Students who completed both aspects of the respective *Diagnostic Tool* were looked at in particular in order to discern if these students could transfer their mathematical knowledge from a mathematics context to a chemistry context for example.

Design of the Diagnostic Tools The concepts/skills tested for each respective diagnostic tool are shown in table 1. Insofar as was possible & as a consequence of the previous research described thus far, the questions with regard to each concept/skill were designed so as to be either 'procedural' or 'conceptual' in nature. What exactly distinguishes 'procedural questions' from 'conceptual questions' can be a matter of contention as demonstrated by Anderson (1995), whereby he states:

> *The concepts 'procedural' & 'conceptual' are not absolute—conceptual problems can become procedural if students are exposed to the same type of problem repeatedly*

Engelbrecht et al (2005) on their study of *Undergraduate Students' Performance & Confidence in Procedural & Conceptual Mathematics*, define 'procedural fluency' to be evident when students portray an ability to carry out procedures 'flexibly, accurately, efficiently and appropriately'. They define conceptual understanding to exhibit itself when students:

Identify and apply principles, know and apply facts and definitions and compare and contrast related concepts

Table 1. Competencies Tested in Each Diagnostic Tool

Competency	Diagnostic Tool	
	Kinetics	Thermodynamics
Calculation of Slope	√	
Multiplication of Fractions	√	
Differentiation of Functions	√	
Instantaneous Rate of Change	√	
Manipulation of Indices	√	
Evaluating an Integral		√
Graphical Representation of a Function		√
Graphical Representation of an Integral		√

Thus the competencies probed in each of the tools were a mixture of both procedural and conceptual-type questions. It should be stressed, when assessing students' ability to transfer their knowledge from a mathematics context to a chemistry context, it was not necessary for students to have a thorough understanding of the chemical concepts on which the pertinent mathematics was 'superimposed upon' so to speak.

This approach was adopted on the recommendation of Hughes-Hallet (2001). The former authors argued that recognising mathematics in another field requires thorough understanding of the context. In order to offset this 'confounding variable' it was decided to present the material in the chemistry context without this impediment.

The design of each procedural-type question consisted of a part (A) for students to provide their answer. For conceptual-type questions, a part (B) was present in order to ascertain whether or not students could explain their reasoning to a person with no knowledge of chemistry or mathematics; this ability if present was warranted to a certain extent, indicative of a level of conceptual understanding. In retrospect a part (B) should have been included for the procedural-type questions as students may have a conceptual understanding as well as a procedural understanding of the underlying mathematical skills being tested.

Results and Analysis

The analysis of each of the questions will thus be explained through a worked example. In the *Thermodynamics Diagnostic Tool*, one of the mathematical concepts probed concerned students ability to represent the function 'y=1/x' graphically & in its corresponding chemical context in the form 'p=nRT/V', with 'nRT' remaining constant. The concept from table 1 that was being probed was that of determining students' competency in the 'Graphical Representation of a Function'.

Nature of the Graphical -Type Questions: According to Moschovich et al (1993), there are two different perspectives from which functions can be interpreted, namely the *process perspective* and the *object perspective*. The *process perspective* views a function as a link between x & y-values; students who view functions in this regard can substitute an x-value into an equation and ascertain the corresponding y-value.

Conversely in the *object perspective*, a function is thought of as an entity (resonating with the APOS (Action, Process, Object, Schema) Theory of Mathematics as commented upon by Gray et al (2000)). Relating this *object perspective* to a function means for example that its graph can be visualised easily by students in a Cartesian Plane.

In short, the authors describe a *process approach* to a function leading to an algebraic perspective, while the *object approach* to a graphical perspective. Sfard (1992) articulates how:

> *Deep conceptual understanding of a function can only happen when also seeing a function as an object*

Thus, with this research in mind, the aforementioned graphical-type questions in both the mathematics context and chemistry context can be deemed conceptual in nature. The absence of a qualitative-reasoning aspect to student answering could lay one open to claims of students being able to memorise the graph for the relevant function without any real understanding of its derivation; however the low number of correct responses (30.9% as can be seen from table 2) is in our opinion further proof of the fact that the question is of the conceptual genre.

The question in the mathematics context was administered to 55 students while the analogous question in the chemistry context was administered to 48 students. Table 2 shows the percentage of correct and incorrect responses for each respective context.

Table 2. Percentage of Correct & Incorrect Respondents Concerning the Graphical-Type Questions

Nature of Response	Thermodynamics Diagnostics Tool	
	Mathematics Context (n=55)	Chemistry Context (n=48)
% Correct	30.9	37.5
% Incorrect	69.1	62.5

The students who answered the question in both contexts were matched; this numbered 30 students. For these 30 students, their level of mathematical understanding as demonstrated by them was analysed via their part (B) response. In analysing their qualitative response, a *General Inductive Approach for Qualitative Data Analysis* as described by Thomas (2003) was deployed.

The salient feature of this method begins with the reading of the text in the qualitative responses in order to distil multiple meanings that are inherent in the text. Snippets of text or 'meaning units', which contain certain strands of meaning, are extracted and then categorised using an apt label. This emergence of categories leads to hierarchical & subordinate categories, akin to a pyramidal-type image. The overarching categories (typically 3-8) thus capture the essence of the data.

In addition these categories were mirrored with being indicative of a certain level of mathematical understanding. Concerning the graphical-type question, for the correct students, this Level of mathematical understanding was *conceptual understanding* while for the incorrect students it was either *conceptual understanding with errors* or a *lack of knowledge.*

While deducting the mathematical levels for the incorrect students, the work of Donaldson (1963) as described by Orton (1983) was also called into play. Donaldson classified errors in accordance with the following criteria:

Structural Errors: Those which arise from some failure to appreciate the relationships involved in the problem or to grasp some principle essential to the solution

Executive Errors: Those which involve failure to carry out manipulation, though the principles involved may be understood.

Arbitrary Errors: Those in which the subject behaves randomly and fails to take account of the constraints laid down in what is given

Thus, once students' mathematical level of understanding was deduced for the incorrect students, it was possible to determine whether students whom appeared to be incorrect upon quantitative data analysis (analysing part (A) of the question) were in fact incorrect or simply made an executive error for example, as evidenced by the category pertinent to their qualitative response.

The possible associations relevant to the matching questions that were investigated are shown in Figure 1.

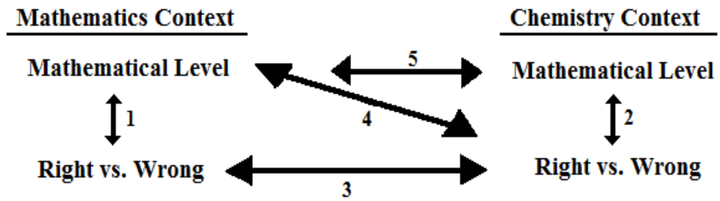

Figure1. Associations Investigated for the Matching Questions

In order to ascertain the presence of particular associations as shown in figure 1, students were grouped into the appropriate categories. If an association appeared to manifest itself, whether or not this was statistically significant was confirmed using Fisher Analysis. The results with regard to this question are shown in table 3.

Table 3. Associations for the Graphical-Type Questions

Association	Association for the Matching Students	
	Appears Present	P-Value
1	√	2.8E-05
2	√	2.8E-05
3	√	1.1E-02
4	√	1.1E-02
5	√	1.1E-02

The finding with respect to Associations 1 showed that there is a statistically significant relationship among the *matching students* (p-value less than or equal to 0.05) between conveying ***Conceptual Understanding of the Function '1/x'*** in the Mathematics Context and Being ***Correct*** in the Mathematics Context, while likewise for Association 2, between Conveying ***Conceptual Understanding with Regards to the Representation of the Function 'P=(nRT)/V'*** and Being ***Correct*** in the Chemistry Context.

Association 4 showed a statistically significant relationship between Conveying ***Conceptual Understanding with Regards to the Representation of the Function '1/x'*** in the Mathematics Context and Being ***Correct*** in the Chemistry Context, while Association 5 showed a statistically significant relationship between displaying ***Conceptual Understanding of the Representation of the Function '1/x'*** in the Mathematics Context and Conveying ***Conceptual Understanding of the Representation of the Analogous Function*** in the Chemistry Context

Perhaps most notably of all, there is a statistically significant association (Association 3) amongst students who were ***correct in the mathematics context***, being ***correct in the chemistry context***; thus confirming that these students could transfer their conceptual mathematical knowledge from a mathematics context to a chemistry context.

This type of analysis was performed for each of the matching questions in both kinetics & thermodynamics. Rather than describing the results for each question, the important association of whether or not students who were correct in the mathematics context transferred this knowledge to a chemistry context (Association 3 in figure 1) are shown for each particular concept that was tested in table 4. The percentage of correct respondents for each particular concept in both a mathematics context and chemistry context is shown in table 5.

Table 4. Overall Results for Each Matching Question with Respect to Association 3.

Concept	Question Type	Diagnostic Tool	Association 3 for the Matching Students	
			Appears Present	P-Value
1)Calculation of Slope	Procedural	Kinetics	√	1.4E-03
2) Multiplication of Fractions	Procedural	Kinetics	√	0.2
3)Differentiation of Functions	Procedural	Kinetics	√	3.3E-04
4)Instantaneous Rate of Change	Conceptual	Kinetics	√	0.84
5)Graphical Representation of a Function	Conceptual	Thermodynamics	√	1.1E-02
6)Manipulation of Indices	Conceptual	Kinetics	√	0.1
7) Evaluating an Integral	Procedural	Thermodynamics	√	0.2
8)Graphical Representation of an Integral	Conceptual	Thermodynamics	×	0.79

Table 5. Overall Results Concerning the % of Correct Responses with Regard to All of the Respondents in Each Particular Question

Concept/ Skill	% Correct in a Mathematics Context	% Correct in a Chemistry Context
1	84.52 (n=85)	44.82(n=58)
2	76.19(n=85)	55.17(n=58)
3	73.80(n=85)	8.62(n=58)
4	53.57(n=85)	36.2(n=58)
5	30.9(n=55)	37.5(n=48)
6	28.57(n=85)	8.62(n=58)
7	16.36(n=55)	10.41(n=48)
8	9.09(n=85)	16.66(n=48)

Conclusions

Looking at the collection of mathematical concepts and skills from both of the Diagnostics tools as shown in table 4, one can see that there were a total of 4 procedural skills probed in tandem with 4 conceptual competencies. For the matching students, they showed more wherewithal in transferring procedural skills from one context to another, thus adding credence to previous research.

If one looks at table 5, they will see that for procedural tasks, a greater percentage of students answered these correctly in their own right for each respective context in comparison with the conceptual tasks.

The questions deployed in this pilot study will be further modified in light of the shortcoming identified within each of them during the analysis of the pilot study results; there will be a stronger focus in eliminating 'confounding variables' when attempting to create similar mathematical tasks in both a mathematics context and chemistry context.

Future research will focus on attempting to answer:

To what extent procedural knowledge in mathematics concepts which students can transfer from a mathematics context to a chemistry context aids or impedes their understanding of the underlying chemical concepts in comparison to conceptual understanding of the same mathematics concepts.

Additionally and by no means less inferior, the question of:

How can students' conceptual understanding of mathematical concepts be improved in a mathematics context and more importantly what are the prominent variables in terms of the characteristics of students, whom can transfer this conceptual knowledge from a mathematics context to a chemistry context.

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CAD forces changes to engineering graphics curriculum

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Abstract

Nowadays computer-aided design (**CAD**) software improves rapidly and we are supposed to update the teaching methods for engineering graphics education. In Mechanical Engineering Department of Istanbul Technical University we have been giving courses about Engineering Graphics in two steps (grade). The first step includes the theoretical courses that cover all subjects of traditional engineering graphics books. The next step is to accomplish some exercises using two dimensional (2-D) drawing and solids-modelling with CAD software's in our computer lab. CAD software clearly includes many traditional engineering graphics subjects (topics). We have updated this course for different faculty curriculum in our university. The course is now focused on International Standard Organization (ISO) standards, CAD modelling and modern manufacturing systems and also effective engineering design communications. Outdated technical drawing material and topic have been eliminated. Engineering Graphics topics can be presented in this paper as shown below. Some topics can be eliminated or added from this list. We will update and give Engineering Graphics courses in the following semester in all other faculties of our university.

Introduction

Engineers must communicate the original idea or concept to other engineers, management, company personals and to the customer. This communication traditionally has occurred on paper, and there exists a standard graphic language for this purpose. For the engineers understanding to read and write technical reports in the graphic language is very important. Many engineering schools have had a course "Engineering Graphics" or "Technical Drawing" or "Engineering Drawing and Graphics" that teaches this standard graphic language.

In the past, designers produced physical models to explain of a design. Today, computer-generated models replace physical models and these models are much more flexible, fast and less expensive. Modern CAD software creates the models and engineering drawings. Most industrial organizations use solid modelling software. The cost of CAD software and hardware gradually to lower, therefore solid modelling becomes affordable to all size company.

Engineering faculties and programs have different curriculum about to teach engineering graphics. Over how many semesters should be teach Engineering Graphics? Which subjects should be included? We have to teach CAD. Should hand drawing be taught? What subjects should be included?

This article represents the adaptation of the curriculum in the Mechanical Engineering Faculty of Istanbul Technical University. The mechanical engineering program at Istanbul Technical University is Accreditation Board for Engineering and

Technology (ABET) accredited. It is a big program with approximately 250 students in Mechanical Engineering with approximately 4000 students enrolled.

The program develops mechanical engineers to understand engineering fundamentals and modern technology, and to have strong leadership, thinking skills and writing.

Engineering Graphic History

Engineers should be able to communicate effectively, since engineering graphics is the engineer's language for communicating product ideas. Therefore the need for training in engineering graphics has a big importance in our faculty. Mechanical Engineering Faculty settled on two semester course in engineering graphics. This was due to several considerations:

- The total program hours that we wanted to limit the program to -132 credit hours,
- Competition with other basic engineering and science courses
- The university's requirement for general education courses
- The importance of engineering graphics for mechanical engineers

The Mechanical Engineering program began in the 1900's. Technical drawing course was use of instrument drawing. CAD technology was begun in the early 1990's. The cost of CAD was so expensive for an official (government) university. It was an easy way at that time that engineering graphics was taught in a traditional format with drawing boards. Hand drawing was the only economic means for drawing engineering drawings (Technical drawings).

As, around 1997, the cost of CAD technology continued to improve and costs decreased, it became apparent that CAD technology and its role in engineering graphics could not be ignored. Eventually, around 1990, the faculty purchased a copy of AutoCAD and ink pens plotter. The software and hardware were adapted to a computer in the technical drawing department. The professor used the software and hardware. Then the software and hardware were added to technical drawing labs for 3 years later.

In ABET process the department revised the technical drawing course and CAD technology. Department decide two semester engineering graphics course. First semester is traditional technical drawing course (RES 105) and then second semester Computer Aided Technical Drawing (MAK 112E). Our educational plan was to introduce students to traditional hand drawing in RES 105 and then build upon their basic technical drawing knowledge again in MAK 112E in CAD technology lab. In this ABET process, drafting tables and drawing by hand is not enough. For ability to finding successful employment in industry students need CAD technology.

It became obvious from industry, students improve CAD and show CAD capabilities, such as mass properties and relate it to cost of part. Redesign of engineering course was begun.

RES 105 – Technical Drawing

The basic objective of this course is to teach students to understand how engineering drawing are communicated in industry

The course is split into two components, theory and practice. Basic engineering drawing books are used to teach engineering graphics theory. The professor provides instruction by using PowerPoint overheads that reinforce important engineering graphic concepts. Students work through exercises in assignments during practice times. The professor solves problems that students encounter during practice time. The adviser discusses or shows the connection between theory and practice in Turkish.

MAK 112E- Computer Aided Technical Drawing

The basic objective of this course is to have students learn to use advanced modelling computer-aided design software.

Technical drawing is prerequired in this course. In one-semester course, technical drawing, the students received instruction on engineering graphic theory and hands drawing instructions with drawing board. Students who take RES 105 are better prepared to do their CAD lab exercises. Some students do not like hand drawing, but work on CAD software is very favourable. AutoCAD software is used for two dimensional drawing. Then Students create some very complicated parts using SolidWorks software. Students prepare their design homework end of the course and are proud of their CAD knowledge.

Basic Change with CAD Forces

When CAD is used in Engineering Graphics education, it forces us to consider changing engineering graphic education. Several examples of these changes are discussed below:

Using Drawing Instruments. The traditional tools used to create technical drawings have evolved over time. Many tools were originally used in ancient Greece to study and develop geometry. Although computers may someday replace the need for some traditional tools, they are useful today for drawing, and more importantly, for sketching. Traditional tolls are devices used to assist the human hand in making technical drawings. The assistance includes drawing lines straighter, drawing circle more circular and increasing the speed with which drawings are made. The tools typically used to create mechanical drawings or sketches consist of wood and mechanical pencils, instrument set, including compass and dividers and triangles.

CAD eliminates the need to use mechanical pencils, pencils, pencil sharpener, T-square, the dusting brush, triangles, protractors, compass, dividers and other drawing templates. These mechanical drawing tools and how to use them is no longer needed in our RES 107 courses at Department of Management Engineering.

Lettering and Lines. In technical drawing course, to learn lettering and line types took a few course hours.

Computer aided design software is used with selection of the proper fonts and lines from the program's menu choices.

Geometric Construction. The technique to draw circles, ellipses, perpendicular and parallel lines by hand, line and circle tangencies intersections of geometry is obsolete. CAD provides these abilities in a few minutes, Jerz (2001).

Oblique Drawing. An oblique drawing is simulated isometric drawing. Its main purpose was easy creating an isometric drawing and not has to draw ellipses by hand. Circles (on the front plane) stay as circles in an oblique drawing.

Multiview Drawing. Multiviews drawings do not be eliminated, like the hand drawing of producing them.

CAD can create multiview drawing in a matter of seconds. SolidWorks makes multiview drawings by automatically and rotating the part and illustrating how the various views are created, Jerz (2001). Sectional views and perspective drawings are created as easy as with CAD.

Dimensioning and Tolerancing. Engineers need to know how to dimension parts is given. Engineers need to better understand the purpose of dimensions and tolerances, their effect on manufacturability, and the costs associated with them.

Design Problems and Teams. Design problems are intended to challenge mechanical engineering students to be creative, individually and in a group. The design problems are not meant to teach the design process as much as how to represent ideas graphically, using drawings and computer models. Any design problems means that all details of the solution are not necessary, Bertoline (2009). For each project, students create the engineering drawings and models necessary to communicate their solution to others teams. The engineering drawing should include the following:

- Initial design sketches
- Multiview drawings, with dimensions.
- Sectional assembly drawings, with part list.
- Pictorial drawings of the final design.

Group projects use a team approach to solve the design problems. The teams should consist of four to six students. Each team should have a group leader to schedule meetings, assign task and deadlines.

Assembly Drawings. A working drawing is a drawing that gives information and instructions for the manufacture or construction of structures or machines. Working drawings may be classified into two groups: detail drawings, which the necessary information for the manufacture of the items (parts), and assembly drawings, which give the necessary information for their assembly.

A detail drawing must supply the complete information for the construction of a part. This information is shape description, size description, and specifications.

Shape Description: The selection and number of views show or describe the shape of part. The part may be drawn in either pictorial or orthographic projection. Sectional views, auxiliary views, and enlarged detail views may be added to the drawing in order to provide a clearer image of the part. We should teach shape description to our students.

Size Description: Dimensions which show the size and location of the shape features are then added to the drawing. The manufacturing process will influence the selection of some dimensions, such as datum features. Tolerances are then selected for each dimension.

Specifications: General notes, material, heat treatment, finish, general tolerances, and number required. This information is located on or near the title block.

CAD eases the complexity of creating assembly drawings. More time should be devoted to assembly drawings since most products are assemblies. Understanding the effect of tolerances can be explored with assembly drawings. This topic also offers opportunity to tolerance stack up analysis and dynamic functional analysis for mechanical engineering students.

Change to Engineering Graphics Curriculum. The information on engineering drawings (e.g., dimensioning, surface finishing, tolerances, and list of materials) includes many other company data such as purchasing, manufacturing, materials requirements planning and scheduling. Regarding to this fact, the students should recognize the importance of this course which will affect their engineering career.

There is much work being done in industry nowadays to planning these data standards that will affect the way engineers work in future. SolidWorks software can include CAD data in an Excel file. This data is in a spread sheet format, it becomes easy to sharing this data with other computer applications.

It is time to update the course topics and decide what should and should not be included. We must eliminate outdated topics presents an opportunity to include new topics. Also we should provide additional emphasis on existing topics.

Conclusion

Big industry corporations don't use drafting boards and hand drawings in our country. Also small engineering firms use CAD. Engineering students should learn to use CAD. Many big industry from automotive, heavy equipment, aircraft and machine tools and consumer product and process industries using engineering graphics and included opinions. Concerning engineering graphics includes CAD/CAM, geometric dimensioning and tolerancing, blueprint reading and practices it to CAD, solid modelling, shape visualization and design for manufacture.

Nowadays engineers should communicate product ideas in two ways: using a computer-generated model or creating manufacturing drawings. Both of them are very important and it is suggested that should teach in an engineering graphic course.

Engineering graphics textbooks include too much information about how manual drafting. CAD makes engineering drawing (technical drawings) more accurate and faster. Therefore, hand drawing topics can be eliminated. Engineering students should concentrate more on the drawing features, their relationships on the assembled product, the effect on manufacture, benefit to product design, the effect on manufacture and the cost of product. Also, they learn the importance of teamwork.

In Mechanical Engineering Faculty of Istanbul Technical University, we believe one semester course in engineering graphics and following semester one more CAD course is an efficient solution for effective learning. In addition to these courses, one semester course about assembly drawing is a good solution for mechanical engineering candidates. Students learn basic topics well and retain it longer when they must reapply knowledge. Learning to use CAD software's to create product design is important. Team work projects are useful to prepare technical reports and presentations.

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Bouncing ball – a mathematisation for second year high school and Matura students

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Abstract

This contribution shows how cooperation of mathematics and physics high school teachers helps students achieve a better understanding of both subjects. During physics lessons, we use an ultrasonic motion tracker to measure the free fall of a ball and two rebounds. A computer programme plots a graph of position vs. time. Second year students (at the age of 16) are able to deduct the equation of a quadratic function based on its graph. From such equation they are also able to read the constant acceleration. For Matura students, we give a practical example of calculus (differentiation) usage.

Introduction

Mathematics teacher used realistic graphs and measurements, obtained during physics course, in her teachings. This way, a mathematician and a physicist have demonstrated how, by inter-subject connections, lessons can be enriched and made more attractive. To make the connection even more obvious, we use copies of graphs that were obtained during physics lessons based on real experiments and that students have pasted into their (physics) notebooks. Judged by the feed-back we received from the students, we are on the right track.

Ultrasonic motion sensor

An ultrasonic motion sensor is an experimental device consisting of a transmitter and a receiver, which can be connected to a personal computer (PC) by an interface. The principle of operation is simple: the device generates short ultrasonic pulses, which travel to the chosen object. The ultrasonic pulse is then reflected and travels back, where it is received by the receiver. Time difference between transmitted and received signal is directly proportional to the distance of the object, which is calculated based on the velocity of sound. This can be done even 100 times per second. Since the measurements system is capable of following one coordinate, it is convenient for the object to move along a straight line. A powerful software programme, written by Dr. Slavko Kocjancic from the Pedagogical Faculty in Ljubljana, plots graphs *x(t)* (position vs. time), *v(t)* (velocity vs. time) and *a(t)* (acceleration vs. time) in real time. Of course, we can choose to display just one or two plots.

Ball rebounds – a mathematician's point of view

We used the above described ultrasonic motion sensor to measure the free fall of a ball and two consequent rebounds. The ball was first held for about three tenths of a second under the motion sensor and was then released. It fell freely to the floor, where it rebound. To describe this motion, we will use a one-dimensional coordinate system, depicted in Figure 1. Coordinate 0 is raised from the floor level for the value of the ball diameter with coordinate system x axis oriented upwards. The recoil is not totally elastic, so the ball did not reach the same level from which it was released. This also holds for the second rebound.

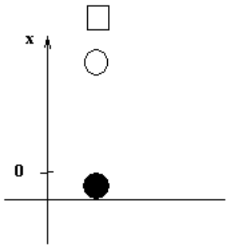


Figure 1. One-dimensional coordinate system that will be used to describe our bouncing ball. Coordinate 0 coincides with the uppermost point of the ball when it is touching the floor. Initial position of the ball is depicted with a dotted line, the square above is the ultrasonic motion sensor.

With the aid of motion sensor, we obtained the following graph:

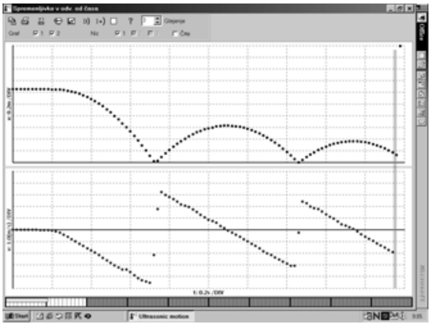


Figure 2. The ball was held for about two tenths of a second under the ultrasound motion sensor and was afterwards released. The upper graph shows $x(t)$, the lower $v(t)$ for this motion.

Let us now »mathematise« the measured points: we need to find an equation describing the position of the ball during the first rebound. We will assume that the motion is uniformly accelerated, meaning that the value of acceleration is constant. The equation will thus be a (shifted) parabola. The fact that we are aware of the value for acceleration is now not important – we will also calculate this value in order to confirm our predictions.

For a moment, we will now continue with »pure mathematics« and forget about physics for a moment. Seeking the equation for the central parabola on the *x(t)* graph, we read the coordinates of three points, for example the *x*-axis intercepts (zero values) and the vertex:

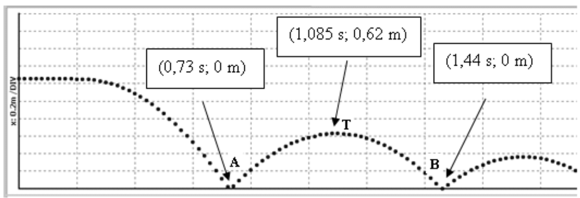


Figure 3. The central parabola, which represents the first rebound, can be used to read coordinates of the three points that lie on it.

We will for now omit the units to make our parabola look similar to the ones students are familiar with. Let us also rename the vertical axis to *y* and the horizontal axis to *x*. The three points are then:

A(0,73; 0)

B(1,44; 0)

T(1,085; 0,62)

We calculated the vertex as arithmetic mean, hence so many digits.

Parabola is defined by three points. We insert these three points in the general formula $y = Ax^2 + Bx + C$ to get a system of three equations with three unknown values: A, B and C. (We will use the capital letter *A* to denote the leading coefficient in order to avoid later confusion with *a*, acceleration.) Because two of these are *x* intercepts, it is easier to use the factored form $y = A(x - x_1)(x - x_2)$.

$$y = A(x - 0{,}73)(x - 1{,}44)$$

$$y = A(x^2 - 2{,}17x + 1{,}05)$$

Using the coordinates of the third point, we can proceed to calculate the leading coefficient *A*. The parabola is positioned so that its vertex is also maximum, which means that the coefficient *A* must be negative.

$$0{,}62 = A(1{,}085^2 - 2{,}17 \cdot 1{,}085 + 1{,}05)$$

$$0{,}62 = A(-0{,}18)$$

$$A = \frac{0{,}62}{-0{,}18} = -4{,}9$$

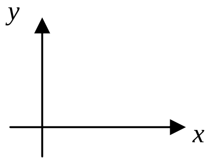
And finally, the equation of the parabola can be written as:

$$y = -4{,}9(x^2 - 2{,}17x + 1{,}05)$$

$$y = -4{,}9x^2 + 10{,}6x - 5{,}1$$

Let us now translate our mathematical calculations back to the language of physics:

Mathematical coordinate system:



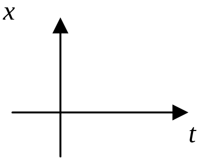
x … independent variable
y … dependent variable

Equation of parabola:

$$y(x) = -4{,}9x^2 + 10{,}6x - 5{,}1$$

Domain: $x \in [0.73, 1.41]$

Our physics system:



t … times (second)
x … position m (meter)

Formula for position as a function of time:

$$x(t) = -4{,}9t^2 + 10{,}6t - 5{,}1$$

the rebound started at t = 0,73 s and finished at t = 1,44 s.

If the above derivation is repeated, this time using also physical quantities, the equation of positions as a function of time can be written as:

$$x(t) = -4{,}9ms^{-2}t^2 + 10{,}6ms^{-1}t - 5{,}1m$$

Let us now calculate the position of the ball at time t = 1,0 s (we must not forget that the »domain« of our function is between t = 0,73 s and t = 1,44 s). We insert *t=1,0* in the equation and the result is:

x = 0,59 m

This can be confirmed by looking at the graph.

If our parabola with the vertex T(1,085; 0,62) is rigidly shifted so that the vertex now coincides with the origin, we get a simpler equation:

$$y(x) = -4{,}9x^2.$$

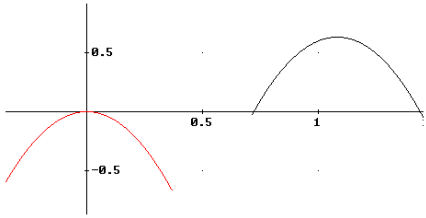


Figure 4. Rigidly shifted original parabola $y(x) = -4{,}9x^2 + 10{,}6x - 5{,}1$ for vector (-1,085; -0,62)

Translated to the language of physics, this means that the ball would reach maximum height, coordinates of which would be labeled as (0,0), at time t = 0.

The equation for position as a function of time would then be $x(t) = -4{,}9t^2 ms^{-2}$.

We know that in the case of uniformly accelerated motion (when initial velocity is 0 and initial position is also 0), the formula for position as a function of time can be written as:

$x = \frac{at^2}{2}$, where a denotes constant acceleration.

Comparing this equation with $x(t) = -4{,}9t^2$, which was obtained by measurement, the constant acceleration a is:

$\frac{a}{2} = -4{,}9ms^{-2}$, from which follows $a = -9{,}8ms^{-2}$.

Very promising! After all, this means that the acceleration of this movement is 9,8 ms^{-2}, which is exactly what is expected.

An appendix for Matura students

By deriving the function $y(x) = -4{,}9x^2 + 10{,}6x - 5{,}1$ we get $y'(x) = -9{,}8x + 10{,}6$.

In physics the derivative of position as a function of time tells the velocity as a function of time. The derivative of *x(t)* can be written as:

$x'(t) = v(t) = -9{,}8\ ms^{-2}t + 10{,}6\ ms^{-1}$

This is the known equation for a straight line. The slope corresponds to the acceleration due to gravity. We can also check the intercept of this straight line with the vertical axis, axis v (Figure 5). We must remember that our function is valid only in the interval between 0,73 s and 1,44 s, meaning that there is no intercept. However, if we prolong the line, we can confirm whether the intercept point is in fact v = 10,6 m/s. Of course, the axis needs to be prolonged as well. In the scope of our accuracy we find out that the intercept point is indeed 10,6 m/s.

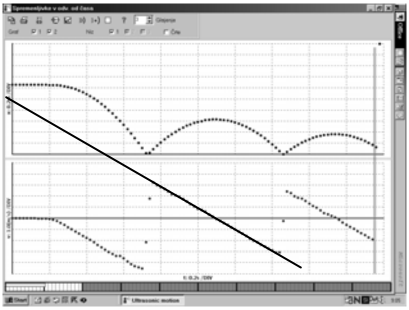


Figure 5. Using the equation for *x(t)*, which was based on the measured points, we calculated *v(t)*. The calculated values are in good agreement with the measured values.

Differentiation of velocity once again brings us to acceleration:

$a(t) = v'(t) = -9{,}8\ ms^{-2}$

Conclusion

We were able to predict the behavior of functions *x(t)* and *v(t)* in the interval of 0,73 s do 1,44 s based on three measured points, assumption of uniformly accelerated motion and command of mathematical formalism (parabola and differentiation). The other measured points provided by the ultrasonic motion sensor confirm our prediction, which was based on just three points. We also successfully calculated the acceleration due to gravity: 9,8 ms^{-2}.

This approach helps to prove students the importance of mathematisation of physical phenomena. The first part of the article, which refers to the parabola, is already suitable for second-year high school students. The part referring to calculus can show Matura (forth-year high school) students the efficiency of integration and differentiation.

It is in fact proper, due to historical reasons, that mathematics and physics teachers cooperate with the teachings of calculus, since this extremely useful mathematic tool was, after all, independently discovered by two giants: physicist Newton and mathematician Leibnitz.

Acknowledgement

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A physics laboratory course designed using problem-based learning for prospective physics teachers

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Abstract

In general, laboratories are exercises with a primary focus on the verification of established laws and principles, or on the discovery of objectively knowable facts. In laboratories, students gather data without comprehending the meaning of their actions. The cognitive demand of laboratory tasks is reduced to a minimal level. To prevent these deficiencies, activities in a physics laboratory course were redesigned using problem-based learning. Problem-based learning is an inquiry based instructional design in which experiential learning organized around the investigation, explanation, and resolution of meaningful problems. In activities, instructional strategy is student-centered and learning has to occur in small student groups under the guidance of a tutor. Authentic real world problems are primarily encountered in the learning sequence. To solve the problems, students propose hypothesis, and test their hypothesis with suitable experiment designs. Laboratory design and instruction strategies are very suitable for performing science process skills.

Introduction

Science educators increasingly perceive the school science laboratory as a unique learning environment in which students can work cooperatively in small groups to investigate scientific phenomena and relationships. Hofstein and Lunetta (1982) suggested that laboratory activities have the potential to enable collaborative social relationships as well as positive attitudes toward science and cognitive growth. The social environment in a school laboratory is usually less formal than in a conventional classroom. Thus, the laboratory offers opportunities for productive, cooperative interactions among students and with the teacher that have the potential to promote positive learning environment. The laboratory offers unique opportunities for students and their teacher to engage in collaborative inquiry and to function as a classroom community of scientists (Gunstone & Champagne, 1990). Such experiences offer students opportunities to consider how to solve problems and develop their understanding. Better understanding of students' science process skills is important since all activities in the laboratory directly related to these skills.

Scholarly efforts have identified serious inconsistencies between goals for science education and learning outcomes visible in school laboratories. "Several researchers have reported that students regularly performed school science experiments with very different purposes in mind than those perceived by their teachers" (Lunetta, 2003). Students tended to perceive either following the instructions or getting the right answer as the principal purpose for a school science task. In the laboratory, students can perceive that manipulating equipment and measuring are goals but they can fail to perceive conceptual or even procedural goals. Students often fail to understand the relationship between the purpose of the investigation and the design of the experiment which they had conducted, they do not connect the experiment with what they have done earlier, and they seldom note the discrepancies between their own concepts, and the concepts of their peers. A laboratory means manipulating equipment but not manipulating ideas for many students (Eylon & Linn, 1988).

Literature Review

In recent years more importance has been placed on the learner's experience. The constructivist perspective of learning science emphasizes the importance of individual interpretation in the process of the construction of knowledge. "Constructivism implies that students require opportunities to experience what they are to learn in a direct way and time to think and make sense of what they are learning" (Tobin, 1990, p. 405). Students need to be able to arrive at an understanding of why they do, what they do, and to construct feasible explanations for their experiences, instead of completing a set of prescribed steps presented by another individual.

Inquiry can be a valuable pathway for the realization of constructivist perspective. In the United States National Science Education Standards (2000), inquiry is defined as the methods that "scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas as well as an understanding of how scientists study the natural world" (p. 23). Inquiry/science process skills stem from how scientists' work and help students understand how scientists think, work and investigate their own questions. Martin (2000) classified the processes of scientific inquiry into "basic" and "integrated" process skills. Basic inquiry/process skills include observing, classifying, communicating, measuring, predicting, and inferring. On the other hand, integrated inquiry process skills include identifying and controlling variables, formulating and testing hypotheses, interpreting data, defining operationally, experimenting, and constructing models. Basic inquiry process skills are usually the main focus of inquiry-based classrooms. However, National Research Council (2000) recommended advancing aimed inquiry/ process skills one step forward and using integrated inquiry/ process skills such as "asking questions, planning and conducting investigations, using appropriate tools and techniques to gather data, thinking critically and logically about relationships between evidence and explanations, constructing and analyzing alternative explanations, and communicating scientific arguments" (p.105).

Laboratory activities have long had a distinctive and central role in the science education for promoting science process skills. Science educators have suggested that many benefits can be attained from engaging students in science laboratory activities (Lazarowitz & Tamir, 1994). Lunetta (2003) defines laboratory activities as “experiences in school settings in which students interact with materials to observe and understand the natural world. Laboratory classes have ranged from activities in which data are gathered to verify a stated principle or relationship to inductive activities, in which students seek to identify patterns or relationships in data which they gather” (p. 249).

Teacher guidance and instruction have ranged from highly structured to open inquiry in laboratory activities. Laboratory classes have been conducted to engage students individually in small groups and in large-group demonstration settings. Sometimes laboratory activities have incorporated a high level of instrumentation and at other times the use of any instrumentation has been purposefully avoided (Gunstone & Champagne, 1990). Laboratory activities can offer important experiences in the learning of science. Laboratory experiences have been supposed to promote central science education goals including: understanding of scientific concepts, the development of scientific practical skills and problem-solving abilities, and interest and motivation (Roth, 1994).

Among the problems cited as responsible for the deficiencies of laboratory experiences, two of them are very important (Tobin, 1990). First, current science teaching is embedded on an inappropriate epistemology. Laboratories are exercises with a primary focus on the verification of established laws and principles, or on the discovery of objectively knowable facts. In laboratories, students gathered data without comprehending the meaning of their actions. The cognitive demand of laboratory tasks was reduced to a minimal level. Second, collaborative methods are not used properly in science laboratories. Students work on their assignments in a leisurely atmosphere and spent much of their time off-task, socializing with their peers.

From a constructivist perspective, the collaboration among students has great potential since group interactions provide an opportunity for the negotiation of meaning and arriving at consensus, important mechanisms in the equilibration of discrepancy and disagreement (Wheatley, 1991). The nature of the interactions among students and research teams in the school laboratory can enhance science concept construction and related learning outcomes. When teachers utilize cooperative learning strategies, researchers have reported better integration between classroom and laboratory activity and enhanced achievement (Johnson et al., 1985). Collaborative planning and discussions of findings provide a forum in which implicit ideas can be made explicit. Communication and reflection are encouraged through the preparation and discussion of laboratory reports. Preparing a report should provide opportunities for individual students to reflect upon and clarify their own observations, hypotheses, conceptions and theories. Dialogue also provides opportunities for individuals to build on the ideas of others to reach understanding and solutions (Lazarowitz & Tamir, 1994).

Collaborative methods provide situations where participants must offer explanations, interpretations, and resolutions to problems (Brown & Palincsar, 1989). Several studies conducted in science courses reported positive effects of cooperative learning methods (Okebukola, 1985; Johnson et al., 1985). Although some studies have lighted on science learning in groups, the literature available remains limited. Additionally, most of these research agendas were conducted in the process-product paradigm and usually had not described what are the learning processes in detail (Eylon & Linn, 1988).

Problem-based learning is an inquiry based instructional design in which experiential learning organized around the investigation, explanation, and resolution of meaningful problems (Borrows, 2000). In spite of the many variations of problem-based learning that have evolved, six core characteristics of problem-based learning are distinguished in the core model described by Barrows (1996). The first characteristic is that learning needs to be student-centered. Second, learning has to occur in small student groups under the guidance of a tutor. The third characteristic refers to the tutor as a facilitator or guide. Fourth, authentic problems are primarily encountered in the learning sequence, before any preparation or study has occurred. Fifth, the problems encountered are used as a tool to achieve the required knowledge and the problem-solving skills necessary to eventually solve the problem. Finally, new information needs to be acquired through self-directed learning.

Laboratory worksheets

Six laboratory worksheets were prepared in line with characteristics of problem-based learning. Two research assistants checked the cases and the parts of laboratory worksheets.

All laboratory worksheets consist of 9 parts. At the first part there is a problematic real life context which can be encountered during the daily life of people. Participants read this situation and think about it. They should understand the context and problem, and propose some solutions to the problem. The cases were developed with the following consideration.

◊ Situations can be encountered in real life
◊ More than two variables in the problems
◊ The availability of lab equipments for possible experiments
◊ Problems from different topics

In the first question, students need to identify physics concepts that can be related to situation. Second question wants participants write the problem of the case by using these physics concepts. First and second questions provide analysis of the real life situation from a physicist's perspective. Moreover, answers to these questions will show that in what degree students understand the situation and problem. Students write a hypothesis to solve the problem in the fourth part. At the fifth part, they design an experiment to test their hypothesis. They should explain their experiment, draw a scheme of their experiment and write numerical values of their controlled variables. In the sixth part participants write their variables. Variables are divided into subgroups as manipulated, responding, controlled, and uncontrolled variables. At the seventh part, they write their experiment results with tables and graphs. Eight part of the worksheet consist of their interpretation of the experiment and results. Participants should write limitation of their experiment and in what degree they believe their results. At the last part, they should write a recommendation as a solution to the problem.

Implementation of the Method

The study began at the fall semester of 2008-2009. There were 18 participants in the study. Because of the laboratory conditions they divided into two groups. Participants worked with pairs according to who they wanted to work with. At the first week laboratory work sheets were introduced to participants. What they are going to do in the laboratory and how they should fill the laboratory worksheets were shortly described. The study spanned to six weeks period of three hours per week. At the first five weeks laboratory worksheets were given to the participants. For the last week, participants prepared their laboratory worksheets similar to their previous worksheets. Alternative laboratory worksheet for sixth week was also prepared by the researcher in case participants would have not prepared it. Every week at the end of the lessons, there was a discussion part in which every group presents their hypothesis, experiment design, results, and their recommendation.

There were two laboratory assistants during the study, one of them researcher. The other laboratory assistant was informed about laboratory worksheets, situations, and possible experiments. Laboratory assistants did not provide any guidance to the participants without participants asked for help.

Conclusion

In general, laboratory activities were implemented for six weeks successfully. Students worked with given laboratory worksheets for five weeks. At the last week, all groups prepared their own worksheets and worked on their topics. Laboratory worksheets and observations of these laboratory sessions indicated the participants' competency of science process skills. During the activities students encountered with many difficulties. However, these difficulties were decreased throughout laboratory sessions. For example, students could not identify the possible variables for the cases in the early weeks. They only paid attention on manipulated and responding variables. As a result of this, they did not try to keep constant some important variables that could affect their design. On the other hand, they began to identify more variables and consider these variables in the later laboratory sessions. These also showed that participants need to conduct more problem-based laboratory activities for improving their competency on science process skills.

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Appendix

Sample Laboratory Worksheet

THE JUNKYARD

In a junkyard, Mr. Üstün, the owner of the junkyard, uses big electromagnet cranes to move old cars. The electromagnet crane he uses is able to lift standard-sized cars easily. However, Mr. Üstün has realized that it is not appropriate for holding bigger cars, such as SUVs, which are two times heavier than usual cars. Because Mr. Üstün cannot afford to buy a new electromagnet crane, he tries to make a more powerful electromagnet crane by doing some changes using the materials that are available in his junkyard. Can you give some advice to Mr. Üstün on this issue as a physicist?

What can be the physics concepts related to this situation?

What is the main problem of Mr. Üstün when you look at from a physicist's perspective?

Write a hypothesis that may provide a solution to the problem:

Design an experiment to test your hypothesis in the laboratory:

What are the variables that can affect your experiment?

Manipulated:
Responding:
Controlled:
Uncontrolled:

Your results and observations:

Interpretation of your results and observations:

What is your recommendation to Mr. Üstün?

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University students' perceptions about the laboratory environments and their interactions in a physics laboratory

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Abstract

This study employed qualitative research methods to study university students' perception about laboratory environments and their interaction in a physics laboratory. It was mainly based on ethnomethodology approach in exploratory and in-depth examination of students' decision making processes in physics laboratory. For an exploratory examination of students' interaction, observations were conducted. In addition to them, in-depth interviews were conducted to examine students' perception about laboratory environments. Analysis of all data was based on content analysis. Findings showed that students regarded the physics laboratory as a beneficial environment for increasing their knowledge and for working in groups.

Introduction

Laboratory activities have been considered an important part of learning science. The purpose of laboratory activities is to develop conceptual understanding through engagement with hands-on activity (Novak 1988). However, in spite of this aim of laboratory, laboratory instruction has not been able to achieve the status it was designed for. It can not accomplish its' intent which is increase meaningful learning (Tamir, 1989). Among the problems cited as responsible for the deficiencies of laboratory experiences, two of them are very important (Tobin 1990). First, current science teaching is embedded on an inappropriate epistemology. Second, collaborative methods are not used properly in science laboratories.

Typically, laboratories are exercises with a primary focus on the verification of established laws and principles, or on the discovery of objectively knowable facts (Tobin 1990). In laboratories, students gathered data without comprehending the meaning of their actions. The cognitive demand of laboratory tasks was reduced to a minimal level. Students work on their assignments in a leisurely atmosphere and spent much of their time off-task, socializing with their peers (Lunette, 2003). These structured laboratories work poorly for students to connect their personal experiences to established scientific principles. It is, therefore, not surprising that traditional laboratories often fail to provide an appropriate learning environment.

In recent years more importance has been placed on the learner's experience. The constructivist perspective of learning science emphasizes the importance of individual interpretation in the process of the construction of knowledge. "Constructivism implies that students require opportunities to experience what they are to learn in a direct way and time to think and make sense of what they are learning (Tobin 1990, p. 405)." Instead of completing a set of prescribed steps, students need to be able to arrive at an understanding of why they do what they do and to construct feasible explanations for their results. From a constructivist perspective, the collaboration among students has great potential since group interactions provide an opportunity for the negotiation of meaning and arriving at consensus, important mechanisms in the equilibration of discrepancy and disagreement (Wheatley 1991).

Literature Review

Laboratory activities have long had a distinctive and central role in the science education. Science educators have suggested that many benefits can be attained from engaging students in science laboratory activities (Lazarowitz & Tamir, 1994). Laboratory activities are used largely for illustrating and confirming information presented by the teacher and the textbook. Lunetta (2003) defines laboratory activities as "experiences in school settings in which students interact with materials to observe and understand the natural world. Laboratory classes have ranged from activities in which data are gathered to verify a stated principle or relationship to inductive activities, in which students seek to identify patterns or relationships in data which they gather." Teacher guidance and instruction have ranged from highly structured to open inquiry in laboratory activities. Laboratory classes have been conducted to engage students individually in small groups and in large-group demonstration settings. Sometimes laboratory activities have incorporated a high level of instrumentation and at other times the use of any instrumentation has been purposefully avoided. (Gunstone & Champagne, 1990) Laboratory activities offer important experiences in the learning of science. Laboratory experiences have been supposed to promote central science education goals including: understanding of scientific concepts, the development of scientific practical skills and problem-solving abilities, and interest and motivation (Roth, 1994).

Scholarly efforts have identified serious inconsistencies between goals for science education and learning outcomes visible in school laboratories. "Several researchers have reported that students regularly performed school science experiments with very different purposes in mind than those perceived by their teachers" (Lunetta, 2003). Students tended to perceive either following the instructions or getting the right answer as the principal purpose for a school science task. In the laboratory, students can perceive that manipulating equipment and measuring are goals but they can fail to perceive conceptual or even procedural goals. Students often fail to understand the relationship between the purpose of the investigation and the design of the experiment which they had conducted, they do not connect the experiment with what they have done earlier, and they seldom note the discrepancies between their own concepts, and the concepts of their peers. A laboratory means manipulating equipment but not manipulating ideas for many students (Eylon & Linn, 1988).

The nature of the interactions among students and research teams in the school laboratory can enhance science concept construction and related learning outcomes. When teachers utilize cooperative learning strategies, researchers have reported better integration between classroom and laboratory activity and enhanced achievement (Johnson et al., 1985). Scientific knowledge is negotiated within a scientific community under the guidance of a skilled teacher. This negotiation can be simulated in a community of learners in the school laboratory (Krajcik et al., 1994). Collaborative planning and discussions of findings provide a forum in which implicit ideas can be made explicit. Communication and reflection are encouraged through the preparation and discussion of laboratory reports. Preparing a report should provide opportunities for individual students to reflect upon and clarify their own observations, hypotheses, conceptions and theories. Dialogue also provides opportunities for individuals to build on the ideas of others to reach understanding and solutions (Lazarowitz & Tamir, 1994).

Many researchers have explored the power of students working in small groups. Students can benefit from both giving help to and receiving help from their peers. The process of giving explanations may encourage explainers to clarify or reorganize material in new ways, fill in gaps in understanding, recognize and resolve inconsistencies, develop new perspectives, and construct more elaborate conceptualizations (Brown & Palincsar, 1989; Tobin, 1990; Novak, 1988). Fellow students may be particularly good sources of help because they may understand better than the teacher does what other students do not understand. They can direct other students' attention to the relevant features of a problem they do not understand, and can explain concepts in familiar terms (Brown & Palincsar, 1989).

Despite the potential benefits, research on verbal interaction and learning shows that helping is not always positively correlated with achievement. As predicted, giving explanations usually has beneficial effects on learning (Webb, 1989). However, empirical results on the relationship between receiving explanations and learning are inconsistent. Although a few studies have reported positive relationships, most studies have shown no significant relationship (Webb, 1989).

Methodology

This part of the research proposal will present rationale for the methodology, fieldwork and sampling plan, and data collection and data analysis procedures.

Rationale for the Methodology. This study employed qualitative research methods to study students' interaction in physics laboratory and examine students' perception about laboratory environments. It was mainly based on ethnomethodology approach in exploratory and in-depth examination of students' interactions in physics laboratory. Ethnomethodology proposed by sociologist Harold Garfinkel (1967). Harold Garfinkel (1967) believed in studying the everyday by treating the ordinary as extraordinary, and developed a theoretical perspective and approach to research known as ethnomethodology.

"…[Ethnomethodological] studies seek to treat practical activities, practical circumstances, and practical sociological reasoning as topics of empirical study, and by paying to the most commonplace activities of daily life the attention usually accorded extraordinary events, seek to learn about them as phenomena in their own right" (Garfinkel, 1967, p. 1). The specific interest of ethnomethodological studies is to determine the "process through which the perceivedly stable features of socially organized environments are continually created and sustained" (Coulon, 1995, p. 16). Thus, by investigating the ways in which actors create social reality though their everyday decision making processes, we are able to understand the underlying logics that are actualized in those decisions (Coulon, 1995). In other words, if we know the reasoning different students use to understand and make decisions about laboratory physics activities, it is possible to explore how social processes are enacted in this process.

Fieldwork and Sampling. The selection of site was based on criterion sampling, one of the purposeful sampling strategies. This study was carried out in physics laboratory at Education Faculty of Middle East Technical University. The informants for this study were university students who were taking SSME 404 (Laboratory Experiments in Physics Teaching) lab courses. The criterion of taking this course was this course's characteristics were appropriate with the aim of the study. In this laboratory course, students were working with a groupmates, and lab design and instruction strategies were very suitable for the social interaction. There were 7 undergraduate students, 3 girls and 4 boys.

Data Collection and Data Analysis. In order to obtain depth understanding and detailed information about students' interactions, in-depth observation was undertaken in the physics laboratory. Interviews were also conducted with volunteer students to examine the students' perception about laboratory environments. The raw data included field notes of the observations and transcripts of the interviews.

This study focused on student-student interaction patterns in one lesson conducted in the physics laboratory. This session of laboratory continued two hours and twenty minutes approximately. There were two research assistants in laboratory for instruction during the observation session. Both research assistants were experienced in laboratory lessons and they worked as an assistant at least one laboratory lesson before. The laboratory session was video recorded and audio recorded. Students did two hands-on experiments for this week.

Field notes analyzed in three dimension; verbal, cognitive and social interaction, to understand the student-student interaction in physics laboratory. However, the assistants worked with students like a part of the group permanently, it was like student-student interaction and the assistant-student interaction were interwoven each other during the laboratory session. Do not consider assistant-student interaction in the study might cause losing important data. Because of this, their interaction with students was not separated in the analysis process. The results of the observation will be presented under three headings; students' verbal interactive activities, students' cognitive interactive processes, and students' social processes.

This study also explored students' perceptions about the laboratory environments, especially about physics laboratory. The interview sample consisted of two male undergraduate students from Secondary Science and Mathematics Education Department of METU. Both of them were on the fifth year of their education and taking SSME404 laboratory course. They had taken many laboratory courses from Physics Department, but SSME404 is their first laboratory courses from the SSME Department. They volunteered for the interview. Interviews were recorded by using voice recorder. They lasted about 45 minutes. After all interviews were completed, the researcher transcribed them.

Data analysis had been done after all data were collected. Analysis of all data was based on content analysis. The content analysis procedures were employed to analyze observation field notes, and interview transcripts. In this process, the data was conceptualized and organized, and then themes, issues and patterns related to the research topic were found. As a result, some common and unique themes appeared in the analysis.

Results

Students' verbal interactive activities. In this part, the results related to the students' verbal interactive activities will be presented. Throughout the session in the laboratory, students mostly asking questions, answering, describing activities and giving background knowledge. Student usually asked five types of questions in the laboratory; knowledge base, procedural, confirming, asking help and extraneous. Knowledge base questions came mostly when students came across new equipment, or did not understand what the other groups do. Procedural questions were about the finding equipments in the laboratory and the steps of experiments. Students asked conformation questions regarding what they understood and how their experiment performance good enough. When students encounter with problems and they think they stuck in activities, they usually asked for help. It was interesting to observe, students asked too many extraneous questions not related to experiments in laboratory. For example, one of the students asked his group friend "Do you want to be a present?". There was no reason to ask this kind of question in the middle of the experiment. Toward the end of the session, the numbers of extraneous questions were increased.

Throughout the session in the laboratory, most of the time students answer their friends' questions verbally. Ignorance occurred a few time during the session. However, these were because they are immersed in their experiment and they did not hear what their friend asked. Because of the structure of the laboratory lesson, students must describe the experiment and give background knowledge about it to the assistant after each experiment. However, these verbal activities occurred among students throughout the session. Experiments were found by one student and the other students did not have information about the experiments, so the students who found experiment described experiments and shared his/her background knowledge with his/her group friends. There were two kind of describing activities observed, one of them informative, about the procedure of the experiment and, the second one evaluative in which they tried to connect experiment results with physics of the happening. Another verbal interaction of students was greeting, when they met each other.

Students' cognitive interactive processes. In this part, the results related to the students' cognitive interactive processes will be presented. Students' interactive processes divided into three subthemes. These are; exploratory/interpretive, procedural/routine, and off-task.

Exploratory or interpretive processes refer to situations in which students use their thinking in activities. It includes planning, hypothesis testing, evaluation, problem solving, evaluation, experimenting, and observing other. These processes generally occurred during the students encounter all type of difficulties. On the previous laboratory sessions students had done mandatory experiment with given handouts. During those sessions, students had not encountered many problems, because most of the handouts prepared according to availability of laboratory equipments by assistants. However, on the observation week, students found their experiments and handout and they suffered from the handout-equipment inconsistency inevitably. In the observed session, student bumped into difficulties such as finding equipment, not working equipment, and undesired experiment results. Students tried to surpass these difficulties with their effort. They planned new strategies, tested their new hypothesis with experiments, and evaluated results to reach a conclusion. They solved small problems and observed other students. Students' activities fully reflected their deep thinking and engagement in the problem solving tasks.

Procedural or routine processes refer to routine execution of task without thorough planning or thinking. Ideas are not developed by student, they come from another source. Students used handouts or books to find experiments without criticize its' appropriateness to the laboratory. They followed the directions of handouts to conduct experiments. The processes under procedural processes were handling the equipments, organizing experiment design, executing the predefined task, writing experiment findings, and repeating the task. These processes were product oriented and students concentrated on procedural handling of information. They did not use their thinking on the experiments much. When assistants forced students by asking in-depth questions about their experiments, they thought about experiments they did.

Off-task cognitive interaction processes were also observed throughout the session. These were conversation about the out of the content, laugh and joke about the experiments and difficulties, and unrelated activities. For example, there was a discussion appeared on the politics, in the middle of the session. Although, out of content discussions and activities are undesired for a lesson, it is unavoidable to happen off-task social processes in a laboratory, because students work in the laboratory for a long period without a break and the structure of the laboratory is very convenient for this kind of interaction processes.

Students' social processes. In this part, the results related to the social processes students experienced in the laboratory will be presented. The different modes in which social processes was constructed in session were collaboration, tutoring, individualistic, domination, and discussion. Throughout the session in laboratory, students mostly experienced the examples of collaboration. All the group members jointed activity with equal participation. They did most of the parts of experiments together, and shared all the knowledge they have. Sometimes tutoring was also observed among students. While one student had more information than the other, he/she explain and show some important points of the topic to the group friends. This process mostly occurred because only one student found experiment and studied that topic. Domination was also observed in one group during the execution of task and explaining the experiment to the assistant. One student found all the equipment, did experiments, worked on difficulties, and explained the experiments to the assistants alone. Her group friend only sat down on a stool and listened. This group, however, worked collaboratively when writing the report. Sometimes group members worked as an individual on a part of the task. The other group friend only checked her work after he/she completed the task. The last but not least social process of students in physics laboratory was discussion. All the student in the laboratory joined the discussion and can said his/her ideas. Throughout the session there were four or five group discussions among all students. The topic of discussion can be everything including physics, conducting experiments, results of the experiments, politics etc.

Students' perceptions about laboratory. In terms of how students perceive what is done in the laboratory, they pointed such laboratory activities as doing experiments, finding equipments, following procedure, finding data, writing report, observing others, friendly conversation, sharing knowledge, assistants ask questions, social activities, learning use of knowledge, and learning names of equipments. One of them states that as a group they do experiments in the laboratory and they look, observe something, touches them, and discover something new for them. Regarding finding equipments, one of the interviewees said that they initially decides the equipments used in the experiments and find them. Concerning following procedure, finding data and writing report, one asserted;

> *"…We begin to do our experiment slowly. We try to prepare our experiment according to laboratory worksheets. Than, we get data and write results…."*

In addition, interviewees perceived assistants, their friends, handouts and prior knowledge as source of knowledge in the laboratory environments. One of them states that they mainly ask assistants questions about things they do not understand while doing experiments. Interviewees also pointed that they usually get help from their friends to overcome some difficulties in the activities.

> *"…I call my group friends; I said them that the results are like this, what can we do…"*

Also, interviewees perceived the laboratory environments as beneficial in many ways. They indicated that it is productive, good for career, pleasure, comfortable, easy to remember and easy to work. In addition to them, they pointed that laboratory environments increase happiness, practice, understanding, creativity, self-confidence and self-control. With respect to career, one of them said that the laboratory activities are good for his future profession. Moreover, the other pointed that they participate in the laboratory environments with pleasure and comfort and they are never bored. Concerning increase in practice, one of them indicated;

> *"…We learn these experiments and we do them alone, this is very useful. It is good for us. We can easily perform these experiments in front of students in the future …"*

Furthermore, interviewees perceived the laboratory as enjoyfull since it enables to put theory into practice. One of them added that as completing experiments, the results of the experiments such as gas explosion give them enjoyment and happiness in the laboratory environment. They also pointed that in the laboratory environments they can get immediate feedback from others (e.g. peer in the work group).

Moreover, interviewees considered finding group friend, unknown participants, finding equipments, appropriateness between experiment and handout, inconvenient conditions and too much people as problems in laboratory environments. One of them pointed the difficulty to select the peer to work in a group during the experiments. Also, he indicated that he feel disturbance related to unknown participants in the laboratory environment. The other interviewee said that there are not appropriate equipments that are written in the handout and this causes problems in the laboratory environment.

Students' perception about group work. Interviewees mentioned six different kinds of social processing occurred in the group works. These were collaboration, cooperation, tutoring argumentation, conflict, and domination. They indicated that they mainly cooperate with their peers in the working groups in the laboratory activities. In terms of social process, one of them pointed the argumentation in the experiments and stated;

> *"… we told experiment results to the other groups, however they said that we found different results, our results consistent with the theoretical knowledge…[than] we discussed our results…"*

Concerning social process, one of interviewees also pointed that they behave as tutor to each other in the laboratory environment. Besides, he mentioned conflict in the laboratory activities and expressed;

> *"…One of the group member want to finish experiment early and said that let we write the theoretical information. Although the other group member wants to see the experiment results, he could not feel the power to complete experiment. Eventually, the other group member makes you lazy…"*

Furthermore, interviewees consider group work in the laboratory environment as beneficial. They pointed that working in a group decrease the time needed to complete the experiment. In terms of benefits of the group work, they asserted that working in the group support and increase social relationship in the laboratory environments and activities. They pointed that they find friend in the laboratory, meet and greet them, help and make warm friendship in the laboratory environment.

Lastly, they perceived indolence and cheating as adversity in the group work in laboratory environments and activities. Regarding cheating in the group work, one of them point out the discomfort for someone cheating on what he do in the laboratory assignments. Concerning indolence in the group work, one of interviewees stated;

> *"…If you are three or four student in the laboratory group, it is possible that one of the students learn nothing in the experiments. Because, two people are enough for these experiments, the other group members are not interested with experiments…"*

Conclusion

The observation part of this study focused on student-student interaction patterns in the physics laboratory. Field notes were analyzed in three dimension; verbal, cognitive and social interaction. The results of this study showed that students' interacted verbally with each other by question asking, answering, ignoring, describing activities, giving background knowledge, and greeting. There were three kind of cognitive interaction pattern identified; exploratory, procedural, and off-task. Lastly, students experienced five type of social processes; collaboration, tutoring, individualistic, domination, and discussion. In general, these observed interaction dimensions implied that students regarded the physics laboratory as acceptable situation for working with each other. They found enough opportunity for sharing and increasing their knowledge.

Interview transcripts were analyzed to understand students' perception about laboratory environments. There were two themes occurred from the analysis: perception about laboratory and perception about group work. Students' perceptions about laboratory was defined under five sub themes; activities, source of knowledge, benefits, enjoy, and problems. Perception about group work was defined under three sub themes; social processes, benefits, and adversity. Theses themes and sub themes are identify most of students' perception about laboratory environments.

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Clothing education and mathematics

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Abstract

Mathematics is regarded as such important, useful, effective and indispensable tool for all science. All civilization have been attached primary importance to mathematics. Once humans had discovered that the examples of Fibonacci series and Golden Ratio appear in Nature, many comments were made on this truth. The Golden Ratio is known by craftsmen very well as an aesthetic rule. Distinctive examples are seen on human body, shellfishes and branches. Productions and researches of craftsmen, scientists and designers have been based on the Golden Ratio and human body used in order to make measurements. This ratio has been used in clothing pattern production, fundamental and auxiliary measures. Preparation of clothing pattern consists of arithmetic processes; however it is regarded as technical drawing. In this paper, the mathematical processes utilized to obtain clothing pattern appropriate for the body form and means of examining anatomy of human body mathematically thanks to the information acquired from mathematics are examined.

Introduction

Science and art are two fields that are usually considered separately. Science represents truth, whereas art represents beauty. Mathematical processes are the expression of truth, clothing design is the expression of beautiful. While theories and proofs stand in the front in science, visual and individual thoughts stand in the front in art. Mathematics and clothing design are two components of science and art. Beauty of proofs in mathematical theories is the inner aesthetics of mathematics.

Almost in every country, mathematics education is as important as a native language education in their system of education. This truth is not only about its usefulness in everyday life but it is also about its role as a facilitator in people's life.

Mathematics is defined as "the study of numbers, shapes and space using reason and usually a special system of symbols and rules for organizing them". It is about trying to look at the situations from other angels and perspective.

Once humans had discovered that the examples of Fibonacci series and Golden Ratio appear in Nature, many comments were made on this truth. Most things in nature follow the golden ratio pattern and are formed according to the formula of Golden Ratio. This shows us the evidence that they are particularly designed. The Golden Ratio is known by craftsmen very well as an aesthetic rule. Distinctive examples are seen on human body, shellfishes and branches. This aesthetic rule discovered by Greek and Egyptians has been used in the architecture and the art.

If the golden ratio is express in geometrical terms, equality of the ratio of the whole straight line to the bigger piece on a (AB) piece of line divided into two with the ratio of the bigger piece to the smaller piece gives us the golden ratio.

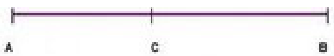

Figure 1. The Golden Ratio on a Piece of Line (Wikipedia,2008)

When a piece of line (AB) is required to be divided into two in accordance with the Golden Ratio, that line should be divided from such a point (C) that the ratio of the smaller piece (AC) to the bigger piece (CB) should be equal to the ratio of the bigger piece (CB) to the whole line (AB). (Wikipedia, 2008)

Ratio of all pieces of lines to the bigger piece in a clothing pattern drawing consisting of horizontal and vertical pieces of line and geometrical shapes is found by equality with ratio of the bigger piece to the smaller piece. When the technical shorts' drawing in Figure 2 is examined, it can be seen that there is a geometrical golden ratio in ratios between divisions with different parts on waist belt. It is possible to see the same ratio in front net and fly length.

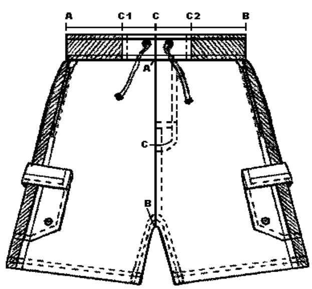

Figure 2. Technical Shorts Drawing and the Golden Ratio (Kathryn, 2005)

Productions and researches of craftsmen, scientists and designers have been based on the Golden Ratio and human body used in order to make measurements.

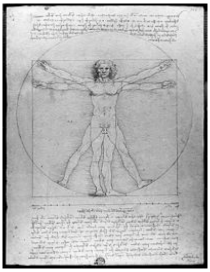

Figure 3. Vitruvius Man Study (Wikipedia,2008)

The Vitruvius Man Study, which was found in one of the diaries of Leonardo da Vinci, which is considered to be a milestone for studies on association-integration of human and nature and which shows the ratios in human body in 1492, is the first step in segmentation of the body. (Evren ve Bilim,2008)

Determining the proportions of the human body started with the finding of the golden proportions of numbers by Fibocanni and drawings of human body by Leonardo according to the golden proportions.

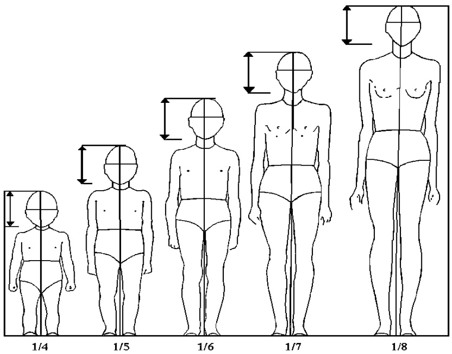

Figure 4. Golden Ratio in Full Length

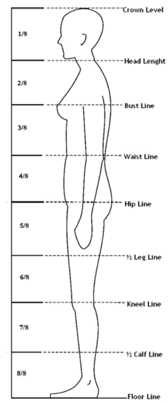

Figure5. Segmentation of Full Length Measurement (Hillers, 1998)

In segmentation of Full Length measurement, ratio of the head to the body varies between ¼ and 1/8 during the development from babyhood to adulthood. A newborn baby's head is bigger than his/her body and when development of the body is completed, head of a normal human constitutes 1/8 of the body. This is a very special ratio both in geometrical and numerical terms for harmony of human body.

Mathematics in the Basis of Clothing Education

This ratio has been used in clothing pattern production, fundamental and auxiliary measures. Preparation of clothing pattern consists of arithmetic processes; however it is regarded as technical drawing.

Use of mathematics in the procedures for the preparation of dressing patterns does not end with the calculations of the proportions of the human body; procedures performed on the two dimensional planes by vertical and horizontal lines, perpendicular angles applied to the essential lines of the body and the patterns given a third dimension with curved lines make it possible to obtain dressing forms suitable for the body.

Mathematical processes are utilized in pattern analysis of complex clothing models for university students receiving education on technical drawing and clothing pattern preparation. Mathematical thinking is very important in each stage of preparing clothing patterns.

The golden ratio is taken into consideration in pre-drawings and artistic drawings during the clothing design progress starting with market research. Technical drawings of the clothing model decided are made and the pattern preparation stage is launched.

In all of the clothing pattern preparation systems of the countries, measurements used in drawing of the patterns consist of two groups. These measurements are primary and secondary measurements. 1st stage in pattern preparation starts with taking "Primary Measurements" from human body. Primary measurements taken from the body are full length, around the breast, around the wrist, around the hip and arm length. As it is seen in Figure 7, Figure 8 and Figure 9, around the breast, around the wrist and around the hip, among the primary measurements, are measured by circular moves; whereas the arm length is measured with vertical moves.

Figure 6. Full Length

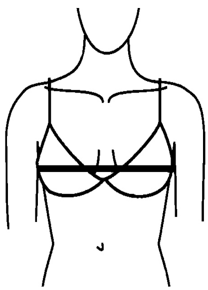

Figure 7. Around the breast

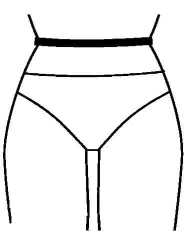

Figure 8. Around the wrist

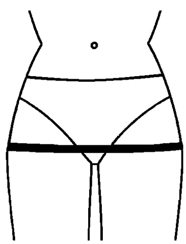

Figure 9. Around the hip (Hillers, 1998)

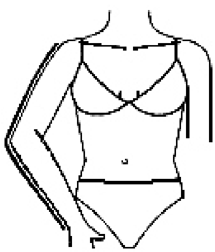

Figure 10. Arm length

In second stage, "Secondary Measurements" are calculated based on primary measurements via mathematical processes. The full length measurement is utilized in calculation of length measurements and the around the breast measurement is utilized in calculation of width measurements among the secondary measurements.

Among the secondary measurements present in Table 1, full length and around the breast measurements are taken as the basis and a series of formulas are applied in calculation of length and width measurements (Table 1). Wideness is added to the measurements calculated via these formulas, depending on pattern features of the dress.

Table 1. Formulas for Calculating Secondary Measurements

Length Size	
Armhole depth	Breast Girth 1/10 + 10,5 cm
Nape to Waist Back Length	Height 1/4 – 1cm
Nape to Hip Centre Back	Armhole Depth+ Nape to Waist Back length
Back Neck Size	1/10 Breast girth 1/2 + 2 cm
Depth of Bust	Breast Girth 1/4 + 3-5 cm
Nape to waist over bust	Nape to Waist Back Length+4 cm (80- 90 Breast Girth)
Width Size	
Back Width	Breast Girth 1/8 + 5,5 cm
Armhole width	Breast Girth 1/8 – 1,5 cm
Front width	Breast Girth 1/4- 4 cm

(M.Muller Shon Konstruktions System, 1992)

The primary measurements are taken in customized clothings and the secondary measurements are found via calculation. Standard measurements are used in preparation of clothing patterns in ready-to-wear industry. When the standard measurement table in Table 2, which is utilized for drawing basic skirt pattern, is examined, it is seen that the measurement differences between primary measurements for normal sizes are repeated with equal intervals. As the size goes smaller, the measurement difference between sizes goes smaller. As the size goes bigger, the measurement difference between sizes goes bigger.

Table 2. Basic Skirt Measurement Table

		36	**38**	**40**	**42**	**44**
Waist Girth	**A**	72	76	80	84	88
Hip Girth	**B**	98	102	106	110	114
Skirt length	**C**	60	62	62	64	64
Waist to Hip	**D**	20	20	20	20	20
Girth of Skirt Hem	**E**	98	102	106	110	114
Skirt Waist Band width	**F**	3	3	3	3	3
Skirt Slit length	**G**	15	15	15	15	15
Zip Length	**H**	18	18	18	18	18

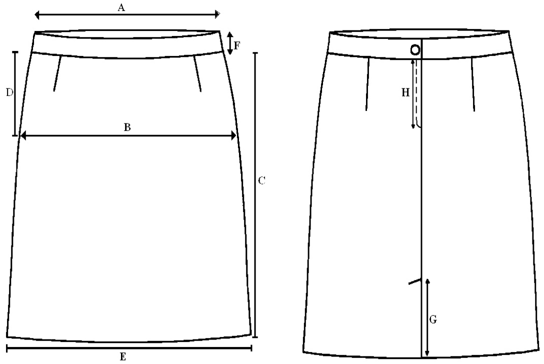

Figure 11. Basic Skirt Measurement Points (Hillers, 1998)

Clothing Pattern Drawing and Mathematics

In Figure 12, which shows how to find the Golden Ratio on a circle's radius, it is seen that the edge length of the square is equal to radius of the circle.

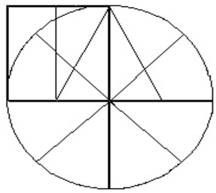

Figure 12. The Golden Ratio in Circle (Kıvanç, 2005)

In Figure 12, which shows how to find the Golden Ratio on a circle's radius, it is seen that the edge length of the square is equal to radius of the circle. When Figure 13 is examined, "Flared skirt ½ waist measurement" consists of 2 edges of the square present within the circle in Figure 12.

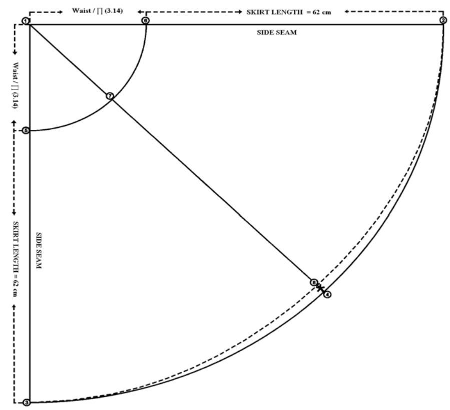

Figure 13. Flared Skirt Drawing (Cardak,2005)

Kid/women/men clothing patterns according to product groups are drawn by utilizing several mathematical processes. Together with these mathematical processes, vertical, horizontal, curved lines, angles, rectangle, square, circle vs. utilized in mathematics and geometry are used.

In many clothing pattern preparation systems, "letter" or "number" system is used to ensure clarity in drawings. Numbering system is used in flared skirt drawing example given from the Optimass Massschnitt Konstruktions System.

When Figure 13 is examined, the Basic Skirt Measurement Table in Table 2 is used in flared skirt drawing starting with horizontal and 90º vertical line. The calculation formula used for waist curve of the skirt in the drawing is [Waist/π (3.14)]. "π" (Phi) number is used in calculation of waist curve measurement in flared and circle skirt pattern drawings. Each stage of clothing pattern drawing and measurement calculation is realized with mathematical processes.

In the basic pentagon drawing seen in Figure 14, there are five edges combining by forming five angles with each other. In this basic pentagon, "π" (Phi) is the ratio of any diagonal to any edge.

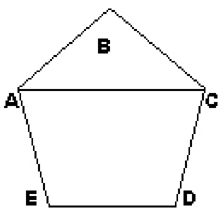

Figure 14. Basic Pentagon Drawing (Wikipedia, 2008)

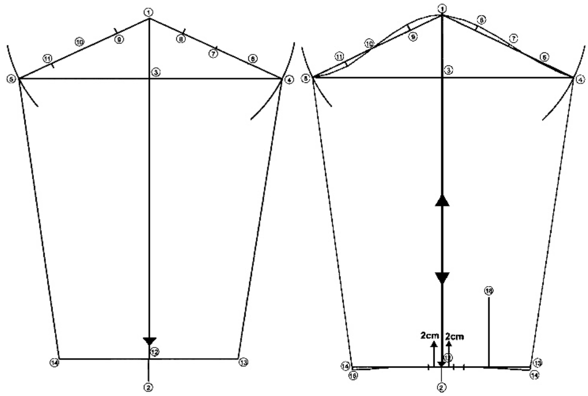

Figure 15. The Men Shirt Arm Drawing (Cardak, 2005)

As in Figure 14, the men shirt arm drawing example in Figure 15 given from the Optimass Massschnitt Konstruktions System consists of a pentagon. In men shirt arm drawing consisting of a basic pentagon, "π" is the ratio of any diagonal to any edge.

The process starts with a vertical line. The arm pattern drawing is made with vertical, horizontal, curved lines, right angle, equilateral triangle and arcs from mathematical processes. Measurements and process steps of the men shirt arm pattern drawing starting with vertical line in Figure 15 are given below.

As it is seen in men shirt arm drawing, it is obviously observed that all the mathematical processes are utilized with existence of the golden ratio in clothing pattern drawing according to product groups.

Figure 16. Square (Wikipedia,2008)

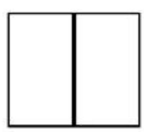

Figure 17. Squares and Rectangle (Wikipedia,2008)

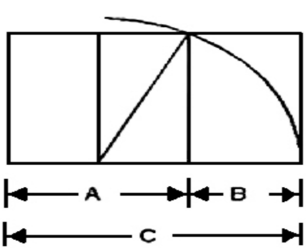

Figure 18. The Golden Rectangle

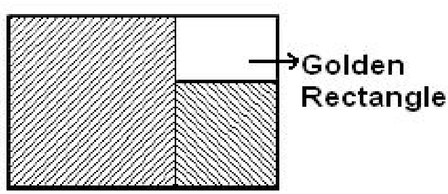

Figure 19. The Golden Rectangle (Wikipedia, 2008)

One of the best ways to explain the Golden Ratio is to start with a square (Figure 16). Edge lengths of the squares give the Fibonacci numbers in order. When a square is divided into two to form two equal rectangles, the circle drawn from the point where the joint edge of the rectangles cuts the base of the square, that is the radius, forms diagonal of a rectangle (Figure 18).

The ratio of the base length (B) of the new rectangle to the base length (A) of the square is the Golden Ratio. The ratio of the base length (A) of the square to the base length (C) of the bigger rectangle is the Golden Ratio too. The rectangle acquired is a Golden Rectangle. Because, the ratio of the short edge to the long edge is 1.618, that is the Golden Ratio. When each square is taken out of this rectangle, the remaining one will be a Golden Rectangle (Figure 19).

If a circle, radius of which is the edge lengths of the squares of the Golden Rectangle from which several squares are taken out, is drawn in each square, a "Golden Spiral" is(Figure 20).

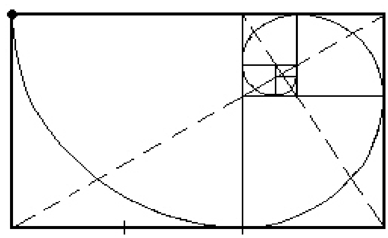

Figure 20. The Golden Spiral (Bilgiportal, 2008)

First stage of clothing pattern drawing starts with drawing a rectangle from vertical and horizontal lines. That is, the golden rectangle is used in drawing of basic patterns. The golden spiral is utilized in many pattern drawings like arm, flounce collar and such.

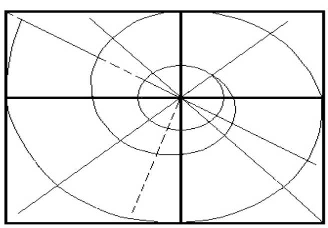

Figure 21. Flounce Collar

The flounce collar drawing made in a piece of circle with its radius as the edge lengths of the squares of the Golden Rectangle from which several squares are taken out consists of the Golden Spiral and the Golden Rectangle in Figure 21.

Conclusion

Clothing is one of the essential components of human life. When people started to cover their bodies due to several reasons, clothing and other details complementing clothing began to form. It is true that people's desire to look aesthetic and beautiful is mainly reflected in clothing. Clothing, which bears a great importance in reflection of human thoughts, is a powerful determinant in expression of social position.

It is known that clothing, which is among the essential components of human life, passes through several stages until it is worn by people. Clothing pattern preparation is among the most important steps of these stages. All the stages of clothing pattern preparation consist of mathematical processes. The golden ratio is repeated infinitely in clothing patterns drawn with processes on two-dimensional planes formed by vertical and horizontal lines in pattern preparation transaction that seems as technical drawing.

It is possible to obtain the clothing form appropriate for the body via processes made on two-dimensional planes, right angles applied to basic lines of human body and patterns acquiring third dimension due to curved lines.

Use of mathematics in the progress of clothing pattern preparation starts with taking primary measurements from human body. Secondary measurements calculated by using the primary measurements are calculated by utilizing mathematical processes and formulas of the pattern system. The same formulas, with slight differences, are utilized in calculation of the secondary measurements in pattern systems of different countries.

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The relationship between students' behaviour in problem-based learning groups and the development of conceptual understanding

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Abstract

The research described here is ongoing and therefore only preliminary results are presented. The aim of the research presented here is to determine and examine the relationship (if any) between the types and levels of behaviour (actions) within the group learning environment of a physics problem-based learning course and the level of conceptual physics knowledge development. To achieve this it is necessary to first determine the different types and levels of behaviour. Quantitative methods such as the Force Motion Conceptual Evaluation (FMCE), examination marks and continuous assessment marks are used to determine the level of conceptual knowledge development. The different behaviours, as described by the different types and levels of actions and are determined using the qualitative method of observation. In addition, the students' perceptions of their own behaviour, along with their rationale for this behaviour are obtained using interviews. The first outcome of this study will be qualitative descriptions of the students' approaches to problem-based learning. These approaches will then be correlated with conceptual knowledge development during the period being observed and to the types and levels of actions a student partook in during this time. The approaches will be correlated with the actions and conceptual knowledge development during the period being observed to inform on the different approaches to learning within a group learning environment associated with deep learning and hence surface learning. Furthermore it will determine the reasons students adopt such approaches and participate with certain actions. This study has been ongoing for 12 months and a preliminary catalogue of actions has been developed for the types and levels of actions students observed when participating in problem-based learning for the mechanics section of a physics course.

Introduction

This study aims to examine students' behaviour (their actions) in problem-based learning. The effect their actions and their approach to problem-based learning have on their conceptual knowledge development will also be examined. Previous research by the Physics Education Research Group (PERG) has shown that there is a difference in normalized gain (Hake 1998) in conceptual understanding by the FMCE between students who learn physics through problem-based learning and students who are being taught through more traditional methods (Walsh et al 2007). The students who were taught through problem-based learning showed a significantly greater normalized gain in the mechanics section of the course than the traditionally taught courses. Initially this was attributed to the fact that students who showed these greater gains were also the students who had chosen to major in physics, as the problem-based learning courses were also the only courses within which the students chose to study physics as their primary subject. The other courses that Walsh's study encompassed had physics as part of the course but not as the major component or focus. This was later disproved by Walsh as the study continued and when a course that had been previously been taught by traditional methods changed to a problem-based learning approach was examined. Walsh showed that when the course switched to problem-based learning the students showed a significantly greater development of conceptual knowledge (understanding) than when the course had been taught by traditional methods (Walsh et al 2007). The aim of this study is to investigate the reasons why students show such a significant gain in the development of their conceptual knowledge when taught through problem-based learning, consequently it is also concerned with the students' approaches to problem-based learning and their resulting actions in a problem-based learning environment. I am defining 'approach' in this study, to be a description of how a student themselves thought they constructed knowledge and understanding through the way they interacted and participated in problem-based learning. By behaviour I mean it to be 'measured' as a comprehensive list of the types and levels of actions.

Setting

Since 2001 problem-based learning has been used as the sole pedagogical approach in introductory physics within the first year of four degree courses (Physics Technology, Science with Nanotechnology, Physics with Medical Physics and Bioengineering, and Physical and Life Sciences) at the Dublin Institute of Technology. The first year physics syllabus is covered by approximately 25 problems which are "real", engaging, place the group in a "professional" role, and require the students to make assumptions, approximations, and deal with omitted information. After a few problems, the students become more aware of their roles and of the expectations the tutors have of them as individuals and as group members. The group is continuously assessed and the students are given regular feedback. A complete set of assessment criteria for the group process was developed at the outset, and includes such factors as the individual level of participation, peer-teaching, questioning and completion of group-assigned tasks (Bowe, 2005). As well as continuous assessment, they are also assessed by multiple choice concept quizzes which they take online. They also sit an open book exam, with problems structured similar but shorter to those the students had solved in groups. In 2006 the problem-based learning format was introduced into the Level 7 Physical and Life Sciences course with a similar design, but with slightly simplified problems and a supplemented by a lecture on the physics involved in the problems. This lecture is taught through a type of peer instruction (Crouch and Mazur 2001).

Research Plan

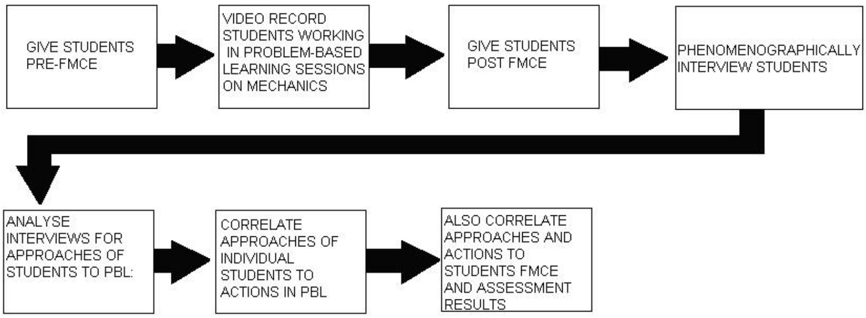


Figure 1. Research Plan

Methodology

This study has involved 24 college students enrolled in either Physics Technology, Science with Nanotechnology, Physics or Medical Physics and Bioengineering at the Dublin Institute of Technology. All of the students involved in the study where asked to fill out; pre and post FMCE, pre and post Colorado Learning Attitudes about Science Survey (CLASS) survey (Adams et al 2006), attitudes and experiences of group work questionnaire and the Honey and Mumford questionnaire. The information obtained from these questionnaires and surveys was used to select the research participants and form the groups in which they would participate in problem-based learning. I tried to obtain a cohort of students with a range of prior experiences and abilities that would function well as a group. Each group of four students completed a number of mechanics problems, the first year of the study completed 6 problems and the second year completing 8 problems. The groups were video recorded while solving each problem. Then each member of each group was phenomenographically interviewed. The students were interviewed individually; the length of the interview depended on the student but typically lasted between 60 and 90 minutes. The students' continuous assessment marks from problem-based learning and their marks on end of year assessment were taken for correlation with the findings.

Video Tape Analysis

The video tapes were used to analyse what each students primary actions were for each session. By primary actions I mean the actions that each student would perform when interacting with other group members and tutors, and go about solving a problem. It's the actions that occurred most regularly that are taken as a student's primary actions for that session. This data has two uses; the first is that each student's actions could be correlated with their approach, which would tell us if students' who had the same approaches also had the same actions. Secondly it would tell us if a student's actions changed or evolved over time. This part of the project is currently ongoing, but below is a sample of a group of four students' primary actions for one session.

Table 1. Students' primary actions for a problem-based learning session

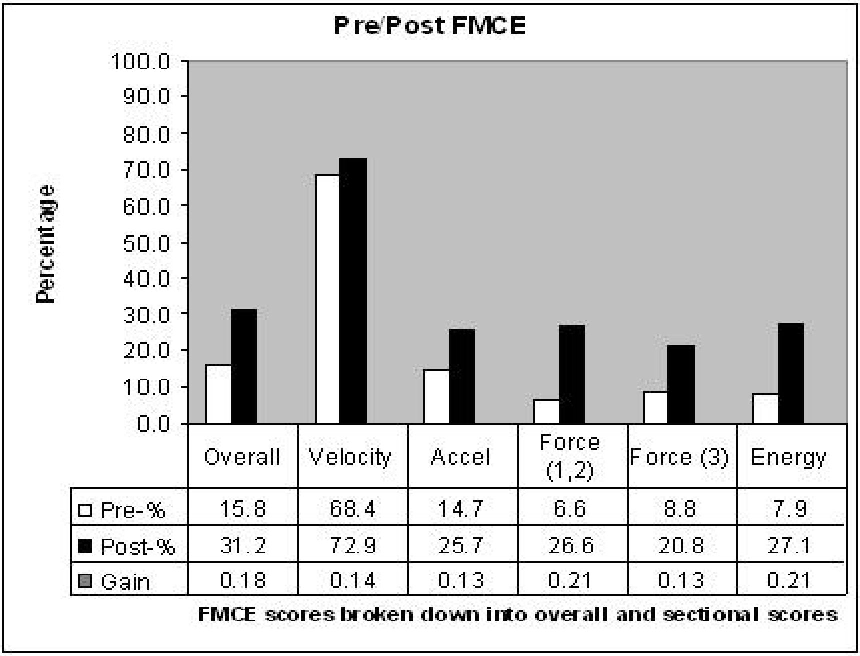
Student	Primary Actions
Student A	Spent majority of time leading group discussion
	Consistently plans method of solution
	Explains concepts and tries to resolve misunderstandings
	Questions their own understanding
Student B	Focuses on mathematical solution of problem
	Works by self within group
	Contributes to discussion only to disagree with another group member
	Attentive when tutor present
Student C	Suggests a lot of ideas
	Questions their own understanding
	Not always paying attention even when tutor present
	Is not always physically engaged in problem
Student D	Never explains their understanding of the solution or concepts
	Asks a lot of questions
	Unfocused in group discussion when tutor is and is not present
	Only focuses when discussion is focused on them

Phenomenographic Interviews

As mentioned previously phenomenographic interviews were used to identify the students' approaches to problem-based learning. To give a brief overview phenomenography is an interpretive research approach that seeks to describe phenomena in the world as others see them; the object of the research is the variation in ways of experiencing the phenomenon of interest (Marton & Booth, 1997, p. 111). The phenomenographic approach was selected for this study on the basis of its potential to reveal variation in the ways introductory physics students experience the act of approaching learning in problem-based learning. So I'm employing interpretive research methods of phenomenogrpahic interview to examine the phenomenon of students' approaches to problem-based learning. In phenomenographic research, a participant group size of between 15 and 20 is considered to be sufficiently large (in this case 24), without becoming unwieldy, to reveal most of the possible view points and to allow a defensible interpretation. Categories of approaches will be formed from analysis of the interview data and the logical relationships between these categories will then be expressed as an outcome space. Interviews have already taken place for the first cohort of the students and as I write this paper I am currently in the process of interviewing the second cohort of students who have just finished the mechanics section of the course. The interviews consisted of a number of questions whose purpose was to direct the student towards the phenomenon, in this case the students' experiences of approaching problem-based learning and the different ways they saw themselves approaching different problems. A number of follow up questions were asked based on any salient remarks the students made in order to establish the phenomenon as experienced. As this was my one opportunity to interview the students a number of shorter answer questions were also asked in order to investigate students opinions on the structure of the course, and the effects other factors (such as group dynamics) had on the way they contributed in the problem-based learning mechanics section. From both cohorts of students the transcripts will be analysed. The categories will eventually result in an outcome space.

FMCE Results

The FMCE results have been taken for each cohort of students that have been investigated for the past three years. The previous two years results are displayed in figure 2(a) and 2(b). Although the results for the groups are not very relevant to the study being discussed, as it is the individuals scores of the students that are of interest in this study, it is worth noting that two extra problems were introduced in 2008/2009 to tackle the consistent low gains on energy and force (3) subsections. As can be seen from figure 2(a) and 2(b) the introduced problems seem to have had an effect on the energy subsection, with an increase in the normalized gain. However it does not seem to have affected the force 3 subsection. These results will be presented in greater detail in a future publication.



	Overall	Velocity	Accel	Force (1,2)	Force (3)	Energy
Pre-%	15.8	68.4	14.7	6.6	8.8	7.9
Post-%	31.2	72.9	25.7	26.6	20.8	27.1
Gain	0.18	0.14	0.13	0.21	0.13	0.21

Figure 2(a) FMCE results 2007/2008 N=18

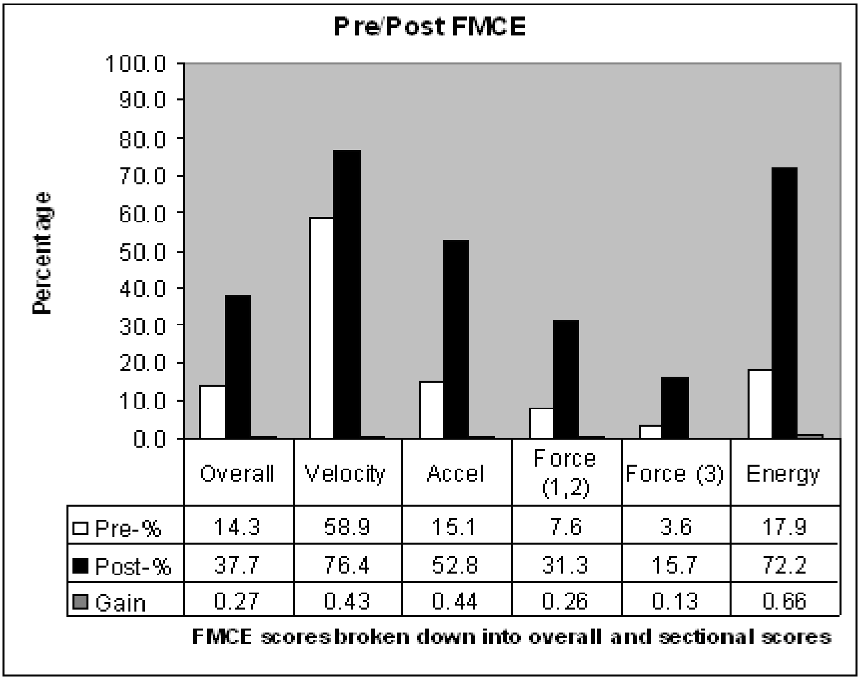


Figure 2(b) FMCE results 2008/2009 N=14

Further Research

Once this study is complete there would be opportunities to extend the study into the Level 7 PBL program. This would allow a comparison and contrast between the two different courses and to further verify the categories that will be revealed by this study. The Level 7 program will not be included in this study due to the time constraints. When looking at groups, there are a number of different factors which could also determine how a student will behave, and how they approach problem solving such factors include;

- What effect the members of the group have on how an individual participates?
- How were the tutors involved in the sessions?
- What style of tutor was involved?
- What type of problem was it?
- How did the group dynamics such as group norms effect students approaches?
- How did previous education of students affect a student's approach?

Although this study endeavours to provide answers to the above questions, the area of group work is so vast by its nature, that further study will be merited to properly answer some of these questions in relation to problem based learning groups.

Summary

We have outlined a structured plan to investigate students' approaches to problem-based learning and the effect these approaches have on how students participate in problem-based learning. Also we wish to investigate the relationship, if any, between these approaches and methods of participation and students' results on the FMCE, continuous assessment and other assessment exams. We have given justification for the methods being employed and are currently carrying out the research as planned.

Acknowledgements

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Assessing the ability of science undergraduate students to process information in a compare and contrast form.

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Abstract

This study aims to assess the ability of the undergraduate Science students to respond to Compare and Contrast Questions by processing scientific information correctly in order to fulfill answering requirements. A sample composed of One-hundred six science students (Biology and Physics) have been asked to answer a test composed of two CCQs: the first, was a General question comparing two basic subjects from everyday's life; the second, was a Science question about two subjects related to the student's major specialization. The test was followed by a survey on the student's opinion about the usefulness of CCQs in the educational process. Students' answers to the two CCQs were evaluated according to four-degree scale (Excellent (E), Good (G), Satisfactory (S), and Unsatisfactory (U)). The results showed that the ability to answer the General question and the Science question were correlated. The majority of the answers were ranked either G or S for both questions. The survey showed that 59% of the students think that CCQs would be useful for enhancing their understanding of the scientific information instructed to them. However, 48% of the students said that they have been rarely exposed to this type of questions during their academic study. We recommend that CCQs should be integrated in the educational process for science undergraduates. Training the students how to process information using critical thinking methods will enhance their ability to investigate and acquire scientific knowledge.

Introduction

Comparing and contrasting as a thinking skill reflects a deep cognitive type of analysis and understanding of two comparable subjects. It is also the process of looking at similarities and differences in a critical way based on connections between ideas and engaging critical thinking. As most other brain skills, comparing and contrasting can be trained, and therefore, enhancing its performance on the academic level. Those skills are particularly important in science education as they help in the proper understanding of different scientific concepts and help the student to process the information and upgrade the level of understanding. A part of critical thinking skills, in general, are student dependent and can vary according to the individual level of intelligence. Another part is subject to the educational process and can be enhanced by continuous training and integration in the educational material and procedure planned by the educators themselves (Browne et. al., 2000; Norris et. al., 1989). Many science educators, especially on the university level, tend to represent scientific concepts in forms of data or direct information. It is expected from the student to work on processing information in various critical thinking forms that would allow them to retain, retrieve and build up upon these concepts in the future as science graduates. Unfortunately, a certain percentage of the students either do not tend to or fail in processing information, and consequently, the expected level of acquired knowledge is not achieved. On the long term, scientific information that were instructed during their academic education become superficial and irretrievable.

Cleveland has categorized the levels of understanding into the following (Cleveland, 1982):

1. **Data** comes about through research, creation, gathering, and discovery.
2. **Information** has context. Data is turned into information by organizing it so that we can easily draw conclusions. Data is also turned into information by "presenting" it, such as making it visual or auditory.
3. **Knowledge** has the complexity of experience, which come about by seeing it from different perspectives. Knowledge is built from scratch by the learner through experience. It is not guaranteed that knowledge would be transferred from one person to another. Information is static, but knowledge is dynamic.
4. **Wisdom** is the ultimate level of understanding.

From Cleveland's categorization we can see that transforming information into knowledge is learner dependent. Knowledge cannot be transferred from instructor to student. However, the instructor might be able to train the student how to process information to acquire knowledge. Comparing and contrasting skills participate in converting information into knowledge. Such skills are particularly important for science students who are expected to be able to process information yielding more profound knowledge necessary to enhance scientific research (Popper, 1934).

In this study we tend to identify the percentage of students who are able to apply comparing and contrasting skills on the scientific information they have been instructed in science classrooms. Comparing and Contrasting skills can be measured by introducing Compare and Contrast Questions (CCQ)s to student sample. The expected criteria for answering a CCQ would be as follows:

1. To identify the identity of the two comparable subjects.
2. To reveal points of comparison (structural, functional, operational, composition, nature...etc)
3. To state these points as similarities or contrasts.
4. To avoid details and mathematical equations.

Subjects and study Design

One hundred six female undergraduate science students from Physics and Biology departments in the "College of Science" were asked to answer CCQ test followed by a survey. The study was composed of three parts: i) the first part was a General CCQ between two objects that are related to everyday's life (e.g a man and a tree; or, a river and a sea); ii) the second question was a science CCQ related to their major specialization, either Physics or Biology, from the basic concepts that they were previously instructed; iii) the third part was a survey composed of 9 questions and a comment area (Figure 1) about the usefulness of CCQs to the educational process from the student point of view. The students have been demanded to answer the questions in the above mentioned order, starting by the General question, then the Science question, and ending by completing the survey.

Compare and contrast organizing charts were provided to students for each CCQ. The students were left free to identify the points of comparison. The student sample involved in the study have received same scientific information relevant to the CCQ in the same structural method and provided with the same educational material in English language. In the survey part, only the number of credit hours completed, student's age, section number, and the student's major Track were demanded from students. The students were demanded not to give any identifying information (such as name or identification number) in the survey, this procedure was taken in order to guarantee the reliability of answers. The time set to answer the two CCQs and the survey was set to 20 minutes. Students' answers to both CCQs were evaluated according to four-degree scale [Excellent (E), Good (G), Satisfactory (S), and Unsatisfactory (U)]. The students who were able to meet the expected criteria for answering the CCQ and providing 4 points of comparison were graded E, while those who met the criteria with two or three comparison points were graded G. Students who partially met the criteria were graded S. Those who did not meet the criteria at all and failed to provide comparison points were graded U.

Results and Discussion

Most of the students were able to respond well to the CCQs. Generally, they were able to identify the points of comparison (either similarities or differences) without going into details or stating mathematical equations. Figure 2 represents histogram and data table of the percentage students and evaluation for both General CCQ and the Science CCQ. The wide majority of students were graded either G or S for both General and Science CCQs. A small percentage has been evaluated as unsatisfactory (U), while almost one fifth of students were evaluated as excellent (E) (Figure 2). The distribution of students over different evaluation grades seems to be consistent, which might indicate that students who possess the comparing and contrasting skills tend to apply these skills on general everyday's life subjects and extend them to their field of study. A relatively small percentage of the students have shown a mediocre ability to compare and contrast (Figure 2).

As previously mentioned, the students ranked S were those who were able to only partially follow the expected criteria for answering a CCQ. These were 34% and 40% for General and Science CCQ, respectively. As science students, this percentage is relatively high and represents a shortage in performance and/or in critical thinking capabilities. However, these students can be trained in classroom in order to enhance their comparing and contrasting skills, and consequently, to catch up with colleagues who obtained G or E grades. The remaining percentage that were graded U probably would need more profound assistance to reveal the main reasons for their failure.

The survey results (Figure 3) showed that the majority of students (59%) think that CCQ is useful for their understanding. However, 48% stated that they rarely have been exposed to this type of questions either within educational materials or in examinations. The survey showed that a considerable percentage of students (54%) depend on their own applying compare and contrast skills to process the given information without receiving an assistance from the instructor; while 71% of them agreed that the integration of CCQs into the educational material would enhance processing and understanding of the given information. The survey also showed that the students presented some concerns regarding integrating CCQ into their final course evaluation (course examination). Only 26% agreed on this idea while the remaining percentage either slightly agreed or disagreed. In our opinion, these concerns might be explained by the fact that this type of question is not integrated properly in the current educational process. We think that this situation might be altered if more focus is given to CCQ in the class room.

Section:	**Specialization:**
Age:	**Completed C/hours:**

Survey on the usefulness of Compare and Contrast Questions in science education

Q1 What do you think about this type of questions?
a. Very useful b. useful c. not really useful d. Useless.

Q2 How many times have you been exposed to this type of questions (either in exam or educational material)?
a. All the time b. Many times c. Rarely d. Never

Q3 How many times have you used comparison on your own in order to understand a lecture?
a. All the time b. Many times c. Rarely d. Never

Q4 Do you think that this type of questions would enhance your understanding of your lecture if your instructor uses it in the classroom?
a. Agree b. Slightly agree. c. Slightly disagree. d. Completely disagree

Q5 Do you want to have more questions of this type in your exam?
a. Agree b. Slightly agree. c. Slightly disagree. d. Completely disagree

Q6 **I don't like** this type of questions because:
a. It needs writing b. It needs thinking. c. I have to study in a different way
d. None of them, I like this type.

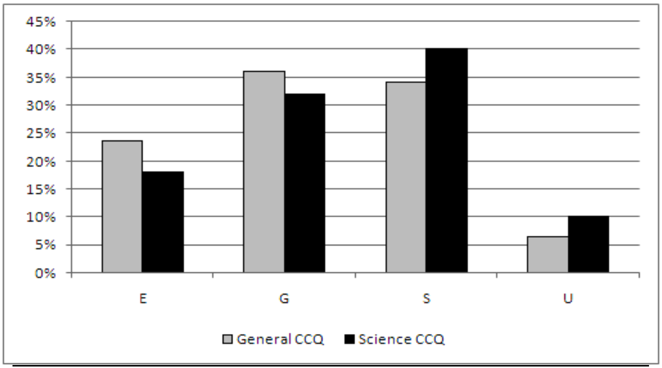
Q7 **I like** this type of questions because:
a. It needs writing b. It needs thinking. c. I have to study in a different way
d. None of them, I hate this type.

Q8 If I get a good mark in this question I would be:
a. Surprised b. Not surprised c. Normal d. I don't care

Q9. This experience would:
a. Change my way of thinking and studying b. Will have no influence on me.
c. Will make me more confused. d. Others, state:…………………

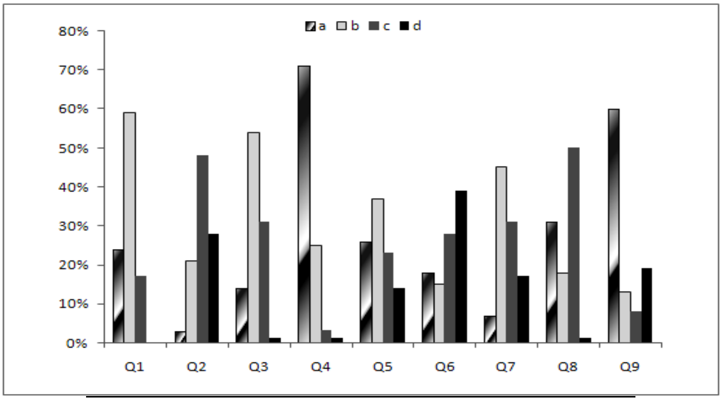
Comments:

Figure 1. Survey on the undergraduate science students' opinion on the usefulness of Compare and Contrast Questions in the educational process.



Evaluation	General CCQ	Science CCQ
E(xcellent)	23.5%	18%
G(ood)	36%	32%
S(atisfactory)	34%	40%
U(nsatisfactory)	6.5%	10%

Figure 2. Histogram representation and data table of percentage students and the corresponding evaluation obtained for both General and Science Compare and Contrast Questions (CCQ)s.



Percentage students corresponding to answers (a, b, c, d)				
Question #	**a**	**b**	**c**	**d**
Q1	24%	59%	17%	0%
Q2	3%	21%	48%	28%
Q3	14%	54%	31%	1%
Q4	71%	25%	3%	1%
Q5	26%	37%	23%	14%
Q6	18%	15%	28%	39%
Q7	7%	45%	31%	17%
Q8	31%	18%	50%	1%
Q9	60%	13%	8%	19%

Figure 3. Histogram representation and data table of percentage students corresponding to answers (a, b, c, d) in the survey. Question number is shown on the x-axis verses percentage students on the y-axis.

Conclusion and Recommendations

From the results of Compare and Contrast questions and survey that was conducted on the undergraduate science students, we conclude that a considerable percentage of science students still fail to fulfill the required acceptable standard of processing the information instructed in the classroom. This represents a threatening drawback in the proper understanding and future buildup of scientific knowledge expected from science graduates. We recommend, based on our results, that compare and contrast questions and thinking essays should be included in audio/visual educational material presented to students, and eventually to be considered as an essential part of course evaluation. We expect that enhancing comparing and contrasting skills on the undergraduate level would produce science graduates with more solid knowledge, capable of leading scientific research forwards.

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Students' understanding of basic physics concepts of Newton's laws of motion at the UAE University

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Abstract

We have investigated the understanding level of some basic physics concepts of force and motion by students taking the introductory physics course in Mechanics at United Arab Emirates University (UAEU). We have developed a short research-based multiple-choice test where we were able to extract some information about the state of knowledge of the students. In general, the students were found to have a poor understanding of the subject. The results of the test have been analyzed by using a mathematical function known as the concentration factor C.

Introduction

Physics instructor all around the world are constantly reporting on students poor and weak level of understanding basic concepts in physics at all levels of study; especially in the introductory physics courses (Redish et al, 1998), (Hammer, 1994), (May and Etkina, 2002), (Obaidat and Malkawi, 2008), (Malkawi and Obaidat, 2008), (Halloun and Hestenes, 1985). Several factors are considered to affect students' attitudes towards understanding physics concepts in introductory physics courses: Ineffective instruction methods, students' misconceptions inherited from pre-college about physics, negative attitudes toward learning physics, weakness in critical thinking, insufficient mathematical skills, poor problem-solving techniques, poor testing methods, and inconvenient evaluation methods could be some of the possible factors.

In the last several years, weak performance in understanding basic concepts of physics has been observed at United Arab Emirates University (UAEU). However, the factors that influence the weak performance are difficult to be completely specified, isolated, and quantified. Some work has been conducted to expose the importance of the issue in the physics department (Obaidat and Malkawi, 2008), (Malkawi and Obaidat, 2008). Never the less, much work still needs to be dedicated to initiate serious studies to revise and enhance the instruction methods, the physics curriculum, and eventually the students' performance.

Multiple-choice questions in general are useful instrument to evaluate student understanding of the physical concepts (Killoran, 1992), especially in large classes. However, usual multiple choice analysis normally relies on scoring. It doesn't give information about the distribution of student's response to incorrect answers, which contains a large amount of significant information on students' understanding physics concepts. If multiple-choice questions are prepared based on various reasoning that students might have about the physics problems, valuable information can be obtained by focusing on mental models that lead students to select the wrong answers.

In this work we have prepared an appropriate multiple-choice questions exam that can provide this valuable information. The exam was conducted on first year science students at UAEU enrolled to many different sections. To measure the distribution of students' responses to multiple-choice questions in all sections, a very convenient method, concentration analysis, is used (Bao and Redish, 2001). Concentration analysis can give hints if the students have common incorrect mental models. A key element of this method is the concentration factor.

The concentration factor

When multiple choice questions applied in teaching physics to first year students their responses to physics problems vary considerably due to several factors (Obaidat and Malkawi, 2008), (Malkawi and Obaidat, 2008), (Bao and Redish, 2001), (Bao, 1999). The distribution of students' responses to multiple-choice exams can provide valuable information on their state of understanding. When the responses are highly concentrated in a particular question, it implies that many students are applying a common mental model associated with the particular question. On the other hand, responses can be close to a random distribution among all the choices if the students have no consistent models of the topic. Therefore, the way in which the students' responses are distributed can yield information on the situations of students' models.

Concentration factor is a function that maps the response of a class on a multiple-choice question to the interval [0, 1] with 0 corresponding to the random distribution of answers selected by students and 1 corresponding to all students selecting the same answer (Bao, 1999). To define the concentration factor, suppose that a multiple-choice question with m choices is given to N students. The concentration factor, C, can be written as:

$$C = \frac{\sqrt{m}}{\sqrt{m}-1} \times \left(\frac{\sqrt{\sum_{i=1}^{m} n_i^2}}{N} - \frac{1}{\sqrt{m}}\right) \tag{1}$$

where n_i is the number of students selected the i-th choice. Herein the value of C can provide information about the concentration/diversity of students' responses on a particular multiple-choice question. For instance, for $C > 0.5$ means that big students population (more than 70%) have selected the same choice, this situation is represented with an H type of response. When $0.2 < C < 0.5$, usually two choices attracts more than 80% of the students' responses, and it is represented by an M type of response. And the L type is given when $C < 0.2$, it specifies that students use random guessing in responding to a question and they don't have dominant models in that topic.

Students' response patterns are formed by combining the question's concentration factor (C) with the question's score (S), which is the percentage of students who answered a particular question correctly. Like the concentration factor, the score has values in the range of [0, 1]. A three-level coding system is used to classify the scores: For a score between 0 and 0.4, a low level (L) is given. A medium level (M) is specified for score above 0.4 and below 0.7, and a high level (H) is given for a score between 0.7 and 1. By combining C and S in the analysis one can get some indication whether the question triggers a common misconception. A situation of low score ($S < 0.4$) but high concentration value ($C > 0.5$) is represented with an LH type of response. It is often indicates that students are likely to have a very popular incorrect model. In a situation of medium score (0.4 to 0.7) and medium concentration (0.2 to 0.5), referred as an MM type of response, students are often in a mixed state between the correct and incorrect models (Bao and Redish, 2001). Students' responses to each question represent a point on the C-S plot. Due to the entanglement between the score and the concentration factor, data points can only exist in certain regions on a C-S plot.

The Test

Our test aims to investigate and quantify the students' understanding of basic physics concepts of motion. The test consisted of 5 multiple-choice questions which tackled basic concepts of force and motion, which are part of the material students covered in an introductory physics course. The questions were written in a very simple English language and tackle directly physics concepts.

The study involved 210 first year science students who were taking their first course in classical mechanics at UAEU. The students were mainly females and were distributed on 12 sections taught by several instructors. The students were given 20 minutes to finish the test. The test covered material that was covered and explained during the first two months of the semester and students sat for test one week after the mid tem examination. The test questions are given below.

1- If the net force acting on an object is constant, then
   a. its velocity must be constant.
   b. its velocity must be changing.
   c. the object must be at rest.
2- Which statement is correct?
   a. An object can move in the opposite direction of the net force acting on it.
   b. An object must move in the same direction of the net force acting on it.
   c. An object must move in a perpendicular direction to the net force acting on it.
3- Two objects of masses m1 and m2 are moving to the east under the effect of the forces F1 and F2 in the east direction. At some instant of time their speeds are v1 = 10m/s and v2 = 20m/s. Which statement is correct?
   a. F1 > F2
   b. F1 < F2
   c. We cannot determine which force is larger

4- If the net force acting on an object is zero, then
  a. the object must be at rest.
  b. the object must be in motion.
  c. the object may be in motion.

5- If an object is moving, then
  a. there must be no forces acting on it.
  b. there must be forces acting on it.
  c. there might be forces acting on it.

Results

Table 1 shows the students' response to all choices in all questions. n1, n2, and n3 correspond to the number of students responded to choices a, b, and c respectively. Table 1 also shows the correct answers for each multiple choice questions. By using equation (1), the value for the concentration factor C is calculated for each question.

Table 1. The students' response to all questions and their concentration factor.

Question	Correct Choice	n1	n2	n3	C	S	Type
Q1	b	85	87	38	0.07	0.40	LM
Q2	a	50	133	27	0.26	0.24	ML
Q3	c	26	122	62	0.20	0.30	ML
Q4	c	101	18	91	0.18	0.43	LM
Q5	c	3	139	68	0.38	0.32	ML

Following the three-level coding scheme, L, M, and H discussed in section 1, it is easy to see that all questions have either LM or ML type, and there are no questions have the other types like, LH, LL, MM, and HH exist.

Discussion

The low performance of our students in understanding the physics concepts in the test is evident as shown in Table 1. The data show that students' responses are grouped into two categories only, ML and LM. The ML type gives a suggestion that large number of students concentrated their answers on the two wrong choices. Questions 2, 3, and 4 are of the type ML as clear from Table 1.This result indicates that students have unclear understanding of the rule of force to motion. For example, as indicated by Question 2, we conclude that many students believe that the direction of motion must be the same as the direction of the force. Also, as seen from Question 5, the majority of students think that absence of motion results from absence of force.

The LM type, as indicated in Table 1, is evident in questions 1 and 4. The LM type indicates a random spread in the students' choices with a moderate number of students picking the correct answer. For example, in question 4, we find that 43% of the students chose the correct answer while the rest chose wrong answers. It is interesting to note that large number of students picked one wrong answer, reflecting again that students think the absence of force results in absence of motion.

Conclusion

We have investigated the level of comprehension of very basic physics concepts related to force and motion among first year students at UAEU. The study was conducted using a well-designed multiple-choice test that focused on the concepts of Force-Motion relation. The concentration factor C and the score S indicate that most of the students have poor understanding of concepts related to Force and Motion topics. The low performance of our student population may reveal that they hold common alternative naïve mental models that need more attention to clarify in the coming years of teaching General Physics courses.

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Tendencies of the use of visual strategies of preservice mathematics teachers in advanced mathematics

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Abstract

The research described in this paper is a part of a wider study. The purpose of this study is to investigate preservice mathematics teachers' tendencies of using visual strategies in advanced mathematics. The study has been performed with three students from each grade levels (1–5), in total fifteen students in a mathematics teacher-training program at a Turkish university. Semi structured interviews have been conducted with students about their use of visual strategies in terms of lectures they have been attended during their education. The questions they were asked to are in the form of "in which lectures they are using/used visual strategies mostly?, how they use them?, if they don't use, why?" The results were discussed in terms of grade level and visual strategy using tendencies.

Introduction

The previous researches about mathematics and mathematics education have a wide range of literature about visualization and visual reasoning (e.g. Arcavi, 2003; Aspinwall, Shaw and Presmeg, 1997; Borba and Villarreal, 2005; Presmeg, 1999; Giaquinto, 1994; Zaskis, Dubinsky and Dautermann, 1996; Stylianou and Silver, 2004; Mancosu, 2005). According to some researchers, (e.g. Zimmermann 1991) visual thinking is so fundemental in some area of mathematics. On the other hand some of them (e.g. Bishop, 1986 cited in Stylianou and Silver, 2004) found that visual representations caused somecognitive difficulties for students in the problem solving process and university students are reluctant to construct visual representations. Consequently, it is very likely for a researcher that wants to learn the position of visualization in mathematics education to achieve different points of view. But it won't be true to say that the only reason of this difference is researchers' different viewpoints. The development of mathematics and mathematics education in the historical process caused also this situation.

Visualization in Mathematics Education

Though visualization was considered initially as a strategy related with geometry, its value and importance was understood later in the other area of mathematics. For some mathematicians, its role in mathematics is indisputable. According to Paul Halmos (cited in, Stylianou & Silver, 2004) "to be a scholar of mathematics you must be born with the ability to visualize".

In mathematics education, visualization was investigated from different points of view. One of them is the problem solving process. Pólya (1945) indicated that "draw a figure" is an effective strategy for problem solving. Stylianou and Silver (2004) contrasted expert mathematicians with undergraduate students to understand the potential and actual use of visual representations in problem solving. They found that visual representations are seen useful by novices mostly for geometry problems, whereas the experts indicate potential application to a wider variety of problems. Another research finding of this study was that experts construct visual representations more frequently than do novices and use them explore the problem space qualitatively, to develop a better understanding of the problem situation, and to guide their solution planning and enactment. Zazkis, Dubinsky and Dautermann (1996) introduced a model (Visualizer/Analyzer model) for mathematical problem solving. In this model, visualization and analysis work together in problem solving process.

However, in some researches, it was shown that university students are reluctant to construct visual representations (Eisenberg and Dreyfus, 1991). According to Eisenberg and Dreyfus (1991) there may be three reasons underlying this phenomenon: Beliefs about mathematics, sociological reasons and cognitive reasons.

Visualization was also investigated in the mathematical learning process. Arcavi (2003) attempted to analyze, exemplify and reflect upon the many different and rich roles it can and should play in the learning and the doing of mathematics.

Definitions and Theoretical Framework

Actually, to find a definition of visualization that was accepted by researchers that working in this area, due to the long history of it, is quite hard. Researchers have investigated this concept in relation with success, mathematical giftedness, conceptual understanding and so forth. and introduced different definitions. The variations has seen not only the definition of visualization but also the other concepts in relation with visualization like spatial visualization, mental representation, visual reasoning, visual thinking etc.

For instance Presmeg (1986) defines visual image as "a mental scheme representing visual or spatial information". This is a quite broad definition that allows for the possibility that verbal, numerical or mathematical symbols be spatially arranged to form an image (Borba and Villarreal, 2005). Another definition was made by Zaskis, Dubinsky and Deutermann (1996):

> "Visualization is an act in which an individual establishes a strong connection between an internal construct and something to which access is gained through the senses. Such a connection can be made in either of two directions. An act of visualization may consist of any mental construction of objects or processes that an individual associates with objects or events perceived by her or him as external. Alternatively, an act of visualization may consist of the construction, on some external medium such as paper, chalkboard or computer screen, of objects or events that the individual identifies with object(s) or process (es) in her or his mind."

If the definitions made by researchers that working in this area, were analyzed some similarities and differences can be noticed (Borba and Villarreal, 2005). According to some researchers like Zazkis, Dubinsky and Dautermann (1996) visualization in mathematics education is considered to be a process that follows a two way path between students' comprehension and external media; on the other hand, according to some of them like Presmeg (1986) emphasize just one direction of that path (Borba and Villarreal, 2005). In the present study, visualization will be used in both senses. Also visual thinking, visual reasoning will be used in the same meaning with visualization.

Using visual representation or learning with visualization was seen in some researches about visualization as a personal preference and individuals were classified according to these preferences. In this context, Krutetskii (1976, cited. Aspinwall, Shaw &Presmeg, 1997) talked about three main types of mathematical giftedness at the school level: Analytic, Geometric, Harmonic. A similar classification to Krutetskii's was made by Clements (1982; cited Zaskis, Dubinsky &Deutermann, 1996). Though, these classifications were generally accepted, they are not so useful in problem solving; because problem solving is situation specific and approach adopted by individual may vary according to the situation (Aspinwall, Shaw and Presmeg, 1997). So in the present study, participants will be selected according to their visual preference, not their mathematical giftedness.

Purpose of the Study

The purpose of the study is to investigate the pre-service mathematics teachers' tendencies of using visual strategies in advanced mathematics. In the direction of this goal, this study addressed the following research questions:

1. In which lectures are/did the pre-service mathematics teachers using/used visual reasoning mostly?
2. How are the pre-service mathematics teachers using visual reasoning?
3. What is the reason/s for not using visual reasoning?

Methodology

The study has been performed with three students from each grade levels (1-5), in total fifteen students in a mathematics teacher training program at a Turkish university. Purposeful sampling was used to select participants. One of the most important criteria for selection of participants was based on their visual preference score they got from Mathematical Processing Instrument (MPI) which was developed by Presmeg (1985). The instrument consists of three sections, named A, B, and C, with different difficulty level. Section B is for university students and is used for determining the participants. There are 12 problems in section B that can be solved numerically, algebraically, and graphically. In the scoring rubric, it was given 2 for a visual solution, 0 for a nonvisual solution. The possible highest score is 24. If the score of participants was 12 or higher, he or she would be considered as having a preference for visual thinking in mathematics. If the score of the participant was lower than 12, so he or she would be considered as have a preference for analytic thinking in mathematics.

Firstly MPI assigned 96 students in the mathematics teacher training program. The participants who were selected for the interviews were considered as visual (MPI's score higher than 12) and non-visual (MPI's score was 10 and lower than 10) in each grade level. Other criterion for selecting participants is their cumulative grade points (CGPA). All of the participants were described as high achievers according to their CGPA.

Semi structured interviews were conducted with students about their use of visual strategies in terms of lectures they have been attended during their education. Before the interviews, definitions of visualization which were made by the researchers worked in this area were given to the participants in both senses. Also a list of the mathematics lectures they have been attended and content of these lectures were given to the participants as a reminder. After reading and talking about the definitions with researcher, interviews started. All interviews were audio taped and transcribed by the researcher. The collected data were analyzed by using descriptive analysis (Yıldırım and Şimşek, 2005).

Research Findings

Following table (Table 1) shows the courses that participants are attending or attended during their education and the number of the students' used visualization in this courses.

Table 1. Number of the participants who say 'I use/ed visualization in this course'

Courses	1.Year	2. Year	3. Year	4. Year	5. Year
Analysis I	3	3	3	3	3
Abstract Math. I, II	-	-	-	1	1
Analytic Geo.I, II	3	3	3	3	3
Analysis II		3	3	3	3
Linear Algebra I, II		-	-	-	-
Differential Equ. I, II			-	-	-
Abstract Algebra I,II			-	-	-
Numeric Analysis			-	-	-
Real Analysis			1	2	-
Differential Geo.				1	-
General Topology				3	3
Complex Analysis				1*	1*

*: Students who say rarely.

All of the students that took part in the study use visualization in Analysis and Analytic Geometry courses. They used it in Analysis especially in curve graphics, application of derivative and integral. According to them, Analytic Geometry is very suitable for visualization, so they use it mostly in this course. This finding is consistent with Stylianou and Silver's (2004) research finding that visual representations are seen useful by novices mostly for geometry problems.

Only two students from seventh and ninth semester mentioned that they used visual reasoning in Abstract Mathematics. The main reason behind that could be the high visual preference score the students got from MPI. The rest of the participants thought that the concepts in this course are very abstract and not suitable for the visualization.

All of the participants who took General Topology mentioned about the usage of visualization in this course. The course content consist of definition the topological space and basic concepts like base, sub-base, continuous functions, homeomorphism; induced topologies by functions; compactness; connectedness etc. and based on generally theorems and their proofs. Participants indicated that they used visual reasoning at the beginning of the proofs to see the correctness of theorem, and to plan the proof process. One of the ninth semester students said:

> **9NV:** First of all, I want to show myself the correctness of it (theorem) by figures in my mind or on paper. If I am not satisfied, the theorem doesn't seem to me true. Otherwise, I can't even prove it.
>
> **…**
>
> If I can't imagine-even sometimes imaging isn't sufficient-… I can't prove it, if I can't see on the paper.

Giaquinto (1994) who looked into visualization from the epistemic perspective argued that one may visualize to strengthen one's grip on something independently known; or visualizing can serve as a stimulus to discovery, sparking an idea for a proof. This student sees visual images as a way to begin proving processes and as a way to convince herself.

> **9N:** One of my friends failed at Real Analysis. After taking General Topology, he passed Real Analysis so easily.
>
> **R:** Why do you think this happen?
>
> **9N:** Perhaps**,** General Topology is a more complex course but the lecturer concretizes the lesson, draws figures.

Another side of the visualization during the problem solving and proving process that was used by the participant in this study is recalling. Participants indicate that they can recall theorems, their proofs and problem solving process easily when they used visual images or figures in it.

> **9NV:** In a proving exercise, it was asked to prove a theorem from Abstract Mathematics course. At the beginning, I thought that I couldn't prove it, because it would be unbelievable for me to remember a theorem from four years ago. But when I have looked and draw some figures, I remembered how I did it.

One of the participants denoted the importance of combining visual and analytic strategies and emphasized this point in her learning process. This student's visual preference score is quite high and according to her, students who wouldn't combine these strategies can't be successful.

> **7V:** Early on when I saw it (a problem or a theorem), I would think that I understood it. But then I couldn't solve it or prove it. I mean I couldn't combine them. But after a year, I have learned to combine them (visual and analytic strategies) and it became easier. It is very important to combine them.

Zaskis et all (1996) indicated that even though both strategies may be available to students, the students can often have difficulty making connections between them. Also they observed that students who can mix, harmonize and synthesize the strategies usually have a more mature understanding of the problem. One of the participant who was considered as a gifted student combine these strategies in her proving process successfully.

> **9NV:** I know that with one figure, a proof can't be made or you can't show the correctness of a theorem with just one figure. But when I draw a diagram or a figure on a paper, imagine it in my mind, I can prove more easily.

The participants' reasons for not using visual reasoning in the lectures were shown in Table 2. Mostly mentioned reason is "Course structure is not suitable for visualization". They indicated that in some courses, like numeric analysis there is no need to use visualization. They also said that sometimes you must only know the formulas and apply them to the problems.

Table 2. Reasons for not using visualization in the courses.

Reasons	Number of participants
Course structure is not suitable for visualization	14
I didn't feel necessity./Personal preference	8
Lecturers don't use and I don't use, too/lecturer's orientation	5
Matter of habit	2
Former education	2

According to them, the other reason for not using visual thinking is lecturers' teaching style. They don't even know whether or not the course has visual sides. They study as how their lecturer thought them in the lessons.

Some participants indicated that in some courses they memorize only (7N). Because the lecturer doesn't use visual reasoning during the lessons and to scrutinize or to visualize on their own take too much time.

> **7N:** I don't use visual reasoning in lectures that seem to be like oral to me. In those lectures, we write theorems and then we prove it. There is no visual image.

Conclusions

As seen in the research findings, there are three main factors that affect participants' visual strategy using tendencies. First of all, participants see visual reasoning as situation specific activity. They use visual strategies mostly in geometry courses and in topics they work with function graphics. Also their personal preference and lecturers' teaching style affect their visual strategy using tendencies. Actually these three factors are in the interrelation and one of them affects the others.

Visual and analytic strategies interaction is an important subject in the researches about visualization. The students who make connections between these strategies understand the problems well. So this kind of thinking styles should be supported by the lecturers instead of imposing their own thinking styles to the students consciously or unconsciously.

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Evaluation of university students' bioethical perceptions about biotechnological studies: cloning case

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Abstract

Cloning technologies is a serious matter and these studies provide comfort and benefit for mankind, however they also give rise to concerns about ethics and moral issues. Especially, the aim of cloning humans is in conflict with the right of the individuals to become single and unique. This study aims to evaluate university students' bioethical perceptions about cloning studies In this study it is intended that the findings can highlight if university students' bioethical perceptions change relating with their majors. Two dilemmas were used to get three major students' perceptions about cloning studies. Of the two dilemmas one was regarding human cloning and the other one was regarding animal cloning. The results of this study revealed that university students' perceptions differed according the tpye of cloning study. They had a negative perceptions when the study was dealing with human cloning, on the other hand, they had a positive perceptions when the study was dealing with animal cloning.

Introduction

In recent years there has been a rapid increase in the development of biotechnological studies all over the world. Genetically modified foods, treatment of genetic disorders, stem cell research, gene therapy, cloning and environmental issues are the well known of these studies. These studies provide comfort and benefit for mankind, however they also give rise to concerns about ethics and moral issues.

Issues related to biotechnology, environmental problems and human genetics can be classified together as "socioscientific issues", and it means that all aspects of science are inseparable from the society from which they arise. Socioscientific issues are typically contentious in nature, can be considered from a variety of perspectives, do not possess simple conclusions, frequently involve morality and ethics (Sadler & Zeidler, 2003), and also describe societal dilemmas with conceptual, procedural or technological associations with science (Sadler, 2004).

Socioscientific issues have become increasingly more important in the field of science education to make science learning more relevant to students' lives (Cajas, 1999; Pedretti, 1999); to improve dialogical argumentation (Driver, Newton, & Osborne, 2000; Zohar & Nemet, 2002), to evaluate scientific data and information (Jimenez-Aleixandre, Rodriguez, & Duschl, 2000; Kolsto, 2001) and to improve scientific liretacy (Pedretti & Hodson, 1995).

Citizens of all ages need a high level of scientific literacy to address socioscientific issues and give informed consent about uses of the new technologies (Dawson and Schibeci, 2003) and also they need to make ethical decisions on how they use science and technology and its products (Macer, 2004). Dawson (2001) suggested that society needs to be able to evaluate critically the potential benefits and risks of scientific advances. University students are also experience with socioscientific issues in their lessons and as they are part of the society, in some situations many of them become decision makers related these issues.

As biotechnology raises various socioscientific issues with regard to ethics, the level of acceptable risk and usefulness of the new products (Reiss & Straughan, 1996), young people need to be informed, not only about the practical applications of biotechnology, but also they need to appreciate the social and bioethical implications so that they can make wise personal choices and contribute to public debate in the future, and they can become informed decision makers (Dawson & Taylor, 2000; Dawson & Schibeci, 2003).

Dybas (2003) defined bioethics is the symbiotic relationship between biology and ethics, encompasses everything from well-known debates on the use of stem cells in medicine, to the impact of terrorism and war on Earth's environment, to how human populations alter the landscapes around them, to how research into these questions is conducted and results are shared. Macer (http://www.biol.tsukuba.ac.jp..) called the term of bioethics more simplistic way. According to him, bioethics is the love of life. He mentioned the three ways to view bioethics; descriptive bioethics, prescriptive bioethics and interactive bioethics. He stressed that developing and clarifying prescriptive bioethics allow us to make better choices, and choices that we can live with, improving our life and society.

Three general moral principles have proved to be serviceable as a framework of principles for bioethics: respect of autonomy, beneficence and justice. These principles can provide the beginnings of a framework through which begin to reason about problems in bioethics (Beauchamp et al, 2008).

Cloning is a reproductive method that raises many important ethical and legal questions. In the area of ethics, it has created serious dilemmas such as the morality behind the use human embryos for scientific purposes, the disposal of unused embryos, the lack of safe scientific measures to support the techniques used. Moreover considering that a clone is a person and not a thing, it has all the rights inherent to human being. He/She will have, as any other individual, judicial personality, different from the person who gave him/her the genetic material, in other words, he/she will become a new individual with its own rights and obligations (Costa et al, 2006).

Of the many controversial issues in science, advances reproductive technologies have a personal relevance for students. Cloning technologies is a serious matter in these technologies. Especially, the aim of cloning humans is in conflict with the right of the individuals to become single and unique. Moreover, copying procedure means the intentional transfer of the defect to the next generation in the case of patients and homosexuals, which is a violation of human rights (Arda, 2004). Dawson and Taylor (1997) mentioned that within the next decade our society will need to consider the ethics of cloning humans and unless all students are taught about the process of biotechnology they are in danger of being woefully ignorant about the technology involved. These researchers also argued that the lack of understanding and associated fear may contribute to an anti-science backlash where society rejects rather than confronts the ethical issues.

Research Questions

This study aims to evaluate university students' bioethical perceptions in relation to the application of cloning technologies. The study address the following research questions:

1. What are the opinions and knowledge of university students' related to cloning studies?
   1.1. What are the opinions and knowledge of preservice science teachers' related to cloning studies?
   1.2. What are the opinions and knowledge of biology students' related to cloning studies?
   1.3. What are the opinions and knowledge of medical students' related to cloning studies?
2. What are the bioethical perceptions of university students' related to dilemmas about cloning studies?
   2.1. What are the bioethical perceptions of preservice science teachers' related to dilemmas about cloning studies?
   2.2. What are the bioethical perceptions of biology students' related to dilemmas about cloning studies?
   2.3. What are the bioethical perceptions of medical students' related to dilemmas about cloning studies?

In this study it is intended that the findings can highlight if university students' bioethical perceptions change relating with their majors.

Sample:

The students who comprise the sample includes; 120 science education students who are preservice science teachers attending a four year pre-service teacher training programme which is not include biotechnology or ethics courses; 35 biology students who are attending a four year science programme which include biotechnology course but is not include ethics course; 70 medical students who are attending a six year medical studies programme which include ethics course but is not include biotechnology course.

Research instruments:

The research instrument was designed to address the research questions. Two dilemmas were used to get three major students' perceptions about cloning studies. Of the two dilemmas one was regarding human cloning used before in literature (http://gslc.genetics.utah.edu) and the other one was regarding animal cloning a science news obtained from a science journal. Students were directed to read each dilemma and chose one of the three choices "yes", "no", "I can't decide" and then write a response what should do to resolve the situation.

Open-ended and multiple responses questions were also administrated to the students to understand their opinions related to potential risks, utility and control of these studies, to assess their knowledge about cloning technology, and also to understand their knowledge related to resources they learnt about biotechnology.

Analysis

Quantitative and qualitative analysis were used for the analysis of the results. Descriptive statistics and comparison analysis were used for quantitative data analysis. The results were analysed using the SPSS 12.00 for Windows software. Data obtained from two dilemmas and open-ended questions were analysed by using qualitative analysis methods. The responses obtained from open-ended questions and type of responses and reasons from the dilemmas were coded and were compared between the three faculties' students.

Findings

Table 1 provide comparison between students' definitions of cloning. The table shows that of the 193 students 47.1% of them defined the cloning term partially true while 23.8% of them defined true. On the other hand, it was found that compared to preservice science teachers, biology and medical students gave more true definitions about cloning term and compared to the biology and medical students preservice science teachers mentioned significant number (23.2%) of false definitions.

Table 1. Frequency of responses about definition of cloning according to faculty variable

	Responses	Preservice science teachers		Biology students		Medical students		Total	
		N	**%**	**N**	**%**	**N**	**%**	**N**	**%**
Cloning	True	20	17.8	11	33.3	15	31.2	**46**	**23.8**
	Partially true	61	54.4	9	27.2	21	43.7	**91**	**47.1**
	False	26	23.2	1	3	2	4.1	**29**	**15**
	No responding	5	4.4	12	36.3	10	20.8	**27**	**13.9**
	Total	**112**		**33**		**48**		**193**	

Table 2 shows the students' perceptions of risks and benefits associated with cloning studies in general. According to the table it was found that 48% of the students thought that risks outweighed benefits while 14.3% of them thought that benefits outweighed risks. In addition 30.1% of the students thought that risks and benefits of these studies were equal.

Table 2. Students' perceptions of risks and benefits associated with cloning studies

	f	%	Valid %	Cumulative%
Risks outweigh benefits	94	48.0	51.9	51.9
Benefits outweigh risks	28	14.3	15.5	67.4
Risks and benefits are equal	59	30.1	32.6	100.0
No responding	15	7.7		
Total	196	100.0		

Table 3 shows the results of the ANOVA test which indicated the students' perceptions associated with risks and benefits of cloning studies according to the faculty variable. As can be seen from the table, the results indicated that statistically significant differences were not found between groups (p>.05). It can be concluded from this result that students' perceptions regarding the cloning study were not change in respect of their majors.

Table 3. Results of ANOVA analysis according to faculty variable

	N, $\overline{X}$, Ss			ANOVA					
	N	$\overline{X}$	**Ss**	**Source of variance**	**Sum of squares**	**df**	**Mean Square**	**F**	**p**
Preservice science teachers	106	1.7736	.8974	Between groups	3.488	2	1.74		
Biology students	30	1.6000	.8550	Within groups	142.74	178	.802	2.175	.11
Medical students	45	2.0222	.9167	Total	146.23	180			
Total	181	1.8066	.9013						

From the table (4), it can be seen that, while most of the students gave "no" responses regarding with human cloning dilemma they gave "yes" responses regarding with animal cloning dilemma. Comparing preservice science teachers and medical students, it was found that biology students gave more no responses associated with human cloning dilemma. On the other hand almost all of the majors' students gave same amount of "yes" responses associated with animal cloning dilemma. Considering this results, it can be concluded that while most of the three faculties' students had negative perceptions about human cloning studies, they had positive perceptions about animal cloning studies.

Results seen in this table (5) indicated the most frequently negative and positive reasons regarding the dilemma of human cloning. From this table it can be understood that negative reasons had more frequency compared to positive reasons. It was found that the most frequently mentioned negative reasons were related with nature, cloning mechanism, clone and ethics. However the most frequently mentioned positive reason was related with a character (mother) found in dilemma story and most of these reasons given by preservice science teachers.

Table 4. Frequency and percentages of students' responses associated with human cloning and animal cloning dilemmas

Students	Responses	Dilemmas			
		Human Cloning		Animal Cloning	
		f	%	f	%
Preservice science teachers	Yes	35	23.8	89	67.4
	Can't decide	31	21	11	8.3
	No	81	55.1	21	15.9
	No responses	-	-	11	8.3
	Total	147	100	132	100
Biology students	Yes	3	8.5	19	63.3
	Can't decide	4	11.4	5	16.6
	No	28	80	6	20
	Total	35	100	30	100
Medical students	Yes	12	16.2	33	62.2
	Can't decide	18	24.3	3	5.6
	No	44	59.4	17	32
	Total	74	100	53	100
Total	Yes	50	19.5	141	65.5
	Can't decide	53	20.7	19	8.8
	No	153	59.7	44	20.4
	No responses	-	-	11	5.1
	Total	256	100	215	100

Table 5. The reasons of students' responses related to human cloning dilemma

	Preservice science teachers		Biology students		Medical students		Total	
Related with	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**
cloning mechanism	15	4	9	1	12	5	36	10
nature	27	-	1	-	9	-	37	-
human beings	5	-	-	-	2	-	7	-
ethics	10	-	13	-	13	-	35	-
the character (mother)	10	28	-	1	4	7	15	36
clone	19	-	7	-	10	-	36	-
society	5	-	-	-	1	-	6	-

Table 6. The reasons of students' responses related to animal cloning dilemma

	Preservice science teachers		Biology students		Medical students		Total	
Related with	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**
natural process	16	75	10	18	11	22	37	115
cloning mechanism (method)	3	-	1	-	3	5	7	5
future generations	-	-	-	-	4	-	4	-
ethics	-	1	-	-	-	-	-	1

As can be seen from the table (6), positive reasons had the most frequency. According to this table these reasons were related to natural process which include ecological balance of the nature. Negative reasons were also determined regarding nature, however the frequency of these reasons were not much as positive ones.

Conclusion

Definition of the cloning term has three significant parts which include organisms or cells arising from a single individual, by asexual reproductive and therefore genetically identical (Mascazine et al., 1998). Considering these parts as indicators each students' definitions were analysed and determined if they had given true, partially true or false definitions. If students gave the one or two parts of these definition their definitions were accepted partially true, if they gave the three parts of this definition their definitions were accepted true and if their definitions were quite different from these parts, they were accepted false.

The results found in this study showed that most students were able to define cloning term partially true (47.1%) and significant of them (23.8%) were able to give true definition. Among these students biology and medical students were able to gave more correct definition comparing with preservice science teachers. However more than half of the preservice science teachers gave partially true definitions. Considering this result it can be thought preservice science teachers had little knowledge, for this reason they need to take courses including cloning studies. In addition to this, due to the biological sciences courses biology and medical students were taken in their programmes, they may be more knowledgeable than preservice science teachers. Nevertheless considerable amount of these students gave partially true definitions or not defined this term. This result also considered that biology and medical students need to improve their knowledge about cloning. Studies also indicated that a significant number of individuals had not know how to define the term cloning, they (17.9%) had not given an accurate definition of cloning, over 38% were able to define cloning, 28% were able to give the complete definition of cloning and over 14% were able to give a complete definition of cloning including the important elements. These individuals were describing their understanding with the rating of five choices. Most of them (%60.3) selected "little knowledge" as the most appropriate descriptor of their understanding however, they were lacking a basic understanding of the basic elements of cloning. In addition only 3.2% rated themselves as very knowledgeable about cloning and 3.8% rated themselves as having no knowledgeable (Mascazine et al., 1998). In contrast these results, another study indicated that students' ability to provide a generally accepted definition and examples of cloning were found relatively poor amongst 12-13 year olds, but improved in older students (Dawson, 2007).

Studies in literature indicated that individuals were concerned about cloning. Moreover occupation and academic association showed significant positive correlation for cloning toward benefits and optimism (Balas & Hariharan, 1998). Another study revealed that teenagers were more likely perceive risks rather than benefits in relation to the cloning studies (Gunter et al., 1998).

In this study the question assessing the students' opinions of risks and benefits was intended to discover whether students found cloning studies risky or beneficial. From the results of this study it was found that students' perceptions of cloning were found negative. The results indicated that most of the students thought that risks outweighed benefits and all of the three major student had the same thoughts.

The results of this study revealed that university students' perceptions differed according the type of cloning study. They had a negative perceptions when the study was dealing with human cloning, on the other hand, they had a positive perceptions when the study was dealing with animal cloning. The results indicated that there did not appear any differences between students' positive and negative responses regarding to their majors. All of the students in different majors had positive responses when the cloning study was related to animal cloning, and had negative responses when the cloning study was related to human cloning.

When it came to giving the reasons of each dilemma, students responded in various ways. It was found that most of the reasons associated with the human cloning dilemma were found negative and these reasons were related to the implementation of the cloning mechanism, natural process and clone itself. Besides, the term of ethics was also one of the most mentioned reason by biology and medical students related to the human cloning dilemma. These students thought that the situation was not ethically right. However students mentioned this reason were not explain their decision in detail. By considering this point it can be thought that preservice science teachers were not think dilemmas in an ethical way and biology students bioethical thoughts were not enough. Although medical students taken courses regarding ethics the result of this study revealed that their bioethical perceptions was poor. Therefore all of the three major students programme should include bioethics courses.

In this study some of the preservice science teachers giving positive decisions regarding this dilemma showed the reasons related with the character found in dilemma story. According to their reasons this person should not have been upset. This reason is thought that preservice science teachers could not give decisions considering the future of the situations instead their emotionally considerations were significantly influence their decision makings. This may be due to their lack of knowledge about cloning.

Gunter et al (1998) were asked all the individuals to rate the relative benefits and risks associated with cloning of animals. They found that all age groups of individuals saw more risks than benefits regarding animal cloning. In this study, in contrast to the human cloning most of the reasons associated with animal cloning were found positive. This result can be correlated with the aim of the study. It can be understood that students thought the risks of human cloning outweighed than animal cloning. However the reasons giving by them were found quite same with the reasons regarding human cloning dilemma. It was found that many of the these reasons were related to the natural process which include protecting ecological balance of the nature by cloning extinction of the species and it was also found that almost all of the three major students were agree with this reason. Balas and Hariharan (1998) found in their study that most of the individuals' responses to the benefits of cloning centered around the possible medical applications or food production of this technology. It can be concluded from these results that individuals' thoughts regarding benefits of cloning technology can be related with nature, medical applications or food production, which means that they can consider the utility of this technology for nature and human beings as well.

In addition it was found that students tended to resolve dilemmas and justify their reasons by considering some of the bioethical principles. They seemed to give undue emphasis to the principles of beneficence and non-maleficence solving both of the dilemmas. How ever it seems that they could not give emphasis to principles of the respect of autonomy and justice.

In conclusion, it is important to make students aware of the practical applications of current developments in bioethical implications and also to make them become well informed decision makers on these issues, especially about cloning studies, considering the important attributes of scientific literacy and bioethical principles. Therefore it is suggested that these students need to support with bioethics courses or biology courses including ethics issues.

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Student understanding of thermal physics concepts and the underlying mathematics in the upper division

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Abstract

As part of our continuing study into student understanding of thermodynamics, we explore student understanding of the mathematical concepts required for productive reasoning about advanced thermal physics. We probe mathematical understanding by analysis of student performance, both before and after instruction, to physics questions as well as to analogous questions stripped of physics context. Our focus has been in two main areas: interpretation of *P-V* diagrams, which require an understanding of integration, and material properties and the Maxwell relations, which involve partial differentiation. We find that in some cases, difficulties with the physics concepts appear to have roots in the prerequisite maths; in others, students perform the mathematical operations easily, but have difficulty understanding the mathematical and/or physical significance of their work, even after instruction. Recently we have extended our research to include assessment of the mathematical concepts at the end of the prerequisite multivariable calculus module.

Introduction

The topic of thermodynamics covers a wide-ranging area that is fundamental in nature, and is utilized in many branches of physics, engineering and other natural sciences. Experience with thermodynamic phenomena at an early age motivates the teaching of basic concepts in the United States starting at the elementary level. Thus it is not surprising that there are hundreds of published reports of investigations at the school level into the learning and teaching of basic thermodynamics concepts, namely heat, heat conduction, temperature, etc. The results of these investigations demonstrate that school children face considerable obstacles in learning to understand the concepts of heat, temperature, internal energy, and thermal conductivity. Beyond these concepts, however, thermal physics has received scant attention in education research, particularly at the university level: the number of published studies worldwide that focus on university instruction is on the order of a dozen or more. Meltzer (2005a) compiled a multilingual bibliography of over 220 publications at all levels.

The published research at the university level clearly indicates that students exhibit significant difficulties when learning thermal physics topics, including conceptual difficulties with heat, temperature, the Ideal Gas Law and the First Law of Thermodynamics (Rozier and Viennot, 1991; Yeo and Zadnik, 2001; Jasiem and Oberem, 2002; Loverude et al., 2002; Meltzer, 2004; Kautz et al., 2005a; Kautz et al., 2005b). Previous results regarding the First Law have documented several common conceptual difficulties, such as indiscriminate application of the concept of a state function (Loverude et al., 2002; Meltzer 2004). Meltzer (2004) has suggested that particular difficulties experienced at the introductory level are also evident at the advanced undergraduate level.

As part of ongoing research at the University of Maine (UMaine) we are exploring student learning in upper-level thermal physics modules, primarily taken by physics majors. Our work extends the tools and results of research on first-year physics learning to upper-division thermal physics. There exists a limited body of research on this topic (Loverude et al., 2002; Meltzer, 2004; Meltzer, 2005b; Thompson et al., 2006; Cochran and Heron, 2006; Bucy et al., 2007; Mountcastle et al., 2007; Pollock et al., 2007). In thermal physics, as with most physics areas, specific mathematical concepts are required for a complete understanding and appreciation of the physics.

The role of mathematics in understanding thermodynamics concepts. Mathematics is a vital part of solving many physics problems, a universal language that can often condense a complicated conceptual problem into a simple relationship between variables. Many convenient representational tools exist in physics (e.g., equations, graphs and diagrams) that simplify analysis of a complex problem. Appropriate interpretation of these representations requires recognition of the connections between the physics and the mathematics built into the representation and subsequent application of the related mathematical concepts (Redish, 2005).

In thermodynamics, two- or three-dimensional graphical representations of physical processes are especially useful in helping to understand these processes. These diagrams can contain information about the thermodynamic 'path' followed in a process, regions of different phase, and critical behavior. Graphs of pressure vs volume, known as *P-V* diagrams, are used extensively as representations of physical processes as well as of the corresponding mathematical models. Information can quickly and easily be obtained from these representations.

Thermodynamics utilizes multivariable functions to represent state functions such as the internal energy, U. These functions describe systems at equilibrium, through equations of state. The change of a state due to various thermodynamic processes requires examination of the derivatives of these multivariable state functions. Thus, partial derivatives are prominent in thermal physics.

Previous work in PER has shown a link between mathematical acumen and success in an algebra-based physics module (Meltzer, 2002), but to date there have only been a few studies in the PER community that attempt to investigate physics students' mathematical difficulties with calculus concepts (Thompson et al., 2006; Black and Wittmann, 2007; Bucy et al., 2007; Pollock et al., 2007; Rebello et al., 2007).

One theme of our research is the extent to which students' mathematical conceptual difficulties may affect understanding of associated physics concepts in thermodynamics. We focus on student understanding of *P-V* diagrams in the context of determining quantities related to the First Law of Thermodynamics, and on student understanding of relationships between material properties using mixed second-order partial derivatives. We sought to isolate mathematical difficulties that may underlie observed physics difficulties by asking physics questions that are completely stripped of their content, and focus on the calculus concepts under investigation (i.e., integration and partial differentiation). We administered physics questions as well as the analogous maths questions to the students in our thermodynamics module. A comparison of student responses and reasoning on these paired questions allows us to pinpoint areas in which confusion may lie. In this paper we describe briefly our previous results, and include new data to broaden the applicability of our conclusions.

We have identified several specific difficulties with student understanding and application of maths concepts in a thermodynamics module. Brown et al. (1989) provide a cognitive model in which students frame activities based on the environment in which they are located. It may be that our students were not able to access their ideas about pure maths concepts in a physics classroom. With the long-term goal of improving student learning through effective curriculum implementation, it is imperative that we ascertain whether students possess the requisite calculus knowledge or if they are simply unable to access and use that information effectively in a physics classroom. To explore this question of transfer, we developed a series of maths questions and administered them as a brief survey in a multivariable calculus module (the final prerequisite maths module for thermal physics) after all relevant instruction. The survey we administered consisted of six primary questions, some with subquestions. The first three questions were maths analogs to the physics questions discussed below. The last three covered the more basic concepts of derivative, slope, and the product and chain rules of differentiation. In this paper we discuss the results from the first three questions only.

Context for research. The results on the physics questions come from students in UMaine's upper-level *Physical Thermodynamics* module, taught in the fall semesters of 2004-2007. The module meets for 3 50-minute sessions each week, for 14 full weeks. This module has been taught by the same instructor (DBM) for more than ten years, using the same textbook (Carter, 2001) for more than fivc years. Students turn in homework approximately once every two weeks and are given two cumulative quizzes and a comprehensive final exam during the semester. The class size is small, usually between 8 and 15 students.

The majority of the students in the module are majoring in physics or engineering physics, with an occasional maths or earth sciences student. UMaine’s introductory calculus-based physics sequence does not include thermal physics. So for some, this was their first exposure to thermal physics at university. Introductory chemistry, which typically covers the First Law and related topics, was not mandatory for some of the students in the module. However, all students in the data set had completed three semesters of calculus, including multivariable calculus, and one or more modules in ordinary differential equations.

We also have data obtained in the last week of instruction in *Calculus III,* which includes multivariable differential and integral calculus. This module is typically taught in lecture sections of 35-50 students, and meets in 4 50-minute lectures each week. Total populations of the module are on the order of 100-150 students each term; the module is taught in both the Fall and Spring semesters. Students in this module are typically majoring in a physical science, engineering, or mathematics. The responses from calculus surveys are not matched across all questions.

Research perspective. We describe student reasoning in our research in terms of *specific difficulties* (Heron, 2003) with the material. We start with targeted, context-dependent results and then generalize across contexts and seek larger patterns of student responses in our data. While we are familiar with more cognitive models from both physics and mathematics education research traditions, we are not currently analyzing our results through these lenses. Fundamentally, our emphasis is on gathering and interpreting empirical data that can act as a foundation for future studies on reasoning in advanced physics and curriculum development to address student specific difficulties.

Student understanding of the physics and mathematics represented on *P-V* diagrams

Background. Meltzer (2004) developed a set of questions probing student understanding of the First Law and related quantities based on processes shown on a *P-V* diagram, relating to findings by Loverude et al. (2002). We wondered if some of the conceptual difficulties might originate in the maths. In addition to replicating Meltzer's experiment in our upper-level thermodynamics module, we designed qualitative questions regarding comparisons and determinations of the magnitudes and signs of integrals that are analogous to Meltzer's questions.

The field of mathematics education research has a limited body of work pertaining to the topic of student understanding of integral calculus concepts. Previous findings indicate that students do not possess the necessary knowledge to allow them to successfully complete problems involving concepts of integration, in particular an understanding of the relationship between a definite integral and the area under the curve, the ability to find areas under the curve when the curve crosses an axis, and the general relationship between a definite integral and the area under the curve (Orton, 1983; Vinner, 1989; Thompson, 1994; Grundmeier, 2006).

Question pair 1: Comparison of Work and of Integral Magnitudes. We have previously reported on comparisons of student responses and reasoning for one pair of questions dealing with the physics and mathematics of work in thermodynamic processes (Pollock et al., 2007). Based on data from Loverude et al. (2002), Meltzer (2004) asked students to compare energy transfers and changes (work, heat transfer, internal energy changes) for two ideal gas processes (#1 and #2), shown on a *P-V* diagram, that have the same beginning states and the same ending states (A and B, respectively; Fig. 1(a)). The first problem, the work question, asks the students to compare the works done by the gas in the two processes. The correct response can be obtained by recognizing that the work done by the gas is defined by the integral of the pressure with respect to the volume, $\int PdV$, and that this integral is represented by the area under the curve for that process.

We paired Meltzer's work question with an analogous mathematics question (Fig. 1(b)), designed to elicit any underlying mathematical difficulties in this context. In this 'integral question', we asked students about the magnitudes of integrals of two functions that have identical beginning and end points. The two processes are replaced with two different functions. We asked the maths question before the physics question, usually in the first week of class. We also interviewed students to get more information on our written results. Interview results supported our written data.

The paired results show that while some students understand integration in this context and have specific difficulties with the physics concepts, that was not the prominent category of response pairs. We found several students who equated the integrals on the maths question and equated the works, indicating conceptual difficulties with the maths and possibly, but not necessarily, the physics. We found that some of the difficulties that arise when comparing thermodynamic work based on a *P-V* diagram—e.g., treating work as path independent—may be attributed to difficulties with the *mathematical* aspect of the diagram, in particular with the correct application of an understanding of integrals, rather than simply physics conceptual difficulties (e.g., treating work as a state function). These results suggest that some students aren't necessarily attributing state function properties to work so much as failing to recognize the same variable as two different functions during integration.

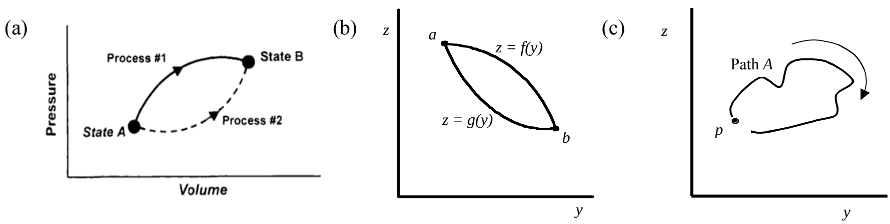

Figure 1. Diagrams used in (a) First Law physics questions, from Meltzer (2004); (b) integral comparison question; (c) closed path integral question.

Question Pair II: Comparison of Internal Energy Changes and Determination of the Sign of a Closed Path Integral. The second question pair contains a physics question that pertains to the change in internal energy of an ideal gas. Students are asked to compare the change in internal energy (ΔU) for the same two processes that were previously discussed. Internal energy is a state function and therefore path-independent. Since both processes begin at identical initial states and end at identical final states, each process produces the same change in internal energy.

The maths analog we designed for the ΔU questions is shown in Fig. 1(c). We refer to it here as the Closed Path Integral (CPI) question. Students were told that there is a function of two independent variables, *H(z,y),* and then to consider the closed path integral $I_2 \equiv \oint_{A,clockwise} dH$. They were then asked whether I_2 was positive, negative, or zero, or if there was not enough information to decide. Since H is a function of z and y, dH is a total differential; the Fundamental Theorem of Calculus applies here, so that the integral of dH is the difference in values of H at the integration limits. I_2 is equal to zero regardless of the path of integration. This question is analogous to a physics question that asks students about the change of a state variable or state function, such as the change in internal energy for a cyclic process. While not a perfect analog, it probes the same concepts of path independence, but in a closed loop rather than comparing two halves of the same loop.

Students performed very well on the ΔU question, with nearly 90% of the students giving correct responses, and reasoning explicitly that internal energy is a state function or is path independent. This is consistent with Meltzer's (2004) findings at the introductory level.

Student performance was very different on the CPI question: half (13/26) of the students gave the correct response, including some with no reasoning. Furthermore, performance on this question may be exaggerated: we asked about the integral of zdy over the same loop, and many students gave the same answer for both questions, including some who said that the integral would be zero. The most common incorrect answer, given by almost a third of students (8/26), was that more information was necessary, such as the functional form of $H(z,y)$. We are exploring refinements to this question to probe these issues more deeply.

The difference in outcomes on these questions shows that some students lack an understanding of the mathematical properties of state functions, and only rely on the physics and/or the physical aspects of the system in question. These results suggest that while students have a better understanding of *state function* than of *process function* in physics, the reverse is true for the mathematical distinction between these two concepts. They also suggest that it is possible to have a basic understanding of a physics concept (e.g., path independence of changes in state variables) without the concomitant understanding of the analogous mathematics (functions), which may come as a surprise to many instructors.

Results from Multivariate Calculus. Both of the above maths questions were asked on the survey in the multivariable calculus module. Overall the results were similar, but some distinct differences exist in the distributions of responses.

For the integral comparison question (Fig. 1(b)), just over 60% of students (14/26) in the thermodynamics module provided correct responses, and less than half of the (102) calculus students did so. In both cases, around one quarter of students said that the integrals were equal. Endpoint-based reasoning was similar in both modules. However, in the calculus module, some students gave responses that either explicitly or implicitly used symmetry to explain why the integrals were equal, implying that path length was important. This reasoning arose in two interviews as well.

For the CPI (dH) question, the distribution was somewhat different. One half of the physics students gave the correct response of zero for the integral, while only about one quarter of the calculus students did so. However, for the same reasons as with the physics students, this statistic overstates the performance, since several of the calculus students said that both loop integrals, zdy and dH, were equal to zero. About one fifth of students in physics, and one quarter in calculus, indicated that additional information was needed. The same proportion, about one fifth, said the integral would be positive in both modules.

The one surprising difference is that about one quarter of the calculus students said that the integral was negative, while *none* of the physics students did so. The most common explanation for this response was based on the direction of integration. It seems that these students treated the integral as a line integral, and applied the sign convention associated with Green's Theorem ('counter-clockwise is positive'), which was covered in the calculus module only a class period or two before the survey was administered. The fact that a number of calculus students responded that the sign of the integral was negative due to convention is evidence that this question is not interpreted appropriately by the students.

Student understanding of mixed second-order partial derivatives and their applications in thermodynamics

Background. Artigue et al. (1990) reported on student confusion about the representation and meaning of a differential. Our work focuses on the extent to which students connect the physical and mathematical meanings of a partial derivative. In earlier work, we have described results from analysis of responses to written questions that illuminate several aspects of student understanding of partial derivatives in thermodynamics (Thompson et al., 2006). We find that students are reasonably facile with first-order partial derivatives. Students are able to describe the distinction between derivatives of single-variable functions and those of multivariable functions, and to recognize the empirical meaning of a partial derivative as a change in a dependent physical variable as a result of a change in a second, independent physical variable. However, we find that students are not nearly so facile with second-order partial derivatives.

The central mathematical concept explored here is known in mathematics as Clairaut's Theorem, or as 'the equality of mixed second partials.' In physics it is typically referred to as the Euler criterion. For any multivariable function for which the second-order partial derivatives are defined and continuous, the 'mixed second partials'—partial derivatives taken sequentially with respect to two different variables—are identical, regardless of the order of differentiation.

(a)

$$\beta \equiv \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_P$$

$$\kappa \equiv -\frac{1}{V}\left(\frac{\partial V}{\partial P}\right)_T$$

(b) Show that in general

$$\left(\frac{\partial \beta}{\partial P}\right)_T + \left(\frac{\partial \kappa}{\partial T}\right)_P = 0.$$

(c) With the usual definitions of isothermal compressibility *(κ)* and thermal expansivity *(β)*, for any substance where both are continuous, show how these two derivatives are related:

$$\left(\frac{\partial \kappa}{\partial T}\right)_P \quad \text{and} \quad \left(\frac{\partial \beta}{\partial P}\right)_T .$$

Figure 2. (a) Mathematical definitions of the thermal expansivity, β, and the isothermal compressibility, κ. (b)-(c): 'β-κ question', based on Problem 2-9 in Carter (2001), asked to students on (b) homework and (c) a midterm examination.

Student understanding of mixed second-order partial derivatives. We have designed and administered questions to students in the context of exploring the relationship between the physical properties of the thermal expansivity *(β)* and the isothermal compressibility *(κ)* of a system (Bucy et al., 2007). The mathematical definitions are given in Figure 2(a). Physically, β describes the response of the system volume to a change in temperature while κ describes the response of the system volume to a change in pressure. Division by volume makes these *intensive* properties, independent of the system size.

The 'β–κ' question was administered to students as part of a homework assignment after instruction on state functions and partial derivatives (Fig. 2(b)), and again in a slightly modified form as part of an examination (Fig. 2(c)). These questions probe student understanding of the mathematics that underlie these physical scenarios, particularly multivariable calculus and partial differentiation.

This question can be solved by a straightforward application of partial differentiation to each expression. One must invoke the product rule and the chain rule, since β and κ are both functions of volume, which itself is a (state) function of pressure and temperature in this case. Then Clairaut's Theorem is necessary to complete the exercise. In the responses, some students did neglect or misapply the product and chain rules, but most often these errors were made only on the homework; most exam responses had no such errors.

The primary difficulty we identified in responses to this question is that students seem to set each mixed second-order partial derivative to zero independently, since one variable 'has already been held constant' during the first partial differentiation (Bucy et al., 2007). This specific difficulty was as prevalent in student responses as correct answers, and a few otherwise correct answers relied on this reasoning to arrive at the correct result on the homework problem. This difficulty persisted after instruction, with almost half (5/11) of the students invoking this idea on the midterm exam. This indicates a higher-order mathematical difficulty than simple differentiation problems, namely the role of fixed variables in partial differentiation. In particular, we see evidence that students misinterpret the meaning of 'holding a variable constant' during partial differentiation, considering the fixed variable to remain constant after differentiation rather than being fixed only during the process.

On the homework, about one quarter of the physics students derived the asked-for equation for an ideal gas only, substituting the respective partials of ideal gas volume into the definitions of β and κ. While reasonable, the question is generally applicable to all substances.

Results from Multivariate Calculus. We designed a physics-less version of the β–κ question for the survey in the multivariable calculus module, which we call the 'α–β' question (Fig. 3). The two questions are almost identical in what they ask of students. The most striking difference between the two questions is the subscripts. In physics it is customary to include in a subscript which variables are fixed, corresponding to the quantities that are fixed during a physical process. In maths notation subscripts are not used, presumably because the fixed variables are obvious. We omitted the subscripts in the α–β question to acknowledge the mathematical standards.

This question had 64 responses, one of the lowest response rates on the survey. Overall the results were similar to the β-κ question, but some distinct differences exist in the distributions. While about one third of physics students correctly equated the derivatives, only about 20% of the maths students did so. Both groups had similar proportions (35%-40%) state that each mixed second partial derivative was equal to zero. The reasoning for this response from the maths students was the same as for the physics students. Finally, a small proportion (10%) of the maths students derived the solution for the function $Z(x,y) = xy$. This is similar to the 'ideal gas' solution used by some physics students—substituting a specific and/or familiar expression in a general solution. This greatly simplifies the solution, but supports the conclusion that each mixed second-order partial derivative is also zero. This specific solution method transcends the context, and may be a general problem-solving procedural method.

Z is a function of the two variables x and y, i.e. $Z = Z(x,y)$. Consider the following two expressions:

$$\alpha = -\frac{1}{Z}\frac{\partial Z}{\partial x} \qquad \beta = \frac{1}{Z}\frac{\partial Z}{\partial y}$$

$$\frac{\partial \alpha}{\partial y} + \frac{\partial \beta}{\partial x} = 0.$$

Figure 3. The 'α–β' question, the mathematical analog to the β-κ question.

Conclusions

By analysis of student use of mathematics in solutions to conceptual physics questions as well as analogous maths questions stripped of physical meaning, we find evidence that students often enter upper-level physics modules lacking the necessary (and assumed) prerequisite mathematics knowledge and/or the ability to apply it productively in a physical context. In some cases, students avoid using physical reasoning to verify their mathematical results. Taken as a whole, these results point to difficulties among advanced students in incorporating calculus and physics into a coherent framework.

Preliminary results from maths questions administered in a multivariable calculus module suggest that the observed mathematical difficulties are not just with transfer of maths knowledge to physics contexts. Some of these difficulties seem to have origins in the understanding of the maths concepts themselves.

We are continuing to collect and analyze data from written questions and interviews, and to expand the scope of our investigation to additional populations.

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teaching and learning strategies

Investigation of secondary education physics course 9th grade curriculum in terms of energy concept, and activity suggestions

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Abstract

The sub-titles of energy contained by the prepared activities were discussed as energy forms, energy transformation, difference between the transformation and the transition, comparison of energy forms and energy transformations, energy transition from hot to cold, insulation, self generated energy transformations, non self generated energy transformations, energy storage, fuels and energy in foods. After the experiment done related to each subject, modelling was performed to provide the students to configure such an abstract concept as "energy" in their minds. These activities was applied on a group in 9th grade as a pilot study during instructing the chapter in fall semester of 2008-2009 academic year, and after the application, the students' opinions related to the activities was consulted. Feedbacks obtained during the application and the students' opinions related to the activities was given in the study.

Introduction

Energy is an abstract concept which requires a high level thinking (Warren, 1983; Ogborn, 1990). Also, since the energy is a common and multi-disciplinary subject which is used by many sciences, it should be considered in physical, chemical, and biological aspects (Gurdal, Bayram, & Sahin, 1999; Ozmen, Dumanoglu & Ayas, 2000). Because of these features, energy is the primary subject which the students mostly had difficulties in configuring (Stylianidou, Ormerod & Ogborn, 2002).

At the end of the concept tests applied on the students, and the interviews done with the students, it is determined that the students had some misconceptions related to the energy (Ogborn, 1990; Konuk & Kilic, 1999; Stylianidou, Ormerod & Ogborn, 2002; Solomon, 1982; Ellse, 1988; Stylianidou, 1997; Trumper, 1998; Unal, Aktamis, & Ergin, 2007). It is seen that these misconceptions are mostly related to the conservation, transfer, transformation, storage, essentialness, abstractness, and definition of energy. Also it is seen that the students had some misconceptions such as "the energy obtained by work done has disappeared, and not conserved; the energy is also a force; if a force acts onto a body, then work is done; confusing the energy transformations; using the kinetic energy and the potential energy instead of each other". For that reason, it should be given a particular importance to instruct this concept by means of proper activities which provide the students to comprehend the “energy” concept and eliminate their misconceptions. From this point of view, various activities intended for instructing the energy concept should be given to the students.

In this study, Secondary Education Physics Course 9th Grade Curriculum was investigated in general in terms of vision and mission, and the acquirements at each chapter was reviewed in terms of “energy” concept. The chapter of “Energy” was investigated in detail, and suggestions and comments were given related to discussing of the “energy” concept on the 9th Grade Physics Course Curriculum. Also some sample activities which can be done according to the acquirements related to the subject titles at the chapter of “Energy” on the 9th Grade Physics Course Curriculum were submitted.

Secondary education physics course 9th grade curriculum and energy concept

Secondary education takes a four-year period. And only in the first year of this four-year secondary education period, in other words at 9th grade, all of the students will take the physics course. For that reason, it becomes important to present the 9th grade courses in such a manner that contain the fundamental concepts of all subjects in general, and is related to daily life. When the curriculum was investigated from this point of view, then it is seen that this point was taken into consideration (Physics Course 9th Grade Curriculum, 2007). In addition, as compared to the previous curriculum, not only the knowledge acquirements, but also the skill and attitude acquirements are given. Also as well as on the primary education curriculum, the expression of acquirements substitute the target and behaviours. In this context, Secondary Education Physics Course 9th Grade Curriculum which will be applied in 2008-2009 academic year was investigated in terms of energy concept. When the previous curriculum was investigated, it is seen that the energy concept was discussed within some chapters in all levels, but it was given as an individual chapter with a title of “work, power, and energy” at 10th grade. However, when we look at new Physics Curriculum, it is seen that there was a chapter with a title of “energy” on 9th Grade Physics Course Curriculum, and within this chapter, the following sub-titles such as work, power, and energy; energy transformations and conservation of energy; energy resources; heat and temperature were discussed. From this point of view, it can be seen an appropriate approach to deal with the energy concept entirety as compared to the previous curriculum. To correlate the energy concept with daily life, some examples were given under the title of “*examples from daily life to be used to give the concept*”. Also when the other chapters on 9th Grade Physics Course were examined, it is seen that the energy concept was also discussed in these chapters.

Method

Sample Activities Related to Energy Concept. By researching the resources existing in field literature related to the sub-titles within the chapter of “Energy” (STTIS Project, 2000; Ogborn, 1990; Ozmen, Dumanoglu & Ayas, 2000; Solomon, 1982; Stylianidou, 1997), some activities providing them to do sample experimental and modelling were prepared. The sub-titles contained by the prepared activities were discussed as energy forms, energy transformation, difference between the transformation and the transition, comparison of energy forms and energy transformations, energy transition from hot to cold, insulation, self generated energy transformations, non self generated energy transformations, energy storage, fuels and energy in foods. Examples were given from daily life and experiments were done related to these subject titles. After the experiment done related to each subject, modelling was performed to provide the students to configure such an abstract concept as “energy” in their minds. These activities will be applied on a group in 9th grade as a pilot study during instructing the chapter in fall semester of 2008-2009 academic year, and after the application, the students’ opinions related to the activities will be consulted. Feedbacks obtained during the application and the students’ opinions related to the activities will be given in the study. A sample experiment were enclosed in appendix.

Data Collection Tool and Analysis of Data. In order to determine the feedbacks received during the application and the students' opinions related to the activities, as data collection tool, semi-structured interview forms were used. The data obtained from the interviews done were recorded by recorder. And these data were saved on the computer, and transferred into written text. And the reliability study of the data was performed after transferring the data into written text. The reliability study of the interview was performed by calculating the consistency percentage of the written interviews. While calculating the consistency percentage, the data were transferred into the written text and encoded by two researchers. And finally, both text were compared and the consistency percentage between the codes given by the researchers were found as .90.

Findings and Comment

The answers given by the students to the interviews done with the students at the end of the application were divided into 6 categories totally. These categories and the sample answers given to these categories were given below;

Modelling and Experimenting;

This category contains totally 18 students' answers.

“I understood the subject better by means of the models related to the concepts.”

“We were able to express the abstract things as concrete by means of the models.”

“Since we did the models visually, shapes were formed in my mind”

64 % of the students expressed that modelling and experimenting helped them to understand the subject better.

Comprehending The Subject;

This category contains totally 20 students' answers.

“It is more instructive and easier to understand”

“It is very beneficial for comprehending and reinforcing the energy subject”

“I understood the energy subject better”

71 % of the students expressed that they understood the energy subject better by means of these activities.

Commenting;

This category contains totally 13 students' answers.

"I think that it broadened my viewpoint."

"I am able to comment related to the subject."

"I started to questioning the events."

"It motivates the student to think and investigate."

46 % of the students expressed that they were able to comment related to the subject, and consider the subject from different points of view.

Its Relationship with Dailylife;

This category contains totally 15 students' answers.

"I connected its relationship with dailylife. A lot of samples are given. And I can consider different samples than these samples."

"It is more realistic"

"There are samples related to dailylife."

54 % of the students expressed that there was a relationship between the activities done and the dailylife.

Creativity;

This category contains totally 9 students' answers.

"I started to think and imagine different things."

"I consider different samples."

"It increased my imagination."

32 % of the students expressed that it developed their imaginations.

Concern about the lesson;

This category contains totally 22 students' answers.

"Lectures are not boring any more, formerly, we were just writing down."

"It increases my concern about the lesson."

"It is a different activity"

"There is visualization."

"The lectures are going well"

79 % of the students expressed that their concerns about the lesson increased.

Results and Suggestions

The experimenting and modelling oriented activities which are applied on the students had attracted students' interests. Also, they expressed that their concern about the lesson had increased. They expressed that they tried to comment and consider the events from different points of view by means of these activities. Also, introducing the abstract concepts such as energy by visualizing them as concrete provided the students to understand the subject better.

Introducing the abstract concepts such as energy by concretizing them as easily understandable by the students can provide the students to comprehend the subjects easily, and consider the events from different points of view. When we examine the 9th grade physics curriculum of 2008-2009 academic year, it is seen that energy concept was tried to be introduced by connecting its relationship with dailylife. We can say that such subjects which were introduced by connecting their relationships with dailylife had attracted students' interests and helped them to comprehend the subjects.

At the next study to be done, it is planned to apply the activities which took their final form by the feedbacks received onto a selected sample, and to investigate the students' achievement levels, and comprehension levels related to the energy concept, and to compare with a control group.

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Appendix

Experiment: Making a simple calorimeter

You can make a calorimeter pot. For this, it is enough to have two foam cups, and a material to close on them. When you put the cups one within the other, and close the brim, then we can say you obtained a calorimeter. And you can put your thermometer and stirring rod on the holes that you opened on the top into the pot.

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Development of pre-service chemistry teachers' understanding of reaction rate

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Abstract

The purpose of this study is to enhance pre-service chemistry teachers' conceptual understanding via constructivist based instruction (CBI) on the reaction rate in a course "Basic Chemistry Laboratory". This study presents an opportunity to see whether pre-service chemistry teachers' conceptual understanding is developed via CBI. Semi-structured interviews were administered to a sample of six participants at a university in the Department of Secondary Science and Mathematics Education. Interviews were carried out both at the beginning in order to check the participants' pre-knowledge and at the end of the semester in order to check whether the CBI improved the participants' understanding on the reaction rate. Analysis of the transcribed interviews, final exam, and homework showed that the majority of the participants exhibited conceptual understanding of reaction rate at the end of the course and had overcome their misconceptions which were determined at the beginning of the semester.

Introduction

In recent years, there has been a shift from the notion that considers students as empty vessels to be filled in to the one stating that learners have already some prior knowledge about scientific concepts in their mind before instruction and take an active role in the learning process. As Driver, Guesne and Tiberghien (1985) state, students come to science classes with already formed conceptions as a result of their daily life experiences, interaction with people, and media. In some cases, these conceptions are not consistent with the scientifically accepted view and they interfere with students' learning since students construct new knowledge based on their existing knowledge. Conceptions, which do not match with the scientifically accepted view, are called misconceptions. Several research studies conducted in order to find out students' conceptions revealed that many students had misconceptions about different scientific concepts despite science instruction (Abraham, Williamson, & Westbrook, 1994; Boo, 1998; Cakmakçı & Leach, 2005; Garnett & Treagust, 1992; Hackling & Garnett, 1985; Haidar & Abraham, 1991; Ross & Munby, 1991; Thomas & Schwenz, 1998).

In general, misconceptions arise from factors that family, culture, attitude, environment, textbooks, belief, teacher, teaching method, and so on (Griffiths & Preston, 1992; Haidar & Abraham, 1991; Harrison & Treagust, 1996; Nakhleh, 1992; Nakhleh & Samarapungavan, 1999; Novick & Nussbaum, 1978; Novick &

Nussbaum, 1981; Stavy, 1988; Stavy, 1990; Stavy, 1991; Tsai, 2001).

Teaching methods are very important in order to remove misconceptions regarding science subjects. In recent years, constructivist teaching strategies has been considered as teaching methods in the science classrooms in order to overcome students' misconceptions. Using constructivist approaches in teaching and learning improve the conceptual understanding. According to constructivist theory, students take an active role in constructing new knowledge. When students actively engage in lessons, they integrate their existing knowledge with new experiences (Vosniadou, 2007). Constructivist learning models assume that the processes of learning involve the building up of knowledge structures and suppose that existing knowledge and understanding is the basis for new learning. These considerations suggest that pre-service teachers should not only learn individual scientific models and principles, but should be taught to perceive how they are linked together. The focus of this research is investigating the extent to which pre-service teachers enhance the conceptual understanding via CBI on the reaction rate.

Students were found to have misconceptions about several scientific concepts, e.g. acids and bases (Ross & Munby, 1991; Schmidt, 1995); electrochemistry (Sanger & Greenbowe, 1999); mole (Tullberg, Strömdahl & Lybeck, 1995); particulate nature of matter (Haidar & Abraham, 1991; Gabel, Hunn & Samuel, 1987); stoichiometry and chemical equilibrium (Huddle & Pillay, 1996). However, there are few studies that were examined students' misconceptions on the reaction rate (Cakmakçı & Leach, 2005). Misconceptions regarding the reaction rate and the relationship reaction rate and temperature have been found in these studies. For example some students thought that the rates of the endothermic and exothermic reactions are affected differently when the temperature increases regarding the relationship reaction rate and temperature (Nakiboglu, Benlikaya, & Kalın, 2002).

As stated above, various research studies have been conducted about the reaction rate. However, most of these studies focused on primary and high school students' conceptions. There are few studies conducted at the university level as well as in the context of reaction rate. The purpose of this study was to enhance pre-service chemistry teachers' conceptual understanding via constructivist based instruction (CBI) on the reaction rate.

Purpose of the Study. The purpose of this study is to enhance pre-service chemistry teachers' conceptual understanding via constructivist based instruction (CBI) on the reaction rate in a course "Basic Chemistry Laboratory". This study presents an opportunity to see whether pre-service chemistry teachers' conceptual understanding is developed via CBI.

Research Question. How the pre-service teachers enhance their conceptual understandings via constructivist based instruction (CBI) on the reaction rate in a course "Basic Chemistry Laboratory"?

Methodology

Sample. Semi structured interviews were administered to a sample of six pre-service chemistry teachers (4 female and 2 male) enrolled in the course of Basic Chemistry Laboratory at a university in Ankara. All the participants volunteered to be interviewed. These students were selected according to their academic achievement (2 lower achiever students, 2 middle achiever students, and 2 higher achiever students). The study sample was convenience sampling which is a type of non-random sampling method because it is extremely difficult to select either a random or a systematic non-random sample.

Instrument. The semi-structured interviews were carried out both at the beginning to check the participants' pre-knowledge on the reaction rate and at the end of the semester to check whether the constructivist based instruction done in the course improved the participants' conceptual understanding on the reaction rate. Each interview was tape-recorded; and they were all transcribed for further analysis.

During the interviews, participants were showed a graphic that demonstrates energy and progress of reaction. Participants were asked to explain the concepts such as intermediate, the rate determining step, activated complex, enthalpy on this graphic.

During experiments about reaction rate, some constructivist teaching strategies were used with every group. These methods and techniques were argumentation, role playing, and 5E.

Interview Question.

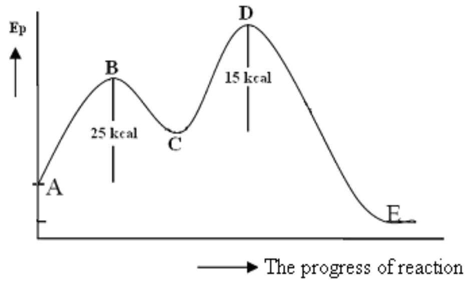

Figure 1. Graphic regarding question on reaction rate

It was given a graphic about the potential energy – progress of reaction above. According to this graphic:

1- Which of the above letters is the intermediate?

2- Is ΔH negative or positive? Why?

3- Where is the rate determining step?

4- What is the activated complex? Which letters represent the activated complex in this graphic?

Procedure

The study was carried out in 2007-2008 academic year. The course lasted 14 week-period and 2 hours in a week. There were 39 first grade undergraduate chemistry education students (pre-service chemistry teachers) in this course. Students were separated to the two different homogenous groups. It was executed the activities regarding laboratory security at the first week. Then, it was respectively made the experiments regarding the particulate nature of matter, physical and chemical changes, the purification of matter, solutions, Boyle law, the determination of the molecule mass of a volatile liquid, the determination of mole mass of a metal, the reaction rate and the factors that affect the reaction rate, chemical equilibrium, acids and bases, and electrochemical cells at the other weeks.

The experiments regarding the reaction rate and the factors that affect the reaction rate were performed at the sixth and seventh weeks. Pre-service teachers were separated to the groups that had three or four students at the sixth week. They were asked the question (How can the chemical reactions execute?). Each student gave a decision by discussing the other students. In this time, two instructors walked around them and listened to their ideas. Then, the groups gave a decision among them regarding the chemical reactions. Therefore, argumentation was used in this time. After that, each group played the role regarding a chemical reaction, so role play technique was used in this time. After the role playing, classroom discussion was started and collision theory was used in order to explain this subject. During the discussion, the potential energy-the process of reaction graphic was drawn and some important aspects about reaction rate were emphasized. Also, it was considered the misconceptions about the reaction rate during the course. Each group was responsible for conducting their own experiment. After finishing their experiments, they all explained what they had done to others by expressing the related theory and misconceptions about the reaction rate.

At the seventh week, the factors that affect the reaction rate were discussed and 5E (Engagement, exploration, explanation, elaboration, and evaluation) technique was used in this time. Firstly, the subject of the last week was repeated with the question answer method. Then, students were told two stories about the effect of temperature to the reaction rate and the effect of concentration to the reaction rate and were asked the answer to the problem in the stories. Students created their hypothesis about the problem and tested their hypothesis by making experiment. Consequently, constructivist teaching strategies were implemented during the course.

Analysis of Data

Interviews were used to collect data. To analyze the data, coding was made and categories were formed. Codes came from both the literature and the researchers' experiences.

Four main categories including "correct answers", "partially correct answers", "incorrect answers", and "no answers" were formed. "Correct Answers" category includes correct answer fully. In "partially correct answers" category, there are correct but deficient ideas. "Incorrect answers" category includes wrong ideas. There are no responses in the "no answer" category.

Interviews' recording and transcribing were made in order to provide validity in this study. Triangulation and peer debriefing were made for credibility (Lincoln & Guba, 1985). In this study, triangulations were achieved by using interview and observation. In peer debriefings, some colleagues with respect to appropriateness of the interview and observation schedules were consulted before conducting study.

Findings

At the beginning of the course, six students were interviewed and it was found that some pre-service teachers had some misconceptions regarding the reaction rate concepts. For example, one participant thought that B and D letters may be intermediate. Another student stated that this reaction was endothermic since ΔH equals 40 kcal (25+15). According to this participant, C was the beginning of the reaction. Also, this student had not got any information about the activated complex. Third student said that this is a reaction, but there is a phase change in accordance with this graphic. Graphic shows the physical change since the potential energy changes in the physical changes and the potential energy does not zero. This student does not consider that this graphic shows the chemical reaction at the beginning of the course. Also, same student thought that between C and D is faster step since the potential energy increases much more in this step. Forth students stated that the matter which forms in the end of the reaction is the activated complex; therefore E may be activated complex. Other students had not got any information about the intermediate and activated complex.

At the end of the semester, many of the participants understood the concepts regarding the reaction rate and showed the conceptual development in this subject. They developed their ability regarding graphic comment and gave correct answers to the question. They stated that CBI helped them to improve their conceptions. However, some students confused that which letter is the slow step and thought that B is the slow step at the end of the semester.

Conclusions and Implications

This study shows that pre-service chemistry teachers have some misconceptions regarding the reacting rate concepts. It is important to diagnose the learners' misconceptions before the instruction. Alternative views of students should be discussed in the classroom in order to overcome these misconceptions and different teaching strategies such as constructivist approach should be used in the classes. Therefore, this study is important since the reaction rate concepts are understood well by students; they can realize the meaningful learning at this subject. Students should be provided the meaningful learning by providing the active participation of students, by construct their knowledge that by using their prior knowledge (Osborne, Erduran and Simon, 2004a). In this study, CBI has been used in order to provide the active participation of students and to construct their new knowledge that by using their prior knowledge.

Students may have some misconceptions about the rate of reaction concepts and chemistry teachers should be informed about the misconceptions and their sources before the instruction. Traditionally designed chemistry instruction (lecturing) is not enough to eliminate students' misconceptions. Teachers should consider the students' misconceptions and pre-existing knowledge when planning the instruction. Education faculties need to devote continuous efforts to prepare teachers who are able to help their students learn properly and to know how to identify students' conceptions and implement teaching approaches that promote conceptual understanding among students.

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On improving students' understanding of the photoelectric effect

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Abstract

We report our research findings on Singaporean student understandings of a topic in modern physics – the photoelectric effect, discuss the possible basis of their understanding, and suggest ways to improve their understanding of this topic. This on-going research involved four junior colleges (JC). The level of the treatment of this topic in JC is similar to that of an introductory undergraduate course. The research was done using pre-test, tutorial instruction and post-test on experimental and control groups in each JC. It was found that there is a significant improvement in the experimental group over the control group for both categories of questions i.e. conceptual questions which are less familiar to our students and questions which are typical of the GCE A-Level exams.

Introduction

In 2006, a new Singapore-Cambridge General Certificate of Education (Advanced Level) Examination (GCE A-Level) physics syllabus (H2 Syllabus 9745) was introduced by the Ministry of Education Singapore. This examination is taken at the end of Junior College (JC) education after 12 years of formal education. In the new syllabus, the weight of modern physics has been increased substantially and the topics include Quantum Physics, Lasers & Semiconductors, and Nuclear Physics. In addition, a new component called 'Essentials of Modern Physics' (H3 Syllabus 9811), was introduced. It is meant to challenge the top physics students and has 6 topics: Special Relativity, Quantum Theory of Light, Matter Waves, Quantum Mechanics, Solid State Physics and Photonics.

With the introduction of the new syllabus, we felt the need to research on student learning of the topics to help guide the development of curriculum. Since the inquiry approach in the teaching of science has been recognized as being effective and is being adopted in science education with considerable success (National Research Council, 1996; National Science Teachers Association Press (USA), 2001), we decided to use the Photoelectric Effect resources found in '*Tutorials in Introductory Physics*' developed by the Physics Education Group (PEG) of the University of Washington (McDermott et. al., 2002), with some appropriate modifications, to implement inquiry-based tutorials in the JCs.

Research Procedures

Selection of the modern physics topics. A survey was conducted among 16 teachers from eight JCs to identify physics topics which face pedagogical challenges. Based upon the survey results and the existing resources such as textbooks, college notes, online resources, research papers (Steinberg et. al., 1996; Keesing, 1981) and the well established content found in '*Tutorials in Introductory Physics*', we chose the teaching and learning of the photoelectric effect to be the first topic to research on.

Adaption of PEG instructional materials. The '*Tutorial in Introductory Physics*' instructional materials consist of pre-tests, tutorials, homework, post-tests and instructor's guide materials. We studied these materials, including role-playing, with some members of the research team acting as students and others as teachers, to understand the probable issues faced during implementation as well as to get a feel of the structure of the materials. In the process, the materials were modified, in consultation with PEG, to suit the Singapore context in terms of the format, common diagrams, terminologies and sentence structures. Here is an example of a modification of a tutorial question.

<u>Original structure</u>:
Is the number of electrons that leave electrode B in case 2 *greater than, less than, or equal to* the number that leave electrode B in case 1? Explain.

<u>Modified structure</u>:
Fill in the following signs (>, <, =) in the boxes. Justify your reasoning for each case.

Number of electrons that leave plate B in case 1.	$\square$	Number of electrons that leave plate B in case 2.

Explanation:

Another example of the modification is that an A-Level exam type question is added into the post-test. The main purpose is to see how students who have undergone the inquiry-based tutorial (experimental groups) and students who have undergone the traditional college tutorial (control groups) compare in their performance of the traditional exam type question. Some of the differences between the two types of questions can be observed from the example below.

<u>An inquiry-based question from '*Tutorial in Introductory Physics*'</u>:
The electrode B is replaced with one made of caesium (Φ = 2.1 eV) and the stopping voltage is again measured. Does the stopping voltage *increase, decrease,* or *stay the same*? Explain.
<u>An A-Level exam type question</u>:
What will be the change in the stopping voltage if the wavelength of the incident light is reduced from 476 nm to 426 nm? Show your calculations clearly.

We believe that one of the key factors in the success of the teaching and learning by inquiry is that facilitators should aim not to reveal the answers to the learners but instead pose guiding questions that lead learners to their own realisations. PEG does not provide us with the answers to the tutorial questions in their materials. Instead, our research team generates the possible solutions as well as our own facilitation questions to be used later on in the field trials. It is also with this same mindset that we collaborate with the participating teachers. This means that the teachers themselves in turn generate their own answers and facilitation questions under the guidance of our research team. One of the simpler tutorial questions and its possible facilitation questions are as follows.

Question: While the laser is switched *off,* is the current *zero* or *non-zero?* Explain.
Possible facilitation questions:
- For this answer of yours, what are the assumptions that you have made?
- Imagine that you are actually doing the experiment. If the laser is switched off and you saw a non-zero reading on the ammeter, what are the possible reasons for the reading?

Implementation of Field trials. The classes provided by the 4 JCs are grouped into experimental and control groups for field trials which involved four main phases.

Phase 0: Teacher familiarization with instructional materials
Phase 1: Administration of pre-test to both groups of students
Phase 2: Tutorial instruction and homework distribution
Phase 3: Administration of post-test

For the experimental groups, to ensure that students are not deprived from benefitting from their usual JC tutorial homework, the teachers return to their normal routine after our intervention. To aid the participating teacher in planning the flow of lessons for the classes, we have also penned out the teaching and learning activities of the topic for both experimental and control groups in chronological stages.

Stage	Control Group	Experimental Group
A	JC Lecture	JC Lecture
B	UW-NIE Pre-test	UW-NIE Pre-test
C	JC Tutorial homework[#]	UW-NIE Tutorial session
D	JC Tutorial session	UW-NIE Homework
E	NIE Post-test	NIE Post-test
F	UW-NIE Tutorial*	JC Tutorial homework
G	UW-NIE Homework*	JC Tutorial session

* Optional, available upon teachers' request.
[#] Refers to the usual JC tutorials that are given to students to be done before coming for their next tutorial sessions.

The familiarisation session, Phase 0, is to allow participating teachers to become familiar with the facilitation procedure and tutorial materials through first-hand experience, where they sit for the pre-test, work through the tutorial questions and finally sit for the post-test, just like what the participating students will do. While the teachers attempt the tutorial, they are allowed to discuss with each other. Research team members were present to listen to their discussions. At various checkpoints of the materials, the research team will intervene by asking for a re-iteration of discussed concepts followed by specific guiding questions to ensure the accuracy of the concepts or to enhance the learning. The teachers are also reminded to pay attention to the kinds of facilitation questions that are posed to them, as well as the mannerism in which these questions are asked to encourage discussion. One 3-hr familiarisation session is conducted for each JC.

The administration of the pre-test takes about 15 minutes. There is no strict adherence to time for the pre-test and students are requested to hand in once they are ready. In addition to finding out more on student understanding, the pre-test help to set the stage for the tutorial and to motivate students to attempt earnestly the tutorial questions. It will also familiarise students with inquiry-based questions, and the recalling of concepts taught during the lecture.

For the convenience of the teachers, Phases 1 and 2 are conducted on the same day. After the pre-test has been administered, the inquiry-based tutorial is conducted for 1½ to 2 hours, depending on time made available by individual class schedules. Students typically form groups of five. Each student is given the tutorial handout. A large sheet of mah-jong paper and markers are given to each group for students to pin down their thoughts during their discussions. The writing on the paper also allows for better facilitation as the facilitators move from one group to another.

At the end of the tutorial session, a homework handout is given to each student to attempt on their own. On a separate day, the post-test is administered by the teacher before he reverts to discussion of the normal JC tutorial questions. The time taken for the administration of the post-test is strictly 30 minutes.

Development of investigative experiment/demonstration. During Phase 0, feedback from teachers prompted us to develop an easy-to-use, hands-on demonstration for photoelectric effect in time for a demonstration session to be included in Phase 2. Teachers found it beneficial and mentioned that it has enhanced the students' learning experiences. The main equipment of this set-up is the phototube which can be purchased online.

Pre-test. The eight concepts that are assessed in the pre-test are as follows:

Qn	Concepts	Brief Description
1	1.1	Constant non-zero current flows in a closed/complete circuit only.
	1.2	Electrons do not have enough energy to escape from the surface of the electrode.
2	2.1	When there is light shining on electrode B, electrons are emitted from it i.e. from B to A.
	2.2	Direction of electron flow is opposite to the direction of conventional current flow.
3	3.1 (only one)	Electrons are released from electrode B in all directions, so not all may reach electrode A.
4	4.1 (only one)	Because the applied voltage is more negative than the stopping voltage, the electrons do not have enough K.E. to reach electrode A.
5	5.1	The lower the work function, the higher the K.E. of the emitted electrons.
	5.2	The higher the K.E. of the emitted electrons, the higher the absolute value of the stopping voltage.

Post-test. The post-test has two questions consisting of several parts. The first question, an adaptation of PEG material, is more conceptual and unfamiliar to our students. The second question is typical of the A-Level exams. There are a total of 26 concepts that are assessed. Several of these are listed below.

Qn	Concepts / Calculation	Brief description
1b(i)	**1b(i).1**	Increasing intensity (with the same wavelength) means increasing the rate of photons incident on electrode B.
	1b(i).2	Therefore, more electrons are emitted per second and this leads to greater current detected by ammeter.
1c(i)	**1c(i).1**	Lower work function means greater maximum K.E. of emitted electrons.
	1c(i).2	Stopping voltage increases as it is now more difficult to stop the electrons from reaching electrode A.
1c(ii)	**1c(ii).1**	Correct use of $eV_s = \frac{hc}{\lambda} - \phi$.
	1c(ii).2	Correct computation.
2e(i)	**2e(i).1**	Shape (S): Shape of individual I-V curve is correct
	2e(i).2	Relation(R): The I-V curve of the smaller wavelength should correspond to a more negative stopping voltage. Proper labelling of curve by wavelength is required.
	2e(i).3	Axes (A): Proper label for axes by physical quantities.
	2e(i).4	Units (U): Proper units for physical quantities of the axes.

Marking of Pre-test and Post-test. Mark schemes are generated for the pre-test and post-test. They involve concepts that are looked out for in the students' answers, rather than specific answers. For the scoring system, sets of rubrics are formulated for both the pre-test and the post-test. In general, if the concept in the mark scheme is absent, Level 0 is given. If the concept is present, Level 1 is given. If the answer is indeterminate, whereby the marker is unsure if the student has the correct conceptual understanding or that the answer is incomplete, Level × is given. For computational steps in calculation, instead of levels, marks of 0, ½ or 1 are given. Computational scores are given basically to see if the student, with the use of the correct concept or formula, substitutes values without carelessness, uses the calculator well and gets the correct values of the quantities asked for. Graphical representation skills are also given the marks of 0, ½ or 1. Note that the pre-test involves no calculation.

As a way to compare the performance of the experimental group and the control group, we assign the three levels 0, × and 1 the values 0, 0.5 and 1.0, and normalize to 1 the total score of pre-test and the total score of each question of the post-test.

For both pre-test and post-test, 5% of the scripts are randomly selected for round-table standardisation among all the research team members. Upon marking half of the scripts, another 5% are randomly selected for moderation among all team members. To ensure consistency throughout the marking, reference notes are also jotted down for scores given for certain types of answers. For example:

> Marker's notes: If student explains correctly mathematically, e.g. by the equation $V_s = (h/e)f - (\varphi/e)$, when the work function of the metal decreases, then the stopping voltage would increase, he will be given Level × for both Concepts 5.1 and 5.2 because the student have not demonstrated that they understand them.

Research Findings

Pre-test Analysis. The entire experimental group size is 152 and that the control group size is 181. The percentages of students who obtained Level 0, Level × and Level 1, of both groups are very similar and thus their data are combined in Figure 1 below.

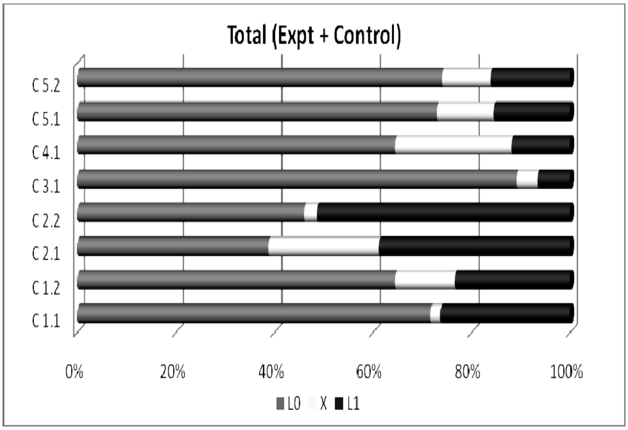

Figure 1. Percentage of students who obtained levels 0, × and 1 in the pre-test

As can be seen from Figure 1, the highest percentage of student (~90%) do not show an understanding of Concept 3.1 which is assessed by Question 3: "Do *all of the electrons*, *some of the electrons*, or *none of the electrons* emitted from electrode B reach electrode A? Explain." This may be due to a combination of factors. Students may not realise that photo-electrons are emitted from the electrode in all directions. They may have difficulty with the structure of the question – that it is talking about electrons which have already been emitted, and if so, perhaps the question may be modified to "Among those electrons that have been emitted from plate B, do all, some, or none reach plate A? Explain."

Students also fair poorly on Concepts 1.1, 5.1 and 5.2, with about 73% of the students getting Level 0. For question 5, more students find it difficult to express their understanding qualitatively, that is, about 10% of students obtained Level × as compared to 2% for Concept 1.1. This is expected as Question 5 is more demanding in terms of the conceptual understanding of photoelectric effect. It is somewhat surprising that only about 50% of the students got Concept 2.2 right since it is a well-known fact that is covered in Year 8.

Students have difficulty explaining Concepts 2.1 and 4.1 clearly as close to one-quarter of them obtained Level × for these concepts. This may be due to the strict marking scheme as necessary to reflect conceptual understanding. For example, in explaining why *none of the electrons* emitted from one electrode reaches the other electrode, if the student states that this is because the electrons are *repelled away* from the other electrode, the answer is classified under indeterminate (Level ×), the reason being that electrons can experience repulsion and yet have enough energy to overcome it to reach the other electrode.

As an additional check that the experimental and control groups are comparable in ability before the intervention, we assign the three levels 0, × and 1 the values 0, 0.5 and 1.0, and normalize to 1 the total score of pre-test. The resulting pre-test scores of the two groups in each school and the corresponding *p*-value from the *t*-Test are shown in Table 1. It is seen when the four JCs are considered as a whole that the difference in scores between the two groups are not significant (p=0.230). Thus, this result is consistent with the claim made just before Figure 1 and it is safe to consider the 2 groups comparable in ability before the intervention, when each group is considered as a *whole*. Note that if considered individually, the odd-man out is JC D, with a significant level of p=0.045, meaning that the experimental group in JC D has a higher ability than the control group.

Table 1. *t*-Test comparison between control and experimental groups on pre-test

JC	Pre-test Mean Score		
	Expt.	Ctrl.	*p*-value
A	0.28	0.24	0.314
B	0.36	0.32	0.606
C	0.39	0.44	0.346
D	0.25	0.11	0.045
All	0.33	0.29	0.230

Post-test Analysis. The entire experimental group size is 136 and the control group size is 137. The performances on the post-test of the experimental group and the control group for each JC are summarized in Table 2.

Table 2. *t*-Test comparison between control and experimental groups on post-test

JC	Post-test Mean Score								
	Q1			Q2			Combined Q1 & Q2		
	Exp.	Ctrl.	**p-value**	Exp.	Ctrl.	**p-value**	Exp.	Ctrl.	**p-value**
A	0.42	0.27	**0.003**	0.39	0.31	**0.084**	0.40	0.30	**0.009**
B	0.62	0.48	**0.023**	0.54	0.29	**0.000**	0.57	0.36	**0.000**
C	0.68	0.59	**0.088**	0.52	0.43	**0.099**	0.58	0.49	**0.060**
D	0.52	0.29	**0.000**	0.43	0.36	**0.120**	0.46	0.33	**0.003**
ALL	0.56	0.41	**0.000**	0.47	0.35	**0.000**	0.50	0.37	**0.000**

When the four JCs are considered as a whole, it is seen that the difference in scores between the experimental and control groups are significant (p=0.000) for Q1, Q2, and Q1 and Q2 combined. The fact that the difference in scores between the two groups is significant for Q1 implies that the intervention is effective in bringing about greater conceptual understanding of the photoelectric effect. This in itself may be expected because the adapted UW tutorial materials emphasize more on the conceptual knowledge. However, the fact that the experimental group outperformed the control group in Q2 shows that improved conceptual understanding of physics improves students' performance in A-Level exam type questions which have a strong emphasis on the quantitative aspects of physics.

If each JC is considered individually, and if each question is considered separately, the situation is more varied. For example, the differences in scores between the experimental and control groups for JC C are insignificant at p=0.088 and 0.099 for Q1 and Q2 respectively but nearly significant at p=0.060 when the questions are combined. Also the case of JC D must be reconsidered since the two groups in JC D have different ability before intervention. These results will be analysed and discussed in more detail in future.

Remarks. For question 1b(i), most of the students who obtained Level 1 for at least one of the two concepts, explained that the number of photons increases, hence the number of electrons increases. Though they are given Level 1, a more accurate answer should involve the rate at which the photons or electrons are released and not merely the number.

For question 1c(i), some students made used of the formula $eV_s = K.E._{max}$ to explain why stopping voltage increases when $K.E._{max}$ increases. We feel that such an approach, while giving the correct answer, involves mainly rote memory and does not reveal the necessary conceptual understandings. There are also a significant proportion of students who simply state that stopping voltage increases when K.E. increases, without any explanation. This is probably because they do not feel the necessity to explain since it is often quoted and remembered as a fact. For questions 1c(ii) and 2c, we find that students are often confused by the units eV and J, applying them incorrectly.

Limitations of analysis

There are various factors that can affect our comparative analysis and it is difficult to clearly determine which factor has bigger influence on the results. As such we do not aim to make any definite conclusions but rather, while highlighting possible relationships, we also raise the limitations of our analysis. They are as follows.

a) It was our intention to return marked homework back to the students before they take the post-test. However, as participating teachers have to keep to their schedule of the JC tutorials, while the inquiry-based homework was distributed, it was not evaluated and returned to the students before the post-test.
b) The experimental groups have received more support in terms of teaching manpower. While the control group has just one class teacher for the tutorial, the experimental group has several researchers as facilitators in addition to the class teacher.
c) Gross nature of marking scheme that does not differentiate number of conceptual mistakes. For example, a student who just wrote the complete and correct formula is given Level ×, while a student who substituted in values into

the formula but contains error in the substitution e.g. use of inconsistent units of joules and eV, also receives Level ×. Perhaps, a more differentiated marking scheme can be explored for a more in-depth analysis of students' conceptual understanding.

Conclusions

The University of Washington Physics Education Group (PEG) photoelectric effect curriculum materials found in '*Tutorials in Introductory Physics*' are adapted by the authors for use in Singapore JC with some appropriate modifications to implement inquiry-based tutorials in the junior colleges. Despite the limitations, the preliminary data and analysis presented here show that the modified materials, when delivered by the inquiry approach, are potentially effective instructional materials. Replacing traditional teaching materials and methods, our inquiry-based materials and teaching approach not only enhance students' conceptual understanding, but also improve their performance in A-Level exam type questions.

From our enriching experience with our research partners, we note several key points with regards to the facilitation of inquiry-based learning and teaching:

1. It is crucial that in the inquiry approach the conceptual understandings are derived from within the student. This would mean that for the facilitator, it is under little circumstances that she will reveal the answers to the students. Instead, the facilitator constantly poses guiding questions to enable the students to make their own justifications. This is important because if the answers are revealed in a rather straightforward manner, not only are the teaching moments lost but this seemingly convenient way of information delivery can also become habitual.

2. Many teachers note that learning by inquiry is a time consuming process. To overcome this difficulty will require much resourcefulness and careful planning. For example, some teachers who carried out learning by inquiry have made use of students as facilitators. We believe that teachers need not incorporate such a teaching style for all topics. A teacher may begin adopting learning by inquiry for one or two of the topics or even sub-topics, to expose the students to the critical thinking procedures and from the group interactions, understand what it really means to do in-depth thinking. Returning to the conventional teaching methods for the other topics later does not mean the loss of the critical thinking skills. In fact, it can serve as an opportunity where students execute the critical thinking skills on their own or in groups.

3. The terms 'learning by inquiry' are usually associated with a kind of teaching and learning process in the schooling environment. But it is really about how we continually acquire knowledge, make realisations, cultivate and improve ourselves at each and every moment throughout our entire lives. Learning by inquiry is a process of self-reflection. However, at the foundation of this learning process, it requires a set of thinking principles that the person must be

clear of himself. It is with these principles that he can then critically assess and question his surroundings and phenomenon. We believe that directly telling and describing to the students what inquiry is and how to learn something by inquiry and expecting them to do so, is not effective. It is necessary to let the students experience learning by inquiry in the classrooms in order to enable them to acquire these thinking principles.

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On choosing skills of high school students at problem solving strategies

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Abstract

The main goal of this study is to find out how "the formed teaching situation" affects two 11th grade students to choose appropriate problem solving strategies. The research was planned as one grouped pre-test and post-test. To do this, the researchers developed a ten-week long formed teaching situation and the data was collected through the pre-test and post-test, which include specific problems. Besides, interviews were organized through the research process. The data analyzed with comparing the problem solutions of the students in the pre-test and the post test in terms of the skills to choose appropriate problem solving strategies. At the end of the analysis, we observed that the formed teaching situation has a positive effect on choosing an appropriate strategy and the participants were aware of the existence of several different problem solving strategies and they tended to use the strategies they have learnt.

Introduction

Nowadays, there is a strong tendency in education to incorporate problem solving as a significant component of the curriculum. The need for learners to become successful problem solvers has become a dominant theme in many international standards (AAAS, 1993; NCSS, 1997; NCTE, 1996; NCTM, 1989, 1991). In this paper we will focus on to find out how "the formed teaching situation" affects students to choose appropriate problem solving strategies.

Problem Solving. As it is seen, there are lots of standards, programs and researches which emphasize significance of problem solving. As such, it is an essential goal of all mathematics instructions and an integral part of all mathematical activities.

When examining some of them deeply, for example, a committee report on the California Assessment Program(1980) *"recommended that time and effort be redirected from drill and practice on computation to the development of problem solving strategies ….[and] that problem solving analysis and modeling should be used as an umbrella in the general math curriculum* " (p.210). And also in the Turkey Ministry of Education (MEB,2005) underline that:

> *"Problem solving is not a topic per se, but a process. The aim is the learning and using the problem solving skills through merging this process into the whole mathematics programme. Besides, the students should learn the value the problem solving process and different types of solving*

methods. In the problem solving process, the method to solve the problem should be valued more than the answer to the problem. The way student solves the problem, which data contributed to the solution of the problem, how the problem was represented (table, figure, embodiment etc.) and how the chosen strategy and representation type facilitated the solving of the problem, should be emphasized. The methods of problem solving shouldn't be given to the student directly but a suitable environment should be maintained to enable students form their own methods of solutions."

There will naturally be a consensus on the definition of problem solving, considering the importance of teaching problem solving in school mathematics. If the problem is defined by Piaget's term of "disequilibrium" on the center, it can be described as a situation or an object which disrupts an individual's present balance thus making him uncomfortable (Baki& Bell, 1997). According to John Dewey "problem" is almost everything that confuses human mind, challenges it and ultimately obscures faith.

"A problem occurs when you are confronted with a given situation-let's call that the given state- and you want another situation- let's call that the goal state- but there is no obvious way of accomplishing your goal. For example, suppose I asked you to find the volume of a frustrum of a right pyramid and gave you values for the sides of the two bases and the height. If you did not know a formula for volumes of frustrums, this would be a problem for you" (Polya, 1965). Providing that you did not have a memorized algorithm, this would make a problem for you. Lastly, suppose you were asked to find the sum of 6+8=___ but you did not have that fact memorized (Carpenter, 1980). These problems correspond to the definition of a problem- wanting to get from the given state to the goal state but lacking a direct route to the goal. Problem solving refers to the process of moving from the given state to the goal state of a problem. Mayer, (1983) collected together thinking or problem solving as a series of mental operations that are directed toward some goal. Similarly, Hayes, (1981) described problem solving as "*finding an appropriate way to cross a gap*." Two major parts of problem solving are (i) representing the problem and (ii) searching for a means to solve the problem (Mayer, 1983).

Polya (1981) has given us a nice classification of problems from a pedagogical perspective:

1. *One rule under your note*-the type of problem to be solved by mechanical application of a rule that has just been presented or discussed.
2. *Application with some choice*- a problem that can be solved by application of a rule or procedure given earlier in class so that the solver has to use some judgment.
3. *Choice of combination*- a problem that requires the solver to combine two or more rules or examples given in class.
4. *Approaching research level*- a problem that also requires a novel combination of rules or examples but that has many ramifications and requires a high degree of independence and the use of plausible reasoning.

Polya argues that both the degree of difficulty and the educational value (with respect to teaching students to think) increase as one goes from type 1 to type 4. Most research has focused on problems of types 1 and 2, but increasing attention is being given by some researchers in mathematics education to type 3 and 4. Besides this, John Dewey is usually credited with having said that children "learn by doing," but as Papert (1975) notes, the appropriate dictum- which he credits to Dewey, Montessori, and Piaget- is that "children learn by doing and by thinking about what they do" (p.219).

Problem Solving Instruction. "*A teacher of mathematics has a great opportunity. If he fills his allotted time with drilling his students with routine operations he kills their interest, hampers their intellectual development, and misuses his opportunity. But if he challenges the curiosity of his students by setting them problems proportionate to their knowledge, and helps them to solve their problems with stimulating questions, he may give them a taste for, and some means of, independent thinking*." (Polya, 1971)

Until recently, Lester classified most problem- solving instruction research into four categories: (1) instruction to develop master thinking strategies (e.g., originality and creativity training); (2) instruction in the use of specific "tool skills" (e.g., making a table, organizing data, writing an equation); (3) instruction in the use of specific heuristics (e.g., looking for a pattern, working backward); and (4) instruction in the use of general heuristics (e.g., means-end analysis, planing). Sure enough, none of these four approaches has been shown to be clearly superior to the others; rather, good problem- solving instruction probably involves some combination of instruction in the use of both of these categories. On the other hand, experience in solving a wide variety of problems over an extended period of time seems to be essential (Lester, 1980).

In his book "Mathematical Discovery", Polya (1965) makes a similar plea:

> *"In mathematics, know-how is much more important than mere possession of information. ....What is know-how in mathematics? The ability to solve problems-not merely routine problems but problems requiring some degree of independence, judgment, originality, creativity. Therefore, the first and foremost duty of the high school in teaching mathematics is to emphasize methodological work in problem solving."(p.xii)*

Researchers such as Carpenter and Lester have noted that many children approach problems in an impulsive way, attending primarily to surface features of the problem statement in order to decide what action to take. The child's goal is to do something-anything. Much school instruction, rather than encouraging children to take a problem seriously and reflect on what the problem statement says, seems to reinforce their impulsivity. Because the children see the problem as a school task rather than as an intellectual challenge that is worth accepting, they grab at answers so as to escape from the task as fast as possible. Successful problem solving instruction often needs to transform the terms of the school situation that previous instruction has negotiated and reinforced. (Killpatrick, 1985)

As a consequence, the main goal of this study is to find out how "the formed teaching situation" affects students to choose appropriate problem solving strategies.

Metholodology

The research was conducted in Turkey with two 11th grade Anatolian Teacher Training High School students in 2007-2008 Education Years. The researcher interviewed with the administrator teachers regarding the conduction of such a research. Following the approval of the managers and teachers in the school, necessary authorization was taken. The researcher briefly introduced his study in one of the suitable 11th grade classrooms, upon receiving the opinions of mathematics teachers, and specified volunteer students, which would like to take part in the study. The reason why the researcher picked this school is its easiness to get to. To test the problem of the research, students' skills to choose the appropriate problem solving strategies were examined through solutions in pre-test and post-test -which include specific problems that can be solved using different kinds of problem solving strategies- along with students' answers. Besides, students were given nick names during the analysis of the data.

Design of the Study. The research was designed as "one grouped pre-test and post-test" (Patton, 2002). The aim for that is to present the efficiency of instruction conditions. The data, prepared to manifest the effects of instruction conditions, were collected through a measurement instrument (pre-test and post-test). This instrument consists of two parts. The first one, pre-test (post-test) A, is comprised of 10 problems, which can be solved through different strategies. The second one pre-test (post-test) B, contains 2 problems, which should be solved through more than one method using different strategies for each problem. Besides, interviews were held by using interview form, to reveal the students' views during the formed teaching situation (Yıldırım & Şimşek, 2006).

Treatment of Teaching Situation. In the forming process of teaching situation, related internet sources and problem solving strategies in various sources were examined and a teaching situation was formed with the help of ideas derived from the examinations mentioned. A total of 14 problem solving strategies, frequently referred to in sources, were discovered as a result of the researches (working backwards, finding pattern, adopting a different point of view, solving a simpler analogous problem, extreme cases, make drawing, intelligent guessing and testing, accounting all possibilities, organizing data, logical reasoning, using model, acting it out, classical solving, using prior-knowledge). Despite the encounter of 14 problem solving strategies when scanning the literature, only 10 of them were introduced to the students during the experiment, these are working backwards, finding pattern, adopting a different point of view, solving a simpler analogous problem, extreme cases, make drawing, intelligent guessing and testing, accounting all possibilities, organizing data, logical reasoning. The strategies of "classical method" and "using prior-knowledge" were considered to be familiar to the students beforehand, therefore weren't presented to the students during the experiment. "Using model" and "acting it out" strategies were among the ones which are not taught to the students.

During the instruction conditions, 10 lessons, each one lasting 40 minutes, were designed for the instruction of 10 strategies mentioned above. In each lesson, the students were given a total of 5 problems, of them 3 during the lessons and 2 as assignments, which can be solved with the help of the strategy that is desired to be instructed. The researcher, by means of outline syllabus, prepared power point slides to instruct each strategy thereby adding everyday life practices. In the instruction we were solving problems with the students, using their ideas. The idea here is for the class to solve problems together, with the teacher serving as "moderator", orchestrator of ideas. The teacher was not to generate solutions, but rather to help the students make the best of resources they have (Schoenfeld, 1983).

In which days or at which hours the courses would be carried out, were planned by taking into consideration of each participant's available time intervals, with the exception of students' school programs. School's seminar hall was used as a location for the instruction. The seminar hall was preferred due to its possessions such as projector and white board and its feasibility to allow a comfortable communication environment with the students.

Findings

At the analysis of the data, the problem solutions of the students in the pre-test, the post test and the homework have been examined in point of the skills of being able to choose the appropriate strategy. The appropriate strategies they have chosen during the problem solving have been examined by comparing the pre-test and the post test. We now want to give the data which belong to Seval's to discuss this research. The strategies that Seval chose in pre-test and post-test problems can be seen in the table below:

Table 1. Strategies That Seval Choosed In Pre-Test And Post-Test Problems

Prob.	**Pre-test A**	Appropriate	Inappropriate	**Post-test A**	Appropriate	Inappropriate
1	Classical Method	√		Working Backwards	√	
2	No answered	√		Finding Pattern	√	
3	Classical Method	√		Classical Method	√	
4	No answered	√		Solving a Simpler Analogous Problem	√	
5	Classical Method		√	Intelligent Guessing and Testing	√	
6	Make Drawing	√		Make Drawing	√	
7	Solving a Simpler Analogous Problem	√		Solving a Simpler Analogous Problem	√	
8	Accounting All Possibilities	√		Accounting All Possibilities	√	
9	Organizing Data	√		Organizing Data	√	
10	Classical Method	√		Logical Reasoning	√	
Prob.	**Pre-test B**			**Post-test B**		
1	Using prior-knowledge	√		Using prior-knowledge	√	
				Accounting All Possibilities	√	
				Adopting a Different Point of View	√	
2	Accounting All Possibilities	√		Accounting All Possibilities	√	

Seval voided 2 problems (2,4) in pre-test A, however it can be seen that she can pick the strategies of *pattern finding* or *solving a simpler analogous problem*, different from the strategies she chose in pre-test after the teaching situation formed. A sample for "finding pattern" strategy which Seval used in solving 2nd problem in post-test A was given Figure-1.

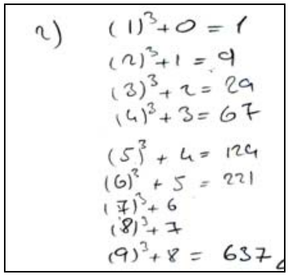

Figure 1. An Example for Finding Pattern Strategy Which Seval Chose in Solving 2nd Problem in Post-Test A

Seval didn't use finding pattern strategy in solving pre-test problems; however she did use it in post-test problems. She explained this as the following:

> "*Actually I am not a kind of person who likes to solve problems, but it is much more enjoyable now, I find it amusing. I haven't understood finding pattern for all my life. Yet I don't think I would be able to find more of them. Still I think many things occurred. I managed to solve pattern problems which I couldn't before.*"

While choosing classical method in 2nd problem of pre-test A, Seval preferred working backwards and logical reasoning strategies in post-test A. Figure-2 depicts an example of classical method, the inappropriate strategy Seval chose in solving 5th problem in pre-test A.

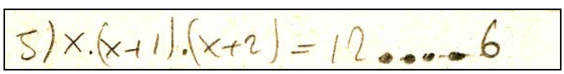

Figure 2. An Example for the Inappropriate Classical Strategy Which Seval Used In Solving 5th Problem in Pre-Test A

An example for the intelligence guessing and testing as appropriate strategy in 5th problem of post-test A, can be seen below:

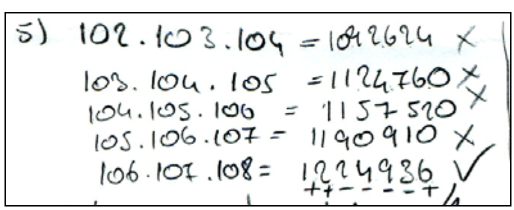

Figure 3. An Example for the Appropriate Strategy of Intelligent Guessing and Testing Which Seval Used In Solving 5th Problem of Post-Test A

Seval solved the 1st problem in post-test B with a single strategy, which she was asked to do by using different strategies prior to the teaching situation. However, following the teaching situation, she realized that there are different strategies to apply a problem. Thus, she picked 3 strategies (*using prior-*

knowledge, accounting *all possibilities, adopting a different point of view)* which are given below as Figure-4.

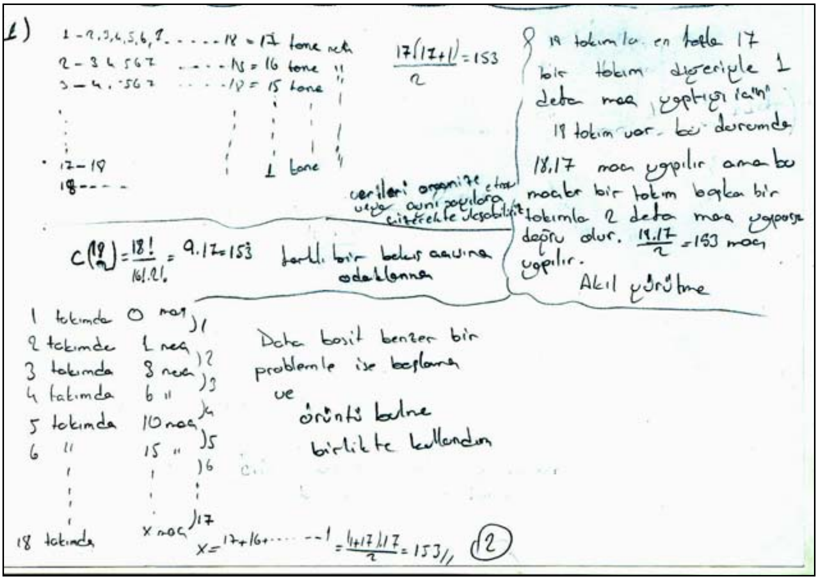

Figure 4. An Example for the Solution Seval Reached In 1st Problem of the Post-Test B, By Applying 3 Different Strategies (*Using Prior-Knowledge*, *Accounting All Possibilities*, *Adopting a Different Point of View)*

Despite the fact that she was asked to solve 2nd problem in pre-test B and post-test B with different strategies, Seval solved the problem by applying a single strategy (*accounting all possibilities)*.

When students' solutions in pre-test and post-test are compared, we can say that teaching situation formed has a positive impact on choosing the appropriate strategies. It is concluded from the solutions and interviews that, prior to the teaching situation, the students didn't take into consideration of the appropriateness of the strategy they chose in pre-test and leaned towards the classical strategy or the strategies they are familiar with. However after implementation of the teaching situation, it is observed that the students can choose the appropriate strategies among the different strategies they have learned. Seval has this assessment regarding to this teaching situation:

> *"In the beginning I used to construct equations. I mean, I generally solve many problems by forming equations. As a matter of fact, I realized that I constructed equations in a 50 % ratio. So it is way it is."*

Another participant who named Selçuk explained his views as follows:

> *"As we continued to learn strategies each day, we perceived that every problem can be solved through different ways; that each problem doesn't have a single solution but more than one. In the end we learned to solve the problems through more than one way."*

Conclusion

As is known, there are lots of standards and programs which emphasize the significance of problem solving. As such, it is an essential goal of all mathematics instructions and an integral part of all mathematical activities. Since the instruction of problem solving is crucial, in this study we pointed out the instruction of problem solving strategies (AAAS, 1993; NCSS, 1997; NCTE, 1996; NCTM, 1989, 1991; MEB, 2005). In this sense, the main goal of our study is to find out how "the formed teaching situation" affects students to choose appropriate problem solving strategies. The appropriate strategies they have chosen during the problem solving examined by comparing the pre-test and the post test. Interviews were conducted with students to bring out their views on the teaching situation.

At the end of the analysis, we concluded that the formed teaching situation has a positive effect on choosing an appropriate strategy and the participants were aware of the existence of several different problem solving strategies and they tended to use the strategies they have learnt. We believe that this improvement is not enough for become a good problem solver. But also we think that 10 lessons is very short time to improve this kind of skills and therefore these kinds of activities should be carried out during the application of whole curriculum (Lester, 1980). On the other hand, experience in solving a wide variety of problems over an extended period of time seems to be essential (Lester, 1980).

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Coteaching as a tool for undergraduate mathematics education

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Abstract

This article presents results of a study that arose from a teacher's professional development proposal based on the sharing of the position of teacher, which is called coteaching (Roth and Tobin 2002). This proposal was adopted by a group of Mathematics undergraduates, their professor, a Math seventh grade teacher and her students. Classes were videotaped and analysed afterwards by all participants. Results show that: (a) with the help of the veteran teachers, the undergraduates found ways of exploring Math knowledge with which they were not familiar before; (b) by dialoguing with the teachers, students could freely expose their ideas and confront them to conventional Math knowledge; (c) by engaging in critical debate teachers could get students' perspective about the analyzed episode; (d) the theoretical-methodological framework adopted was a fundamental tool that allowed a clearer understanding of the whole process.

Introduction

The aim of this article is to propose a reflection about the initial teaching qualification of mathematics' undergraduate students at Universidade Federal de Minas Gerais, Brazil, using data gathered at Teaching Practice classes. The study involved four undergraduate students, their Teaching Practice Professor (the second author of this article), seventh-grade students and their Math teacher.

Traditionally, Mathematics Teaching Practice classes have followed a model in which the undergraduates do an internship in a school where they observe classes and then engage in discussions with their college professor, who provides theoretical support for reflection. Such model has been adopted not only in Brazil but also in other countries, as the studies of Roth and Tobin (2002) attest. Defying this traditional model, the undergraduate students accepted the challenge of not only observing classes but also sharing the teaching with both the school teacher and their college professor. Such approach has been called coteaching, which designates the situation in which teachers share classes and, as a follow up, reflect and analyze the events that took place during the class.

In this article, we have described and analyzed experiences based on coteaching. This approach allowed a direct assessment of concepts and presumptions established by the undergraduates, enabling the birth of a specific type of knowledge which is only attainable through practice. The analysis of the records revealed meaningful unexpected and irreversible learning processes which cannot be reproduced at a different moment or in a different context. In order to clearly expose our arguments, we will first present the concept of coteaching based on recent works (Roth 2002; Roth and Tobin 2004 and Gallo-Fox et al. 2006) and contrast it with other processes of professional development traditionally used in Teaching Practice. Then, we will describe and analyze the experiment we carried on.

Coteaching: a fecund approach in teacher professional development

Coteaching outstands among the teacher development approaches that share a dialect perspective because it focuses on the role of practice in the qualification of teachers, combined with the building of educational environments that are rich in learning possibilities. Soares (2004), in a comprehensive study about Roth's researches (2002), evidences the latter's efforts to reveal the concrete conditions that surround the work of a teacher. In order to do so, Roth uses an approach whose core is the dialect relationship between praxis and praxeology, that is, the study of conditions which occur in chronological and in phenomenological time.

Phenomenological time is the irreversible time of immediate personal experience. It is the prevailing time of the classroom, where everything takes place in a continuum and decisions are taken with minimum time for reflection. In this process, a specific type knowledge is built through action. This knowledge results in the creation of tools which help teachers in their daily practice and are available to those who engage in real activities. On the other hand, chronological time is the one in which reality is represented, or, better said, re-presented as an interpretation of what has taken place in the past.

These time dimensions do not exist in isolation. However, the acknowledgement of their existence allows us to express ourselves more clearly about different time experiences. In teaching practice, when we plan a class, our attention is focused on the chronological dimension of time because we are able to think about past experiences and project events to the future. In contrast, while teaching lessons, we are immersed in the phenomenological dimension of time.

Nevertheless, we believe that certain forms of knowledge acquired through practical experience cannot be passed forward in the form of instructions or directions because they develop while teachers face real working conditions. These forms of knowledge are what differentiate experienced teachers from new, inexperienced ones.

Such perspective has been largely explored by current researchers (Roth, Tobin, 2004). The practice of classroom sharing followed by reflection has been studied by these researchers, who call it “coteaching” and “cogenerative dialoguing”. This is a process in which two or more teachers take responsibility for the planning, executing and discussing the witnessed events. According to these authors, “coteaching” is based upon phenomenologic epistemology, which focuses on the fact that teachers learn together about teaching practice.

The concept of habitus, as developed by Bourdieu (1983), can contribute to our analysis. Based on the interpretations of Sewell (1992) and Roth (2002), we understand habitus as a matrix of perceptions that individuals create as they are exposed to the same environment for a long time. Beginning teachers act based on the perceptions with regard to their teacher that they have developed as students, which means they have not yet built the habitus of a teacher. Habitus develop in a dynamic manner in phenomenological time. This matrix of perceptions evolves as the individual, usually unconsciously, becomes able of anticipating the outcome of his or her actions in the immediate future. Only confrontation with reality in the performing of the job allows the habitus of a teacher to develop. Precisely because the habitus develops in the phenomenological dimension of time, and in a manner that is more or less unconscious, it strongly resists change. That helps us understand why it is much easier to change one's words than one's actions. Because it is our intention to access what happens in the phenomenological dimension, we chose a theoretical-methodological approach which can help us understand what the teacher learns about his or her profession while acting. Thus, our challenge as researchers becomes to verify what happens during the movement of habitus development.

Capturing movement is, however, a complex task because many circumstantial elements interfere in the work of a teacher. There are factors deriving from broader social conditions that tend to change slowly, such as the lifestyle of the families that compose the school community, which is linked to their social class. Other factors change faster. The meeting of the teacher with his or her students is influenced, for instance, by the emotional state of the people involved and such emotional state is dependent upon the circumstances that interfere with each person's daily life. As our research intends to achieve an understanding of the learning process of undergraduates and teachers during a shared experience, we are subject to all those factors.

Sewell (1992) has developed a procedure for understanding the impact of social actors' power of action in social structures. According to this author, we all have, to some degree, the ability to transform the structures we deal with through our power of action or agency. Transforming actions result from the tension between the existing conditions and the will to change them.

Throughout our investigation, we took the asymmetry between experienced and inexperienced teacher into account. That means that the ability to produce change, or, as pointed out by Sewell (1992), of using the agency with the purpose of producing changes in the environment is also differentiated. An inexperienced teacher tends to feel uncomfortable because he or she is unfamiliar with the environment or with the role he or she plays in the classroom as he or she changes from the position of a student to the one of a teacher. We may say, quoting Roth (2002), that the beginner has little room to maneuver because he or she has not had or has had little confrontation with his or her image of what it is like to be a teacher. However, this situation can be problematized. A beginner could be more able to produce changes than a veteran teacher because he or she does not have as much engagement to the rigid structure of the school.

Broadening the room to maneuver

The undergraduate students that take the course of Mathematics Teaching Practice have a compulsory internship in Elementary and Middle Schools. For a period of time, the four undergraduate students that take part in this research accompanied the Math teacher classes, monitoring the students, especially those that face difficulties in the subject. After becoming familiar with the environment, the undergraduates accepted the challenge of sharing the teaching of two geometry classes.

The episode we are about to describe took place during the second class. The Math teacher recalled briefly what had happened in the previous week and the class progressed under the coordination of the undergraduates. Katia, one of the undergraduates, occupied a central role, explaining the relative positions of a line and a circle. Katia had the intention of sticking to the principle agreed by the four undergraduates of not providing definite answers to the students, making them "construct" the concepts, responding their doubts with new questions.

The verb "construct" is between quotation marks because we noticed that the undergraduates strongly believed was the idea that students construct knowledge when, guided by the teachers' questions, they reach an answer that reproduces the concept that the teacher aims to transmit. However, the fidelity to the agreed principle brought Katia to a dilemma a short time after she had begun her first performance. In fact, she had few options to resort to, or, in other words, she had little room to maneuver, a characteristic trait of beginners.

In her next move, Katia intended to elicit the relative positions of a line and a circle from the students. In theory, there are three possible relative positions: the line may not meet the circle; it may meet the circle in two points; or it may meet the circle in one single point. Katia's challenge consisted of making students understand that those are the only existing possibilities without telling them what established knowledge in theoretical Mathematics is. In order to do so, she should pose a question that would make students think. The difficulty consisted in formulating an appropriate question which did not contain hints of the answers she was trying to elicit.

Episode1

1. Katia: So, now I'll give you a line… ((she draws a line segment and a circle on the board)). Let's imagine you have these in your hands. How could you position my line and my circle? You have a line… If you could actually hold the line and the circle…. I'd like you to tell me… ((changing the intonation to make a question)) in which ways can I position my line and my circle? Which are the possible positions relating to these… line and circle that I gave you… do you understand?
2. Student 1: No.
3. Katia: No? ((Smiling and looking at the Math teacher)) I want to arrange the two... combine these two things…. How could I put it? ((Silence))

The episode goes on with the tension between Katia's efforts to be clear and her determination not to provide the answer she would like to hear from the students. This tension led the undergraduates Gil and Kenia and the Math teacher to interfere, but practically all the attempts to clarify the task to the students without violating the agreed principle resulted in failure, that is, it as difficult for the undergraduates to make themselves understood by the students.

The clash between the undergraduate's proposal and the students understanding illustrates how the building of the teacher's room to maneuver progresses. Faced with the students' incomprehension, Katia did not have an array of ideas to help her make the students understand what was being asked of them. Gil found the solution to the problem by drawing a secant line to the circle on the board. Later, Kenia said that she felt Gil had betrayed the group at that moment. But from Gil's point of view that was the only way to make it clear to the students what they were supposed to do. Angelo agreed with him pointing out that, from the teachers' perspective, all the attempts to communicate with the students had failed and the class had gone to a "stalemate". This episode illustrates how a negative situation can contribute to broadening the teacher's room to maneuver. In this case, the group learned that it is not always possible to pose a question to the students avoiding any hint of the answer, that is, it was necessary to adjust the original plan. Let's observe the outcome of the episode.

When reality and imagination come face to face

Laura, one of the students, expressed the wish to go to the board and present a suggestion. She used Gil's drawing and added a line that could be interpreted by any Math teacher as a tangent line. Although that seemed to be her intent, the Teaching Practice professor posed her a question: "What would you call your example? What is going on?".

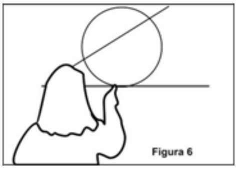

Figure 1. Laura drew a tangent line to the circle

Laura answered in a very low voice, talking incomprehensibly, and running her index finger over the space where the circle and the line met in her drawing (FIGURE 1). Gil, dismissing the answer and noticing the movement of another student, asked if anyone had said anything. Immediately, Laura turned and faced the class. The other student, who had stood up, said that *that* (Laura's drawing) was a tangent. The Math teacher then invited her to make a drawing showing the position she was suggesting because, according to her, in Laura's drawing the line appears to meet the circle in two points. The episode proceeded with the following dialogue:

Episode 2

1. Math teacher: What's your intention? First thing.
2. Laura: Not to cut the... ((Laura starts erasing the line she had drawn and, through gestures, indicates a line intercepting a circle, showing that she does not intend to make a secant line)).
3. Math teacher: Not to cut in two points?
4. Laura: Yes.
5. Math teacher: Let's see... ((Laura starts making a second drawing which depicts a line precisely in the same position as in the first drawing)).
6. Kenia: Cut in how many points?

7. Laura: Something other than two points. ((Smiles)).
8. Kenia: Is it possible not to meet in two points?
9. Laura: No... ((whispers)) Only if it was more...
10. Math teacher: A circle and a line... Can the line meet the circle in more than two points?
11. Student 1: No. ((Speaks low))
12. Math teacher: Do you think it can't? ((Silence. Students do not answer)).
13. Teaching Practice Prof.: ((coming on the scene, he approaches the board and points to Laura's drawing while he speaks)): Only if it is like she drew here, look. You place it at the very edge and then you have a bunch of points of the circle meeting the line. ((Kenia and the Math teacher smile)).
14. Math teacher: But Laura's intention was to draw... meeting in how many points, Laura? ((Teaching Practice Teacher gradually withdraws from the scene)).
15. Laura: No... to meet... in this part... ((she runs her index finger over the region of the drawing where the line and the circle touch)).
16. Teaching Practice Prof.: A bunch (of points).
17. Laura: Yes... a bunch... Someway that was not two points ((she gestures, indicating the secant already drawn to reinforce the idea that she meant to draw the line in a different position)).
18. Kenia ((looking at Laura and talking to her)): Only that there's no way of meeting in many points. Here in the picture it is not exactly the way we wanted it ((she runs her finger over the same region that Laura had shown previously – the region where the line and the circle meet)).
19. Katia: Angelo talked about precision, do you remember?
20. Kenia: Draw a very thin circle to see what you think. Draw it. ((Laura draws another line very close to the one she had drawn before – FIGURE 2))

Figure 2. Laura makes a second attempt

21. Kenia: Look, it is not meeting. You meant it not meet.
22. Teaching Practice Prof. ((interrupting Kenia)): So that is a third position, look. Let's see what we have found out: there's the line which touches in two points; there's the line that touches in many points ((he draws another line similar to Laura's)), we don't even know how many; and there's a line that does not touch… those are different things (...) ((Smiling and addressing the undergraduates)) I'd like to see how you are going to find the way out of this situation.

23. Kenia: Why do we have the impression, guys, that the line touches (the circle) in many points? ((Laura hands the chalk to the Math teacher and walks back to her desk)).
24. Teaching Practice Prof. ((smiling)): It's because it does touch (the circle in many points). You can see it touches, can't you? ((Everybody smiles; Gil withdraws from the scene. Only Kenia and the Math teacher remain)).

The good humored intervention of the Teaching Practice Professor marked a turning point in the direction of the class. For Kenia, the correct attitude to pursue concerning Laura's drawing, and which she tried to implement, was to correct the student's suggestion and convince her, that, if her drawing was more precise, the line would be tangent to the circle (turn 22). Nevertheless, the Teaching Practice Professor interrupted this process (turn 24) and highlighted what the drawing revealed. Kenia still attempted to regain control of the situation (turn 25), but the answer the Teaching Practice Professor provided to her question made clear that he would not allow her to correct the answer supplied by the student (turn 26). At this moment, he was sure of what he intended and his unyielding attitude, combined to the fact that he was a more experienced teacher than the undergraduates, compelled the group of teachers to confront a situation that had not been foreseen in the original plan. A tension had been produced, creating opportunities for all to learn.

By proposing a new situation, Laura triggered the *agency* (Sewell, 1992), that is, the ability of using the available resources in a creative manner. She knew the idea of tangency, but she wanted to produce something new – a "tangent" that intercepted the circle in two or more points. Laura explained this in her own words during the assessment of the episode: "I always try to create controversy… that is always my intention". At the moment she decided to challenge what she considered to be set knowledge, Laura had in mind past experiences as well as the possibilities that see could predict for the immediate future given certain conditions of the environment. She believed the environment would be welcoming, once she was used to the Math teacher, who stimulated students to freely express their ideas. With her drawing, however, she could not convince the others (classmates and teachers) that such a thing as a line that was tangent to a circle in two points existed. Faced with an impasse and pressured by those who attempted to correct her drawing, she did not know how to defend her point. However, she did not give in, that is, she did not admit the possibility of the line touching the circle in only one point. As she later explained, to her, a point had arbitrary dimensions: "(…) one point may be two, because we don't know the size of a point. And that was not clear to me".

The Teaching Practice professor, on the other hand, did not know Laura's intentions, but he realized that she wished to produce something new and that she resisted the idea of simply accepting what Kenia was trying to teach her. He then used his agency in order to prevent her idea from being somehow distorted and supplanted by what would be considered correct by conventional school Mathematics. His action created a new possibility which had not yet been envisaged by the undergraduates.

The undergraduates were perplexed with the challenge that had been set. Angelo said that: “First we laughed, and then we saw that the students were supporting the idea. At that moment we realized that the thing was complicated”. Kenia explained her position on the matter on those terms: “At the time, I thought about withdrawing from the scene too. Do you know how I felt? (I thought:) he (the Teaching Practice Professor) created the mess, now, he should sort it out. Because everyone is helping each other here, forcing the kids to follow a path… he goes and deviates it even more, now, he should take responsibility”.

Lessons the students learned and taught

We conducted this study to gain a better understand about the fecundity of creating an environment where veteran teachers share their classes with beginners. This kind of environment allows the direct confrontation of all participants and thus enables the construction of a knowledge that can only take place through practice in concrete situations. We have also commented on the difficulties of perceiving the learning process of a group that is still in movement. A possibility is to conceive learning as the participation of the subjects involved in concrete activities (Goulart, 2005). Having said that, we are left with the task of examining how veteran and beginning teachers were able to create an atmosphere that was apt to promote a greater understanding of what was happening at that moment. From the undergraduates’ perspective, beyond the concept of tangent, new knowledge was about to be engendered.

Assessing the episode, the Teaching Practice Teacher told the group of teachers what he had in mind, even though he had acted quickly without much time to think, moved by a perception forged by his teaching experience, that is, moved by an acquired *habitus.* His first motive was to force the group to accept Laura’s idea with more precision. The students’ attitude suggested that her thoughts were restricted by the drawing, by the empiric data. And it is not possible to draw a tangent; one can only imagine it. Laura’s drawing made it clear that there is a distance between what the students could perceive empirically and what the teachers demanded that they comprehend. In order to understand the idea of a tangent it is necessary to conceive an imaginary situation in which the line and the circle are infinitely thin. With her attitude, Laura brought up the possibility of discussing the contrast between empirical reality and the imagination inherent to theorization.

The Teaching Practice professor decided, then, to tell the students that what their classmate’s drawing suggested was acceptable: there, many points were common to the line and the circle. He further explained that, while the students were working with reality (empirical), the teachers were using the “imagination of the Mathematicians”. In the assessment meeting, which took place afterwards, the undergraduates came to the conclusion that the episode had been enriching in terms of learning for them, but they were still not aware of what the students had learned.

The group of teachers then decided to hold a meeting with the students. While the class was watching the video, Laura affirmed she was aware of what the teacher’s expected because she was familiar with the theoretical definition of a tangent. She stated: “The fact that the tangent touches (the circle) in a single point is not a simple one. It is simple to say that". At that moment, she was affirming that, from her point of view, repeating a concept using the same words as the teacher is a simple mental task. However, it is difficult to deeply comprehend the meaning of the theory. While teaching, it is easy for the teacher to fall into this "trap". If students are able to memorize the concept the teacher is teaching the teacher tends to interpret that ability as acquisition of knowledge. Laura's declaration, however, challenged the undergraduates' idea that they would make students construct knowledge through guided dialogues. Laura showed that students may well come up with the answers the teacher wants to hear without actually constructing the concept.

And how did Laura become aware of that? From our viewpoint, it was not solely through reflection, but through action and reflection. Proposing her idea, being questioned, drawing, observing her drawing, reflecting, explaining, she saw her ideas developing. Her awareness was born from the struggle and the tensions inherent to the activity. However, her learning process took place alongside that of the other participants, that is, the production of knowledge happened in the context of an unforeseen collective movement in which everyone acquired new knowledge. To the teachers the revelation that Laura was aware of the definition of a tangent came as a surprise.

And how did the undergraduates broaden their perceptions about the student's learning? The change in the direction of the class provoked by the veteran teacher was crucial. Acting, he challenged the undergraduates' original idea, according to which the construction of concepts happens through conducted dialogues. In our example, the revelation that the student already knew the correct answer confirmed the deceitful nature of the pact they had established during the planning of the classes.

The veteran teacher's intervention showed that it was possible to go beyond the classic Mathematical concept and explore unknown paths. The fact that he accepted and faced the challenge proposed by the student provoked the authentic investigation of new knowledge that was emerging. That new knowledge referred to the fact that there was an insurmountable distance between the concrete reality of life and the theory built by the scientists. Thus, the role of imagination and the fecundity of a real investigation in the classroom.

Conclusion: coteaching integrated with professional development

The activity created the opportunity for the undergraduates to widen their room to maneuver. The sharing of classes enabled the veteran teachers to explore acting possibilities that had remained unknown until that moment. We recognize, however, that this experience was a starting point in the professional development of the beginners. The teaching of a class more open to dialoguing, in which students ideas have further purpose than simply to confirm what the teacher wants to teach, is dependent upon a prolonged contact with similar situations.

On the other hand, even though they believed in the richness of dialoguing with the students, the veteran teachers only had a deeper perception of what had happened during the assessment discussions that took place after the class. From our perspective, the declarations of the students broadened everyone's knowledge in many ways, especially by demonstrating that a lot of time and intellectual work are needed in order to apprehend certain ideas that have long been established by theoretical Mathematics and that may seem simple to adults familiar with the subject.

The sharing of the classes and the analysis of the episodes by those involved bred original ways of acting and thinking which were absorbed by the actors, who gave them new meanings. Thus, both teachers and students produced new acting possibilities that can be exercised in the social structures of which they are a part. That suggests the recording and the analysis of our experiment may contribute to the reflections of educators in other contexts.

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Teaching and learning the concept of energy at 14 years old

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Abstract

The concept of energy plays a key role in science, and is a basic concept in all school science curricula. It is often introduced in the middle school prevalently considering its relation to social uses, without a coherent treatment of its scientific meaning. This is the main approach adopted in the Italian textbooks. Energy is seen as a not well-defined physical quantity, which is used, destroyed, conserved only in specific system. When these ideas become stronger, it is very difficult to reconstruct pupil conceptions. To tackle this problem, an instructional sequence about energy transformation was proposed and implemented in a middle school in Italy. The sequence proposes the experimental exploration of simple processes using energy as a way to look at phenomena. The rational of the instructional sequence, and the main results of the school experimentation are here discussed.

Introduction

The concept of energy plays a fundamental role not only in physics but in every scientific subject. It is used not only as a guide in the scientific investigation, but also as a cognitive organizer of phenomenologies, i.e. as a way to look at phenomena in the basic scientific education. This is a key concept also in the social and economic context and also in relation with environmental issues. For these reasons, this concept has also a relevant position in all school scientific curricula at any level.

A central problem from the education point of view is evident in the middle school and appears in the Italian textbooks: the focus is on the social-economic aspects of energy, without any connection or a coherent analysis from the scientific point of view. Energy is seen as a not well-defined physical quantity, confused often with the concepts of force or power. The energy is in principle abstract, but in real life it is concrete, in fact we pay for the "energy consumption". Energy is used, destroyed, transported, and is conserved only in specific system. It is not a surprise that these ideas about energy, well-known in literature (Millar, 2005), become stronger if not adequately discussed and it is very difficult to favour the reconstruction of pupil conceptions. Inquiry methods for a teaching-learning path about energy transformation was proposed and implemented in a pilot class of a middle school in Udine (Italy). The sequence is based on experimental exploration and some quantitative analysis of simple processes. This is a part of a project for a research based vertical curriculum in the framework of MER (Model of Educational Reconstruction-Duit 2006), starting from primary school (Heron et al. 2008). The guide criterion for such a curriculum is to promote ways of thinking, that can be completed later in the curriculum, which activate the concept of energy transformation, conservation and type, as a state property of systems.

In this work, we discuss the goals and the rational of the instructional sequence and the main results of the experimentation in school and the related implication on the re-design of the proposal.

The goals of the middle school path

There is a wide literature extensively treating the learning of the concept of energy (Millar 2005). Difficulties emerging from the different use of the word energy in a scientific context and in everyday life (Driver, Warrington, 1985) suggest the need of building a sharing on the meaning of expressions like transforming, conserving, loosing, transmitting energy in different contexts. For this purpose, it is possible to analyze simple situations by means of measurements which allow to put the bases for quantitative treatment of the concept of energy, energetic balancing, conservation of energy. We also supposed that this could help the change from a force-like descriptions of processes (Carr, and Kirkwood, 1998), to a energy-like vision oriented to recognize states and transformations.

Students often consider the energy as a substance, a fuel possessed by living beings and objects in movement and consumed during the movement itself (Watts 1983; Trumper 1993). This idea is particularly persistent because it allows to make reasonable predictions on everyday phenomena. It is therefore important that students associate the energy to a system, but at the same time they need to recognize the abstract nature of it and not identify it with the system itself.

Pupils aged 6-12 often identify different form of energies, but in analyzing a specific transformation they recognize only one of the energy forms involved, associating the energy prevalently to effects they can perceive (Brook, Wells 1988, Carr, Kirkwod 1998). They also have difficulties in associating the energy to a system, and the conditions under which it remains constant (Duit, 1984; Driver, Warrington, 1985; Solomon, 1985; Trumper, 1993; Brook, Wells, 1998). A primary goal of our path is that the students must be able to identify the system under observation, know that the energy of the system can transform in different ways, know that it is conserved and it exists in different types: kinetic energy, potential energy, internal energy and energy associated with light.

At this age, simple measurements can be carried on with pupils. The will is to offer the opportunity to test oneself in situations in which quantitative analyses are possible in order to start energy balancing and conservation. The first principle of thermodynamics, in which heat and work are ways of changing the internal energy of a system, is the goal in perspective.

The instructional path for middle school: “Energy in vertical”

The path consists of 14 activities based on the inquiring method and focused on the recognition of the main energy types, starting from the energetic analysis of systems in free fall, to be followed by considering several other situations in which the potential energy of a system transforms in kinetic energy (rotational and translational), internal energy and energy associated to light. For each activity there is a worksheet organized in: a problem, the exploration of a situation that can provide an answer to that problem; the construction of the conceptual micro-step activated by the exploration.

1. The instructional approach involved the analysis of a free fall process of three different balls (one made of plasticine, one made of plastic and one for playing ping pong), for a preliminary exploration of different transformations that will be analyzed thereafter, in particular considering those involving different modalities of hitting the floor. The analogous behaviour of the three balls in free fall allows to introduce the idea that all balls acquire kinetic energy in falling and that the initial action of lifting the balls by hand provides the initial energy.

2. In order to analyze the energy involved when identical balls are released in free fall from the same height, balls are dropped into a box filled with flour (fig. 1a). The hole deepness created by each ball constitutes an indicator qualitative and visibly recognizable of the falling energy. The free fall from different heights allows the recognition of the role played by the difference of level.

3. From the comparison of craters deepness made by balls with different mass it is recognized that the falling energy also depends from the weight of the considered ball. A simple proportional reasoning lead to recognize that energy must depend on the product of ball's height and weight.

4. The quantitative study of the rebounding of the ping pong ball directs to the discussion of successive energy transformations.

5. This analysis justifies the fact of considering other collision processes, such as those involved in Newton's cradles. The qualitative and quantitative observation of oscillation, when only one ball moves, provides the opportunity of recognizing that the falling energy, which progressively will be named as gravitational potential energy, is only associated to the difference of level and not to the followed path. The recognition of the fact that in Newton's cradle the first and the last balls reach the same height in the first oscillations, aims at building a sharing on the meaning of transformation, lost and conservation of energy.

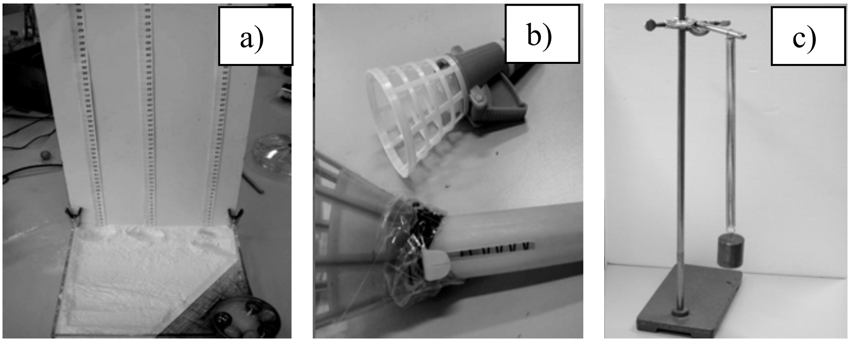

Figure 1. Examples of the apparatuses used in the path. a) box filled with flour to explore balls "falling energy". b) toys used to launch balls upward; c) a more common spring-mass system set-up.

6. The analysis of the phenomenon on long time scales leads to recognizing that the (mechanical) energy of the system tends progressively to decrease. The

persistence of the oscillation at the beginning, in contrast with what was observed in the ball hitting the floor, leads to question in which forms the energy is transformed, recognizing that the energy is associated to the sound and to the deformation of colliding spheres.

7. In addition to exploring how the gravitational potential energy transforms in other types of energies, it is possible to identify ways of lifting the ball i.e. of giving it gravitational potential energy. For this purpose, a toy to launch balls upward is used (fig. 1b). By means of simple quantitative measurements, it is recognized that the height reached by a ball is well-defined once the initial compression of the spring is fixed, activating the recognition of the transformation from elastic potential energy, initially introduced as energy of the spring or elastic energy, to gravitational potential energy.

8. The spring of the toy launching balls upward, when this toy is in a vertical position, allows also to introduce the inverse transformation. The spring may be charged by simply putting a mass on it: the decrease in gravitational potential energy is transformed in elastic potential energy.

9. To deeply study this process, it is explored what happens when a mass is hung on a spring (fig. 1c). Initially the mass is held up by hand. When the mass is slowly released, the mass comes down a little till the spring reaches a new equilibrium (the mass stands, does not move). From the equilibrium then, the mass is lifted and suddenly releas ed so that it is free to oscillate. The analysis of these different steps allows to recognize energy transformations involved: from gravitational potential energy, to kinetic energy, to elastic energy and then again to kinetic energy, to gravitational potential energy. The re-thinking of the motion persistence and of its symmetry with respect to the equilibrium position is another opportunity, to build a sharing on the meaning of energy related concepts.

10. The yo-yo game allows to: continue the vertical exploration of energy; recognize the role of the hand in re-establishing the energy quantity of the yo-yo; introduce the rotational kinetic energy.

11. That energy is better analyzed using a upturned bicycle on which the posterior wheel is put in rotation by pushing on the pedals. The bicycle constitutes a compact palestra to explore transformations of different forms of mechanical energies, but also to recognize that mechanical energy transforms to internal energy when the wheel is stopped by rubbing the hand on it.

12. The use of the dynamo offers the opportunity to explore, by means of a bike, an energy transformation which involves the energy associated to light.

13. The dynamo of the bike activates the discussion on how it is possible to use for practical reasons the rotational kinetic energy. Other situations in which the rotational kinetic energy is involved are opportunities to consolidate and generalize the built concepts: the turbines of windmills activated by the wind or the water; the led activated blowing on a fan/electricity generator; an electrical torch supplied by an oscillating magnet generator.

14. The analysis of different situations in which the external energy is transformed in internal energy of a system concludes the path: the salt r the sugar melt in water (internal energy associated to chemical bounds); the evaporation, the fusion, the piece of plasticine modelled by hands (as examples of different energies associated to a structure), the heating of a system (internal energy associated to temperature changes), iron thread cut or broken by stressing it.

The context of experimentation and the sample

The path here presented was experimented for the 1-7, 9 and 11 items. Two in-class activities (3 hours each) in two successive weeks during May-June 2008 in a third class of a middle school in Udine, composed by 19 pupils (aged 14). The sample here analyzed was constituted by 16 students (9 female, 7 male), which attended the entire 6 hour module of activities plus 1 hour for filling the tests. Five students were not Italian mother tongue and three of them were having clear difficulties in understanding and writing the text in Italian. The students, according to their school curricula, attended science only 2 hours per week in the last three years, mostly focusing on the study of living beings. They rarely attended to demonstrative experiments and are not used to the lab activities. The concept of energy were used in lessons of science, mainly regarding living and chemical processes, even if it was never systematically introduced.

Pre-Test data analysis

The pre-test data analysis is here presented for what concern items Q1-7, related to the general idea of energy, and Q10-12 e Q16-17, concerning specific situations explored in the classroom activities and documented also with the analysis of the work-sheets. Here and in the following: the number of students in our sample (N=16) that gave an answer or wrote a statement is indicated in parentheses; NA indicate no answer at all.

Q1. What do you know about energy? Energy was identified: by the different forms it takes (2); as a force (2); as the capability to do action/movement (3); capability to do work, produce electricity, keep still (1); by usefulness for the world" (1); NA (7). Each of the following forms is cited only a time: kinetic, potential, thermal, chemical, solar, nuclear.

Q2. As far as you know, are there things that make energy? Yes (10), quoting systems as the sun (5), water or wind (3); batteries (2), food (2); lamps (1); No, because energy can neither be created or destroyed, it is transformed (4); NA (2)

Q3. As far as you know, are there things that have/possess energy? Yes: 11 (having energy=it transforms or it transfers (2); all bodies (2); the sun (2); the batteries (2), lamp (1), foods (1); car (1); magnets (1)); NA: 5.

Q4. Is energy conserved? Explain. Yes (7), it transforms (2), if not used (2), in the batteries (2) in power centrals (1); No, it is lost (1); NA (8).

Q5. Can energy be transformed? It transforms from a form to another (7); in the transfer from a body to another (2); energy becomes a system (1); NA (6). Examples: transformations of thermal/chemical energies (8); machinery (3)

Q6 -Can energy be lost? No, it is not lost, but it is transformed (3); It is lost, because it is transformed (1), NA (11).

Q7. What types of energy do you know about? Kinetic (15); potential (3); mechanic (5); gravitational (6); thermal (14); electrical (10); magnetic (2); chemical (7); hydric (5); radiating (2); solar (10); nuclear (12); eolic (1); NA (1).

Q10-11-12: Bicycle. Q10. I pedal for moving the wheel of the bicycle. What kind of energy transformation do I produce? Q11. The bicycle wheel is stopped rubbing my hand on the wheel. What kind of energy transformations are involved? Q12. Where has the energy gone? Q10: Kinetic→ movement energy

(2), energy→kinetic energy (1), thermal→kinetic (1) or electric/chemical energy is produced (2), kinetic (6), transformation of the power (1), NA (3). Q11: Kinetic →heat (3), thermal (5), transferred to the hand (1); NA (7). Q12: in the hand (4), thermal energy (4), it disappeared (1), it is lost (1), it is still there (1), NA (7).

Q16. Toy launching balls upward - What kind of energy transformation are involved? A) Energy transformations (3: kinetic→gravitational (2), gravitational →elastic (1)); B) one or more energy forms (8); C) the force (1); NA (5).

Q 17. Mass-spring system: Q17.2 Does the spring possess energy? Q17.3 Does the mass have energy? Q17.2: Yes (16–kinetic (4), gravitational (1); elastic (3); static (1), "make power against the mass (1)). Q17.3: Yes (9–gravitational (3), potential (2), only in movement (2), the mass (1)); No 4; NA (3).

From reported data it emerges: many students are not very familiar with the concept of energy, as it is evidenced by the number of un-answered questions (Q1, Q4, Q6); the remaining students express themselves in an assertive way (Yes, No; energy is the capability to do work; nothing is created or destroyed), associate energy to systems, but do not show sharing of ideas about the meaning of energy transformation. It emerges clearly considering the answers of items Q10-12/16-17, in which a great dispersion, limited correlations between answers, a lack in the recognition of energy forms really involved, become evident.

Work-sheets data analysis

In the following the analysis of answers to 2 work-sheets used in the path is reported.

Work-sheet 1 – The potential falling energy. In analyzing the situation in which the three different balls (plasticine/plastic/ping-pong balls) are lifted at a certain height and then released in free fall to the floor, to the requirement of identifying the type of energy possessed by the falling plasticine ball, the students answered: "kinetic" (11), "potential" (2), "energy" (1), NA (2). The association of the kinetic energy to a moving body is mainly not problematic.

When the students are requested to compare the plasticine ball case and the plastic ball one, they gave the following answers typologies to the question:"What are the differences in the energy transformations?": T1A (3): Distinction of the energetic process involved in the impact ("the transformation is kinetic and potential", "energy is not muffled"); T1B (5): only an energy form, or a specific energy process, without distinguishing the two cases ("it becomes kinetic"; "kinetic-gravitational-kinetic-gravitational"). T1C (1): different falling energies; T1D (1): Description: "a ball stops, a ball moves"(1); T1E: NA (6).

As far as the energy of the ping-pong ball hitting the floor is concerned (Dawson-Tunik, Stein 2004) the students statement typologies were: T2A - energy-like (10): "a part of the energy passes to the floor" (4), "the energy decreases (3), "the energy becomes potential" (1), "at the impact the energy of the ball does not increase anymore" (2); T2B - force-like (2): "great velocity great weight"; T2C-description (1): "at the impact it bounces"; T2D: NR (3).

The successive requirement is to make explicit a hypothesis about what happens to the ball energy after bouncing on the floor, the following topologies of answers were found: T3A (7) - energy like interpretative hypothesis, associating energy to the system sometimes (T3A1 - energy decreases, it is re-absorbed by the ball (5); T3A2 – energy transformation (2)); T3B (3) - force-like interpretative hypothesis: “it is repulsed back in the air”; T3C (2) – different material explanation (“the ball bounces more time because of the different material it is made”); T3D (4) kinematical description: “the height/velocity decreases” (4). The students adopted force-like or energy-like explanations according to the context and therefore different students are classified as T2B or T3C.

To the requirement of analyzing the decreasing height of the ping-pong ball re-bouncing and of making explicit the different energy transformations involved, all answered used only the concept of energy: T5A- Different energies associated to different phases (1): “Potential, kinetic, potential”; T5B- energies involved in the net transformation (2): “gravitational potential”, “kinetic”; T5C-energy associated only to one of the involved processes (5): during the falling potential energy (1) or kinetic (2); gravitational/potential at the impact (2); T5D: NA (8)

Then students were requested to indicate “the types of energy that the ball has” in the points: A, from which it starts falling; B, at the first impact with the floor; C, at the maximum height of the first bouncing; D, at the second impact. The answers typologies were: T6A (2): gravitational-kinetic-potential-kinetic; T6B (3): kinetic-potential-kinetic-potential; T6C (3): potential-potential-kinetic-potential; T6D (1): it falls-hits-returns up-falls again; T6E (6): NA. The analysis of phenomena subdivided in phases allows to recognize the single processes, favouring the identification of energy forms involved in each phase and the constructing of a picture more and more coherent (2/3th of the sample).

Work-sheet 6 – The Newton’s cradle [moving only a ball]. As far as the requirement of “describing the observed motion of the pendulums” (the Newton’s cradle) is concerned, we found the following typologies: T8A - energy transmission descriptions (6): the ball in the middle “transmits the energy”; T8B - force/momentum like descriptions (2), as “ the sphere on the left transfers force/motion to the sphere on the right”; T8C - kinematic description (7): “the pendulums oscillate”; T8D (1): NA. Some pupils specified: “the motion continues” (2-stressing on the persistence of motion), or the process continues “until the energy finishes” (3- stressing on dissipation).

When students are requested to reconstruct “the energy transformations”, only energy-like analyses emerged: T9A (6): cyclical transformation of energy: potential, kinetic, potential, kinetic; T9B (5): only a process, the one implicitly assumed as the more relevant: “potential-kinetic” (3); “potential-mechanic” (1); “kinetic–potential” (1); T9C (5): NA. The quantitative analysis of the process, using a optical projection method to detect the displacements of the first and the last balls, directs most of the students (14 against 2 NA) to declare that energy, acquired by the last ball, is equal to energy, initially possessed by the first ball, explaining that: “at the first throw, energy is the same” (4); “at the first throw, energy passes to the second [ball]” (3); energy is transported (2); “the height is always the same and the energy is equal” (1); “the forces are equals” (2); NA (4).

Post-Test data analysis

The post-test data are reported in this paragraph, concerning items Q1-Q8, Q10-12, Q16-Q17 (the same as in the pre-test).

Q1: Energy is identified by: the different forms it takes (4); the characterizing properties (6-transformation (4), conservation (2), the fact of being in the systems (3); a force (3); capability to make actions/movement (3) and work (1). NA (6). In terms of mutually exclusive categories the identification occurs: recalling the properties (6) and/or specifying the existence of different forms (5) (tot.8); associating to the capability of making work/movement (2); quoting specific energy forms (3): kinetic (3); potential (2); mechanical (1); elastic (1); gravitational (2); work (1); thermal (3); electrical (3); chemical (1).

Q2 –Yes (13- quoting following systems: the sun (3); the human body (2), the fire (1)); No, because it is transformed (2); NA: 1.

Q3- Yes (13 – all bodies (8), when they have a specific position (3) or are moving (2), only in a case the mill is re-called as an example); NA (3).

Q4 – Yes (8 – it cannot be depleted (1); it is transformed (4), as in the machineries (1); only sometime (2)); no, it disperses (2); NA (7).

Q5 – It is transformed from a form to another (8); it is transformed (3), NA (5). Examples: potential→kinetic (5); gravitational→elastic (1), kinetic→rotatory (1), chemical→potential (1); solar→ thermal (2); hydraulic→electric (1).

Q6 – It is not lost, it transforms (3- the same as in the pre-test); yes, it is lost (6 –when it is transformed (1)), it is dissipated 4 (in the environment, in the air (3), in the interacting systems (3); NA (3). Examples: Newton's cradle (5), the ball falling on the floor (3), the bicycle (1), the guitar string (1).

Q7 - kinetic (15); potential (14); mechanic (10); elastic (10); rotatory (2); gravitational (1); work (1); thermal (4); chemical (4); eolic (2); magnetic (1); solar (1); nuclear (1); hydric (6); muscular (1).

Q10-11-12-Bicycle: Q10: potential→kinetic (1), kinetic→rotatory (2), potential (1), kinetic (7), thermal (1), NA (4); Q11: kinetic→potential (2), kinetic→thermal (3), thermal (5), kinetic (1), potential-mechanic (1), the hand warms up (1), NA (3); Q12: in a system (13 - hand (9); environment (2); wheel (2)); it was transformed (4- in heat (2); dissipated (2)); NA (2)

Q16 – *Toy launching balls upward* – involved energy transformations are listed (12: from potential energy or elastic energy to kinetic energy (10), from mechanical energy to potential energy (2)); only one involved energy form (2: mechanic, gravitational); a process (1: it [the energy] of the ball launcher toy and the height reached by the balls); NA (2).

Q17-Spring-Mass: 17.2 Yes (16 – elastic (9), kinetic (1), gravitational (1); hold the mass (1) 17.3 Yes (12 – potential (9); No (4)

Comparison of pre-test and post-test data and discussion

The answers given in the post-test are more rich and specific in making explicit aspects of the scientific conception of energy (see fig. 2- Q1). For Q2 and Q3 the answers are mainly affirmative, with a significant change in Q3 in reaction to the identification of energy as a property of all systems (from 2 to 8).

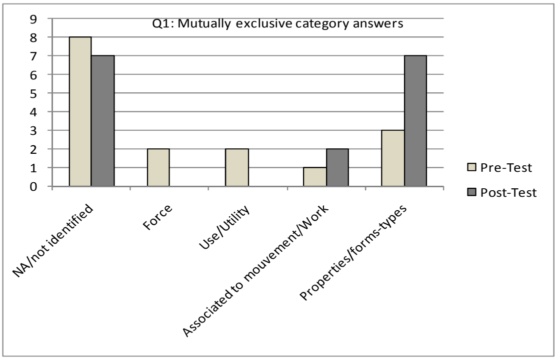

Figure 2. Q1 - Energy identification categories

Fig. 3 shows a net shift towards Q5-categories in which energy transformation is referred to a change from an energy form to another. In the pre-test, among 10 examples proposed, most of them are cases in which thermal and chemical energies are involved (8), without identifying or associating them to specific systems. In the post-test, the 11 indicated transformations, are contextualized in the examples used in the path (free fall of an object, pendulum, bicycle) and the potential energy→kinetic energy transformation prevails (5).

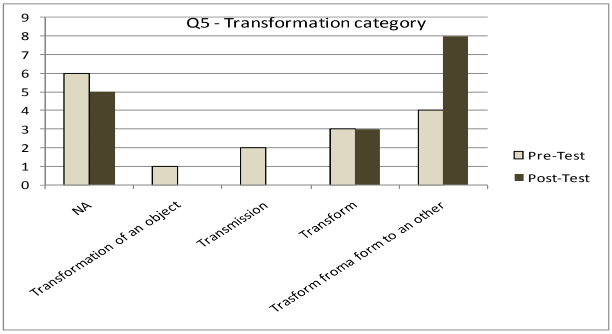

Figure 3. Q5 - Energy transformation categories

Regarding the meaning of Q6-energy loss the proposed activities favored the anchoring of argumentation to well specific situations. Regarding the quoted energy forms in Q7 a significant change about the potential energy emerges. From examples in Q10-12/16-17 it emerges: a greater consciousness in associating the energy and the relevant transformations to systems; the partial overcoming of the tendency of recognizing a single energy form in transformations. For example in the mass-spring system there is no sharing in which energy type has to be associated to the spring (pre-test); in the post-test, elastic energy is prevalently associated to the spring.

Conclusions

In the framework of MER, a research-based process was aimed at designing educational paths to teaching/learning energy at different school levels. The path presented in this work aimed at introducing to middle school pupils, the concept of energy as a physical quantity associated to a system in a well defined condition (property of state), that can be transformed in different types: kinetic, potential, internal, energy associate to light. The strategy of the path is to analyze concrete situations linking energy types and physical systems and conditions. The aim is the reconstruction of pupils' ideas toward a scientifically oriented conception of energy, able to favor future developments, avoiding those ideas that prevent from learning.

The proposed path was implemented in a middle school in Italy, focusing on the exploration of the energy associated to mechanical processes. The results of the pre/post tests and the work-sheets proposed to the students, indicate that students acquired the capability to analyze situations in terms of energy transformations, to associate energy to systems and in particular to recognize potential energy as a form of energy, reshaping their attitude from describing processes in terms of the concept of force to descriptions in terms of energy states and transformations. Some partial results were also obtained about the deep-rooted conceptions on "energy loss", reshaping students' attitude from an energy disappearance conception to an energy transformation way to look at phenomena, associating energy to systems, but also, in few cases, growing up a primordial idea of energy conservation.

These global and punctual results, obtained from the analysis of the instructional material used in class, will be used to develop a revised path version and extend the experimentation in school.

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Application and evaluation of ecological footprint as an environmental education tool towards sustainable life

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Abstract

The aim of this study is to analyze the impact of ecological footprint applications used as a tool of environmental education on changing the awareness, attitudes and behaviours of science and technology education teacher candidates towards environment and sustainable life. The research was applied on 49 third grade pre-service teachers studying in Gazi University Faculty of Education Science Education Program. In the research, "Environmental Education Survey" was used as data collection tools. In the analysis of statistical data, correlation method and paired samples t-Test were used. Following results are obtained from analyzes: It was seen that awareness, attitude and behaviour points of the teacher candidates rose on the phase of post-test. That result shows that applying ecological footprint is an environmental education tool effective in changing the awareness, attitudes and behaviors of the teacher candidates towards environment and sustainable life.

Introduction

In 1992, the United Nations Conference on Environment and Development, the Earth Summit took place in Rio de Janeiro, Brazil. It was the largest ever-international conference and the central aim was to identify the principles of action towards "sustainable development" in the future. Literally, sustainable development refers to maintaining development over time. However, it has been suggested that there are more than seventy definitions of sustainable development currently in circulation (Holmberg and Sandbrook, 1992). Below just a small number of such definitions and the varied interpretations of the concept which have flowed from these different ideas. Definitions are important, as they are the basis on which the means for achieving sustainable development in the future are built.

"In principle, such an optimal (sustainable growth) policy would seek to maintain an "acceptable" rate of growth in per-capita real incomes without depleting the national capital asset stock or the natural environmental asset stock"(Turner 1988).

"Development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987).

Sustainable development requires decreasing the consumption speed of the non-renewable sources, protecting species of plants and animals, to provide continuity of general unity of the ecosystem minimising the negative effects on the quality of air, water and other natural elements. Environmental protection is the essential of the sustainable development concept, and focused on the sources of the environmental problems, not their symptoms (Türkiye Çevre Sorunları Vakfı, 1991).

Education is pre-condition of a sustainable development. It develops and strengthens the capacity of evaluating and making preference for sustainable development of individuals, groups, associations, institutions, and countries. Changing the aspects of the individuals, it makes our world safer, healthier and more comfortable and increases the quality of life (UNECE, 2003).

Education is critical for promoting sustainable development and improving the capacity of the people to address environment and development issues. To be effective, Education for Sustainability (ESD) should deal with the dynamics of both the physical/biological and socio-economic environment and human development, should be integrated in all disciplines, and should employ formal and nonformal methods and effective means of communication (Wheeler et al, 2003). Education for sustainable development is a lifelong process from early childhood to adult education. The education is of special importance for the children since the values, lifestyles and attitudes are determined in the early ages.

Environmental education (EE) and education for sustainable development (ESD) have become growing priority at the local, national and international levels in recent years. The central role of EE and ESD in fostering both the values and the skills necessary to fulfil the broader goals of sustainable development is reinforced by the United Nations recent launch of the Decade of Education for Sustainable Development in 2005 (Globescan, 2005).

Fien (1993), asserted that the education for sustainable development improves critical thinking, reflection, and action abilities when making long-term decisions about the nature for a better world.

Orr (1994), explained that education encourages the students to look from conventional box with his sentences "If the students were appropriate to the technological societies of future, they would be successful adults and achieve to constitute a sustainable future making effective decisions now".

Fien and Trainer (1993), underlined that sustainable individuals can get ready in education process, judgements and attitudes can be turned to behaviours considering and broaden the subjects of sustainable development.

The concept of an "ecological footprint" is an almost intuitive measure of the impact of individuals or societies on nature. It provides a simple yet elegant accounting tool that can help us see the impact of human consumption patterns on the earth. Today, humanity's ecological footprint is already over 30 percent larger than what the world can offer.

The ecological footprint is a measure in hectares of the land used by an individual to meet the needs and absorb waste materials that is required to sustain a city, region or country. The footprint helps students understand the concept of sustainability (Turner, 1995). Ecological footprint is an educational tool that is more effective than the knowledge that we have didactically in terms of changing our environmental attitudes and behaviours positively, because it expresses our negative effects on the world digitally. In this study, if using the ecological footprint, as an environmental education tool is effective in changing the awareness, the attitudes and the behaviours of pre-service teachers directed towards sustainable life, is searched.

Problem

Is using the ecological footprint as an environmental education tool effective in changing awareness', attitudes, and behaviours of pre-service science and technology teachers towards sustainable life?

Sub-Problems

These problems were asked in this research;

1. Before and after the ecological footprint application as an environmental education tool, is there a considerable difference between the awareness, attitude, and behaviour points of science technology teacher candidates, who participated in the research, directed towards sustainable life?
2. Before the ecological footprint application as an environmental education tool, is there a considerable relation between the awareness, attitude, and behaviour points of science technology teacher candidates, who participated in the research, directed towards sustainable life?
3. After the ecological footprint application as an environmental education tool, is there a considerable relation between the awareness, attitude, and behaviour points of science technology teachers candidates, who participated in the research, towards sustainable life?

Methodology

Sample and instrument. In this research a quantitative research design was used. The participants of this study consisted of 49 pre-service teachers, who were enrolled in the science education program at a Gazi University Department of Education in Turkey. In the research, "Environmental Education Survey" that was developed by Meyer (2004) was used to measure awareness', attitudes, and behaviours of the pre-service teachers directed towards sustainable life. The survey mentioned above applied in both pre-test and post-test. It was composed of 35 expressions and prepared using Likert-type scale. In the survey, the expressions related to sustainable life, ecological footprint, and environment were used. The expressions in the survey were prepared in three dimensions to measure awareness, attitude, and behaviour towards sustainable life. There were 20 expressions to measure awareness, eight to measure attitude, and seven to measure behaviour. Each expression has equivalent weight in the survey. The replies of the negative expressions in the survey were converted and considered in total evaluation. The extent validity of Environmental Education Survey was ensured taking the views of the field experts. Cronbach α co-efficient of Environmental Education Survey was calculated 0.74.

Education Design. The pre-service teachers were educated about sustainable living through active learning methods over a 5-week period. The pre-service science and technology teachers were divided into groups via various grouping methods at each phase of instructional interventions (e.g., puzzle method). The following activities were used throughout the instructional interventions:

In the first lesson in the week of the research, "Environmental Education Survey" was applied to science and technology teachers as pre-test and later, the studies, of which stages will be mentioned below, were carried out in the lessons.

In the first week of the instructional treatment, students were facilitated to find answers to the following questions through group discussions: "Why are we not sustainable?" "What prevents our world and country from being sustainable?"

In the second week, the pre-service science and technology teachers played a commercial game. The instructor introduced the concept of sustainable development.

In the third week, the students in groups discussed how the sustainability of the natural ecosystem is established and drew their ideas on posters. Following the poster drawing activity the groups presented their posters to their classmates.

In the fourth week, the ecological footprints of the pre-service science and technology teachers were calculated by using software ("Ecological Footprint Measurement Survey) available on the Internet.

In the last week, pre-service teachers were applied "Environmental Education Survey" again as post-test.

Analysis

In this research, single group pre-test post-test comparative associated sample test model was used. To determine if a considerable difference between the pre-test and post-test points of pre-service teachers, sample t-Test analyse was used in the research. When pre-test and post-test points belong to the same group, they form associated sample. Associated sample t-Test should be used to consider if the difference between the two-sample mean is meaningful (Büyüköztürk, 2005).

If there was a relation between awareness, attitude, and behaviour points of the teacher candidates, who participated in the research, directed towards sustainable life is examined with correlation method calculating Pearson correlation co-efficient. The pre-test and post-test point distribution, measure of central tendency values (mean, median, and mode), and central distribution (standard deviation, variance, skewness, and kurtosis) values of awareness', attitudes, behaviours of pre-service teachers, who participated in the research, towards sustainable life were reported. Since correlation method and points seems continuous to find the association between two variables and explain it, calculating Pearson correlation coefficient is convenient in terms of examining the association between these variables (Büyüköztürk, 2005).

Findings and Commentary

In this section, the findings, which appeared when evaluating the data that collected in the research, and statistical analysis of these were presented. The findings were interpreted regarding the order of sub-problems.

Findings Related to First Sub-problem and Commentary. With first sub-problem of the research, if there was a meaningful difference between awareness, attitude, and behaviour points of science and technology teacher candidates, who participated in the research, towards sustainable life was searched before and after ecological footprint application as an environmental education tool.

Before and after ecological footprint application as an environmental education tool the statistical analysis results of awareness, attitude, and behaviour values of the pre-service science and technology teachers, who participated in the research, towards sustainable life, were shown in Table 1.

Table 1. The Statistical Analysis Results of Pre-test and Post-test Awareness, Attitude, and Behaviour Points Associated with Sustainable Life (*N*=49)

	Awareness		**Attitude**		**Behaviour**	
	pre-test	**post-test**	**pre-test**	**post-test**	**pre-test**	**post-test**
Mean	38.69	62.51	16.02	24.80	14.78	20.61
Median	39.00	63.00	16.00	25.00	14.00	20.00
Mode	40	65	15	24	14	20
Std. dev	5.359	4.542	1.677	2.081	2.084	2.060
Variance	28.717	20.630	2.812	4.332	4.344	4.242
Skewness	-.315	.001	.326	.284	.082	.310
Kurtosis	.396	-.728	.081	-.131	-.482	-.359

As it is seen Table 1, the average awareness, attitude, and behaviour point of teacher candidates participated in the research towards sustainable life, which was calculated in the post-test, after ecological footprint application as an environmental education tool is higher than the average point, which was calculated in the pre-test, before the application.

t-Test analysis was used for the samples about whether there was a meaningful difference between awareness, attitude, and behaviour points of teacher candidates towards sustainable life before ecological footprint application as an environmental education tool and their points after the application or not. The analysis results were shown in Table 2, 3, and 4.

Pre-test and post-test dependent t-Test results for awareness directed towards sustainable life are shown in Table 2.

Table 2. Pre-Test And Post-Test Dependent Variable t-Test Results For Awareness Directed Towards Sustainable Life

	N	$\overline{X}$	***S***	***sd***	***t***	***p***
Pre-test	49	38.69	5.359	48	21.414	.000
Post-test	49	62.51	4.542			

As it is seen in Table 2, there is a meaningful difference ($t48=21.414$, $p<.01$) between awareness pre-test points of teacher candidates, who participated in the research, towards sustainable life and the points of the post-test, which was applied after the application of the education process associated to ecological footprint as an environmental education tool. While the average awareness point of pre-service teachers towards sustainable life was $\overline{X}=38.69$ before the application, it increased to $\overline{X}=62.51$ after the application of education process about ecological footprint as an environmental education.

This finding shows that ecological footprint application that is an environmental education has a considerable effect on increase of awareness levels of pre-service science and technology teachers towards sustainable life.

Pre-test and post-test dependent t-Test results for attitude directed towards sustainable life are shown in Table 3.

Table 3. Pre-Test And Post-Test Dependent Variable t-Test Results For Attitude Directed Towards Sustainable Life

	N	$\overline{X}$	*S*	*sd*	*t*	*p*
Pre-test	49	16.02	1.677	48	19.374	.000
Post-test	49	24.80	2.081			

As it is seen in Table 3, there is a meaningful difference between attitude pre-test points and post-test points ($t48=19.374$, $p<.01$) of pre-service science and technology teachers, who participated in the research, towards sustainable life. While the average attitude point of pre-service teachers towards sustainable life was $\overline{X}=16.02$, before the application, it increased to $\overline{X}=24.80$ after the application. This finding shows that ecological footprint application that is an environmental education has a considerable effect on the positive change of attitudes of pre-service science and technology teachers towards sustainable life.

Pre-test and post-test dependent t-Test results for behaviour directed towards sustainable life are shown in Table 4.

Table 4. Pre-Test And Post-Test Dependent Variable t-Test Results For Behaviour Directed Towards Sustainable Life (*N*=49)

	N	$\overline{X}$	*S*	*sd*	*t*	*p*
Pre-test	49	14.78	2.084	48	11.933	.000
Post-test	49	20.61	2.060			

As it is seen in Table 4, there is a meaningful difference between behaviour pre-test points and post-test points ($t48=11.933$, $p<.01$) of pre-service teachers towards sustainable life. While the average behaviour point of pre-service teachers towards sustainable life was $\overline{X}= 14.78$ before the application, it increased to $\overline{X}= 20.61$ after the application of education process about ecological footprint as an environmental education. This finding shows that ecological footprint application that is an environmental education has a considerable effect on acquiring of pre-service teachers, who participated in the research, behaviours towards sustainable life.

Findings Related to Second Sub-problem and Commentary. With second sub-problem of the research, if there was a meaningful relation between awareness, attitude, and behaviour points of science and technology teacher candidates, who participated in the research, towards sustainable life was searched before ecological footprint application as an environmental education tool.

It is examined that before ecological footprint application as an environmental education tool, whether there was an association between the awareness, attitude, and behaviour points of teacher candidates, who participated in the research, and if there was, how relation it was, using correlation method and calculating Pearson correlation co-efficient. Data that was mentioned above was shown in Table 5.

Table 5. Awareness, Attitude, and Behaviour Correlation Before Ecological Footprint Application (*N*=49)

		Awareness	Attitude	Behaviour
Awareness	Pearson Correlation	1	.019	.216
	p		.896	.137
Attitude	Pearson Correlation	.019	1	.383**
	p	.896		.007
Behaviour	Pearson Correlation	.216	.383**	1
	p	.137	.007	

In respect of the data in Table 5, a high-level, positive and meaningful association (r=0.383, p<.01) was found between attitude points and behaviour points of science and technology teacher candidates towards sustainable life, before ecological footprint application that is an environmental education tool. However any association could not been founded between those and awareness point. These data shows that the attitudes of pre-service science and technology teachers, who participated in the research, change more positively, and their behaviours will change more positively. That finding could be interpreted as changing of the attitudes towards sustainable life positively will ensure responsible behaviour towards sustainable life. Before the application directed towards sustainable life, non-existence of a relation between awareness points and attitude and behaviour points of pre-service teachers is caused by that they did not have information about sustainable life and ecological footprint subjects in the beginning.

Findings Related to Third Sub-problem and Commentary. With third sub-problem of the research, if there was a meaningful relation between awareness, attitude, and behaviour points of science and technology teacher candidates, who participated in the research, towards sustainable life was searched after ecological footprint application as an environmental education tool. It is examined that after ecological footprint application as an environmental education tool, whether there was an association between the awareness, attitude, and behaviour points of teacher candidates, who participated in the research, and if there was, how relation it was, using correlation method and calculating Pearson correlation co-efficient. Data that was mentioned above was shown in Table 6.

In respect of the data in Table 6, high-level, positive and meaningful associations were found between awareness and attitude (r=0.406, p<.01), awareness and behaviour (r=0.587, p<.01), and attitude and behaviour (r=0.419, p<.01) points of science and technology teacher candidates towards sustainable life, before ecological footprint application that is an environmental education tool. It is seemed that there is a meaningful increase in awareness, attitude, and behaviour correlation of pre-service teachers, after ecological footprint application, which is an environmental education tool. Those findings show that the awareness of environment and sustainable life increased due to comprehension of ecological footprint during the lessons about ecological footprint and this increase effects the attitudes and behaviours of pre-service teachers positively. In respect of these data, in the educational process, in which ecological footprint is used as an environmental education tool, awareness level of environment and sustainable life increases more, and the attitudes and behaviours will change more positively; the attitude that will change positively ensures the behaviours towards sustainable life be gained as responsibility.

Table 6. Awareness, Attitude, and Behaviour Correlation After Ecological Footprint Application (*N*=49)

		Awareness	Attitude	Behaviour
Awareness	Pearson Correlation	1	.406**	.587**
	p		.004	.000
Attitude	Pearson Correlation	.406**	1	.419**
	p	.004		.003
Behaviour	Pearson Correlation	.587**	.419**	1
	p	.000	.003	

Conclusion

In respect of the research these results were attained;

• A meaningful difference ($t48=21.414$, $p<.01$) between awareness pre-test points of teacher candidates, who participated in the research, towards sustainable life and the points of the post-test, which was applied after the application of the education process associated to ecological footprint as an environmental education tool was found.

• There is a meaningful difference between attitude points ($t48=19.374$, $p<.01$) of pre-service teachers towards sustainable life before and after ecological footprint application, which is an environmental education tool.

• It was seen that there is a meaningful difference between behaviour pre-test points and post-test points ($t48=11.933$, $p<.01$), which were calculated after ecological footprint application as an environmental education tool, of pre-service teachers towards sustainable life.

• A high-level, positive and meaningful association ($r=0.383$, $p<.01$) was found between attitude points and behaviour points of pre-service science and technology teachers towards sustainable life, before ecological footprint applications which are environmental education tools. However any association could not been founded between those and awareness point.

• High-level, positive and meaningful associations were found between awareness and attitude ($r=0.406$, $p<.01$), awareness and behaviour ($r=0.587$, $p<.01$), and attitude and behaviour ($r=0.419$, $p<.01$) points of pre-service science and technology teachers towards sustainable life, before ecological footprint application, which is an environmental education tool.

The data collected in various studies supports the results of this research.

In Japan, a personal ecological footprint calculator that is Internet web-based was developed in a research, which was made to assist the citizens to realise the magnitude of their ecological footprint. In respect of the results of the research, one of the necessary conditions for ecological sustainability is whether we achieve "One Planet" lifestyle and ecological footprint is an effective educational tool to alter our lifestyles (Wada et al, 2007).

Wackernagel and Rees (1996) asserted that the concept of ecological footprint should be united with the intramural and extramural education activities. They expressed that ecological footprint could be used in the games and school projects to study on energy and material flow of nature, to make experiments related to sustainable lifestyle, and to provide concrete local applications for mathematics, biology, and physics lessons, which are taught at schools simultaneously. According to Meyer (2004), although ecological footprint is not effective on altering attitudes and behaviours of the people, who learn, directly, it alters their information and alteration of information might alter attitudes and behaviours soon. Therefore ecological footprint can be used as an educational tool to increase the information about sustainable life and develop the attitudes and behaviours. The science education for sustainable education requires active participation of the students in setting the processes and the models to fill the gap between the real world and the class. Studies of the students on the sustainable life conditions in local scale, is important. The educators should encourage and motivate the schools continuously to let the environmental problems to be learned, to let them be comprehended, and let solution suggestions be presented (Herremans and Reid, 2002).

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The development and evaluation of second level lessons within the framework of the *Cognitive Acceleration through Science Education* methodology

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Abstract

The CASE (Cognitive Acceleration through Science Education) programme was developed in the UK for the 11-14 year age group to encourage higher level thinking, in order for them to better attain the objectives of the curriculum. Prior to this study the successful CASE programme was implemented across the primary and second levels in Ireland and its effects were monitored. The effectiveness of the programme on cognitive development was tested by tasks assessing Piagetian levels. The results of both programmes show increases in formal-operational thought. This study now concentrates on the development and implementation of second level science lessons, central to the CASE methodology- *Thinking Science through Topics*. Increasing the relevance and density of the use of the CASE methodology beyond stand- alone activities to use within entire topics demanded development of additional resources. Six chemistry and physics topics on the Junior Certificate science course were chosen, materials and lessons were designed in accordance with the CASE methodology- to promote higher order thinking- and subsequently used by five teachers, trained in the use of the cognitive acceleration tools. Results from the cohort indicate that the cognitive levels of the experimental group after the intervention were much greater than that of the control group.

Background

The CASE programme, initiated in the early 1980's, came in response to an international problem in the world of science education. Research showed that demands of secondary science curricula in many nations far exceeded the observed capabilities of students studying it. The inclusion of tasks which involve complex scientific concepts and abstract models require students to use what Piaget called formal operational thinking. This type of thinking is essential for the manipulation of formulae, the design of scientific experiments and making the necessary connections between concrete experimental data and abstract scientific theory. From this perspective the study of science becomes a challenge to students who have not yet reached the formal operational period. In response the CASE (Cognitive Acceleration through Science Education) programme was founded by a group-Adey, Shayer & Yates (1989)- at King's College London. The main aim of the programme was to increase the proportion of secondary students with formal operational thinking, and hence cater for them to have a more meaningful and solid engagement and understanding of the scientific concepts covered in the National Curriculum.

The theoretical foundation of the CASE methodology is partly Piagetian, with an emphasis on providing conflict situations to young adolescents (11- 14 years) which encourage equilibration and the construction by students of the reasoning patterns of formal operations. Of equal importance is the Vygotskyan influence, with an emphasis on social construction of reasoning, through metacognitive reflection and a carefully managed use of the language of thinking. In particular they were influenced by his proposal of a Zone of Proximal Development (ZPD) which proposes that children not only have a set of developed skills but they have some undeveloped cognitive skills, which they are capable of using successfully. These potential capabilities of the child may develop by chance, because of the effort of the child or due to the mediation of a peer or of an adult.

Methodology

There are five main pillars that are central to the success of the CASE programme and they are shown in *Figure 1*. Firstly, concrete preparation involves setting the scene or presenting the context of a problem. The idea being that any difficulty encountered in the class is purely intellectual and not due to poor understanding of the task or miss-use of the equipment. The second pillar, cognitive conflict is central to the methodology. It is the part of the class where the students are faced with a problem that challenges their prior knowledge and personal hypothesis. The teacher plays a vital role by encouraging students to look at the problem from different perspectives and by encouraging dialogue about any difficulties experienced. Leading from this is the social construction part where students work collaboratively in groups of up to four people trying to resolve the cognitive conflict. Metacognition follows where the students are encouraged to reflect on their thinking and explain their thoughts to each other as they solve problems or perform tasks. The teacher plays an important role in this process by asking the students questions that probe their ideas. In essence it is the re-establishing of equilibrium. Finally, bridging is the part of the class where the teacher assists students in applying their new thinking into different but relevant contexts. Bridging is regarded as a powerful teaching strategy, where students are encouraged to keep practising and challenging the new thinking developed long after the lesson they first learned it in is over.

In addition to these underlying principles the authors of the programme regard duration and density as other important features. Feuerstein's work suggests that to have a permanent effect on the way that people think an intervention programme must be allowed to operate over a sufficiently long period of time, to make a permanent difference to the way in which student's process fresh learning and approach problem solving. The original CASE programme had operated over two years on the grounds that previous successful interventions, such as that of Feuerstein's *Instrumental Enrichment* (1980), had shown no effects in less than two years. A supplementary reason was the time required to change the teaching practise of the secondary science teachers.

The original CASE project materials, *Thinking Science*, contained a total of 32 activities, each designed to last approximately 65 minutes. The activities were intended to be enrichment to the regular science curriculum and for delivery at a rate of about one lesson every 3 weeks over a 2-year period. The materials were designed to address individually each of the schemata of formal operations and incorporate the pillars shown in *Figure 1.* The success of the programme on students' cognitive development was monitored by using Science Reasoning Tasks as pre-, post- and delayed post-tests with both an experimental group (taught by CASE methodology) and a comparable control group. Results from the original study showed that greater gains were achieved by the experimental group, especially by the male cohort. Since then the CASE programme has been used in several countries around the world, including Ireland where similar gains in cognitive development have been recorded.

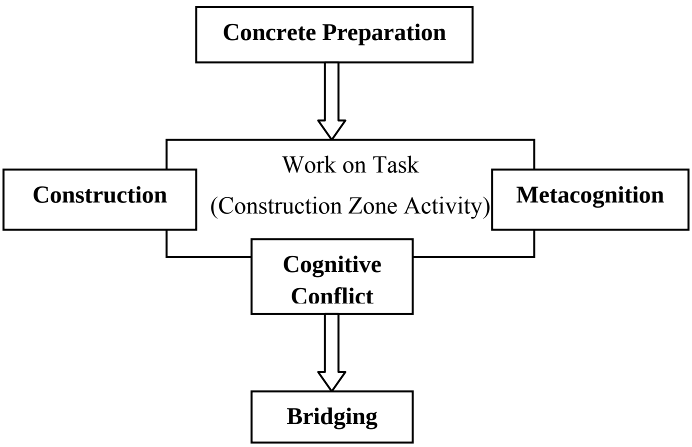

Figure 1. Pillars of CASE methodology

Development of *Thinking Science through Topics*

The second level school system in Ireland is by-in-large similar to that in other countries. Students start second level education at approximately 12 years of age after completing eight years at primary level. The first three years of second level are comprised of the Junior Certificate curriculum, which ends with a terminal examination of approximately ten subjects, usually including science. Following this is the two year course of the Leaving Certificate curriculum, which also ends in a terminal examination, usually of seven subjects. The science subjects at this level are split into physics, chemistry and biology, all of which are optional.

For the past two years studies have been carried out implementing and monitoring the CASE programme in the final year of primary level and the first year of second level. Results are in line with those achieved in other studies and very positive effects on cognitive development were shown. Leading on from such promising results it was decided to extend the usability of the CASE materials, *Thinking Science* within the Irish context. Anecdotal evidence showed that teachers who used *Thinking Science* felt the activities were an extra add-on to the already over-loaded curriculum and also not all the CASE activities fitted directly into the Irish Junior Certificate science curriculum. There may have been a temptation therefore to avoid using CASE in the classroom for these reasons. As it may have been overly ambitious and unrealistic for us to ask the curriculum to be cut down for certain teachers who choose to use *Thinking Science* it seemed more appropriate and possible to incorporate the CASE methodology into the existing topics on the curriculum, and so *Thinking Science through Topics* was developed. This also would ensure density of the methodology and also the step-by-step building of the formal schema that is recommended by the inventors, as opposed to just choosing *Thinking Science* activities by random.

Table 1. Junior Certificate science topics that were selected for development in *Thinking Science through Topics*

Topic	Section in Junior Certificate Science syllabus	No. of lessons
Acids & Bases	*Chemistry*; Classification of substances & Air, Oxygen, Carbon dioxide and Water	5
Chemical Reactions	*Chemistry*; Atomic structure, Reactions & compounds	4
Density	*Physics*; Force and Energy	5
Equilibrium	*Physics*; Force and Energy	3
Forces	*Physics*; Force and Energy	4
Pressure	*Physics*; Force and Energy	4

This intervention was designed for use in the second year of the Junior Certificate Science course, typically with students between 13 and 14 years old. The topics chosen were the main components of the science curriculum studied in the experimental schools and can be seen in *Table 1*. The materials were designed by first initially identifying the aims and objectives of the course in relation to each of the topics. Following this the content in each of the topics was matched with its corresponding Piagetian level using the Curriculum Analysis Taxonomy, an analytical tool developed by Adey and Shayer (1981) intended to gauge the cognitive demands of science syllabi. This provided a useful estimation of the level of thinking demanded by the science curriculum activities. This was necessary to ensure that the lessons were devised in a method of progression, so as to challenge those students at all levels of cognitive ability. *Table 2* shows an example of the Curriculum Analysis Taxonomy for Acids and Bases, used in the development of *Thinking Science through Topics*. From there lessons were compiled, with the CASE methodology central to the lessons.

Table 2. Example of Curriculum Analysis Taxonomy for Acids and Bases

Topic	2A Early concrete	2B Late concrete	3A Early formal	3B Late formal
Acids and Bases	'Acid' as name of substances with certain properties- turns litmus red, attacks metal, sour taste. But only one at a time, the properties are not seen as defining characteristics.	Acids and bases are opposing factions. The pH scale as an interval scale of degrees of acidity. Neutralisation by equal quantities of acid and alkali. If you double quantity of acid, or if you double its concentration you need twice as much alkali.	Reaction of $H^+ + OH^-$ $\rightarrow H_2O$. Limits to change of pH by dilution alone. Acids are solutions, without water they are not acidic. Conservations during neutralization: nothing lost and new product in principle recoverable.	The reaction between an acid and an alkali, understood in terms of disturbance of the equilibrium between H^+ and OH^- ions in water. Use of molar quantities for finding equation of reaction between an acid and an alkali. Can appreciate that there are H^+ ions even in 1.0M NaOH, and hence has rational understanding of pH scale.

Implementation of *Thinking Science through Topics*

The *Thinking Science through Topics* programme was implemented in five Irish schools, both in urban and rural regions, with approximately 130 students. In four of the five experimental classes the programme was delivered by the class teacher after receiving specialized CASE training.The training consisted of a mixture of theory on the CASE methodology, practical introduction to the lessons and feedback from the teacher on difficulties and successes of the lessons as written. The lessons were adapted accordingly and all materials, including teacher and student workbooks, materials and practical equipment were distributed to each of the schools. In one of the classes the lessons were co-delivered by the first author and the class teacher. The details of the experimental and control classes are given in *Table 3*, including the lessons that were delivered to each class.

Table 3. Details of participating schools and intervention

School	Gender	Group & (Number)	Number of topics	Name of topics	Teacher
A	Female	Experimental (22) Control (22)	3	Pressure, Forces, Moments	Class
B	Male	Experimental (43)	2	Acids & Bases, Chemical Reactions	Class
C	Female	Experimental (19) Control (20)	3	Pressure, Forces, Moments	Team*
D	Male	Experimental (27) Control (22)	3	Pressure, Moments, Acids & Bases	Class
E	Female	Experimental (23)	2	Density, Pressure	Class

*Team denotes both the class teacher and 1st author

Data Collection

The effectiveness of the lessons on cognitive development were assessed by Science Reasoning Tasks (SRT's) developed by the Concepts in Secondary Mathematics and Science (CSMS) team in the 1970's. These tasks assess the ability of students to use Concrete and Formal reasoning strategies. The key characteristics of the tasks used in this study can in be seen in *Table 4*.

Table 4. Features of SRT's used in this study

	No.	Name	Content	Range	No. of items	Internal consistency*
Pre-test	IV	Equilibrium in the balance	Inverse proportions in the balance problem.	2B- 3B	13	0.84
Post-test	VII	Flexible Rods	Control of variables; deduction of effects of variables on bending of rods.	2B- 3B	17	0.86

* Kuder-Richardson co-efficient r_{tt}

These tasks were administered by the first author directly before and after the *Thinking Science through Topics* intervention with both the control and experimental groups. The tasks were marked by the first author to ensure consistency and each student was given a score. From this the students were ascribed a level of cognitive development, i.e. 2B, 2B*, 3A, etc. , using the Rasch scaling developed for the test instrument. This in turn enabled a total score to be converted to an equal-interval cognitive scale. The high internal consistency values, as measured by the CSMS team, show that all the items in the tasks are telling the same story. Perfect internal consistency is indicated by an r_{tt} value of 1.

Results

156 students completed both cognitive tasks (pre- and post-tests) and hence their scores were valid for statistical analysis, 106 of whom were part of the experimental group and the remaining 50 were part of the control group. The average age of the students was 14.2 years at time of pre-test. Initial analysis showed that there was no significant difference between the pre-test scores on Task IV for the experimental and control group, with means of 4.2 and 3.7 respectively. Similarly there was no significant difference between the male or female students in both the experimental and control cohort at the beginning.

However, the post-test scores (from Task VII) for both the experimental and control groups were significantly different (at the 99% confidence level). The mean post-test score for the experimental group was 8.3, while it was 4.7 for the control group. Both groups scored higher in the post-test but the greater gains were made by the experimental group.

In order to gain greater insight into the degree of change that the control and experimental groups had it was necessary to analyse the data further in terms of scores they achieved in the pre- and post- tasks determining Piagetian levels. This was done through Residual Gain Score (RGS) analysis. This technique works by using the pre-test score for each control person as a covariate to his post-test score, and a regression line is computed for the pre- and post- test scatter. The pre- test score for each experimental group student was then entered into the regression equation, and the difference between the predicted and actual post- test score estimates the effect of the intervention in comparison with the control. This method of analysis is valuable in as far as each student's gains are compared with control students of similar pre- test scores. **Table 5** shows the pre- and post-test means and the gains made by each group.

Table 5. Pre- and post-test means and RGS mean for experimental & control group

School	Group & (Number)	Pre-test mean	Post-test mean	Mean RGS*
A	Experimental (16)	4.3	9.1	4.4
	Control (21)	3.8	4.5	0.1
B	Experimental (30)	3.7	5.8	1.4
C	Experimental (14)	6.3	9.6	3.8
	Control (14)	3.6	4.9	0.5
D	Experimental (27)	4.8	10.9	5.9
	Control (15)	3.6	3.8	-0.5
E	Experimental (19)	2.5	8.3	4.5

* = (Post-test score - Predicted Post-test score)

It can be seen that the residual gain scores for the experimental groups were greater than the comparable control group in all cases. The mean RGS for the entire experimental group was 3.889, while it was 0.003 for the control group. This number shows the actual score that the experimental group got was over that predicted by the results of the control group. The mean RGS value of the control group implies that this group scored as predicted but no greater than expected. Graphically the data is shown in *Figure 2*, showing the greater residual gain scores for the groups that were part of the *Thinking Science through Topics* intervention programme.

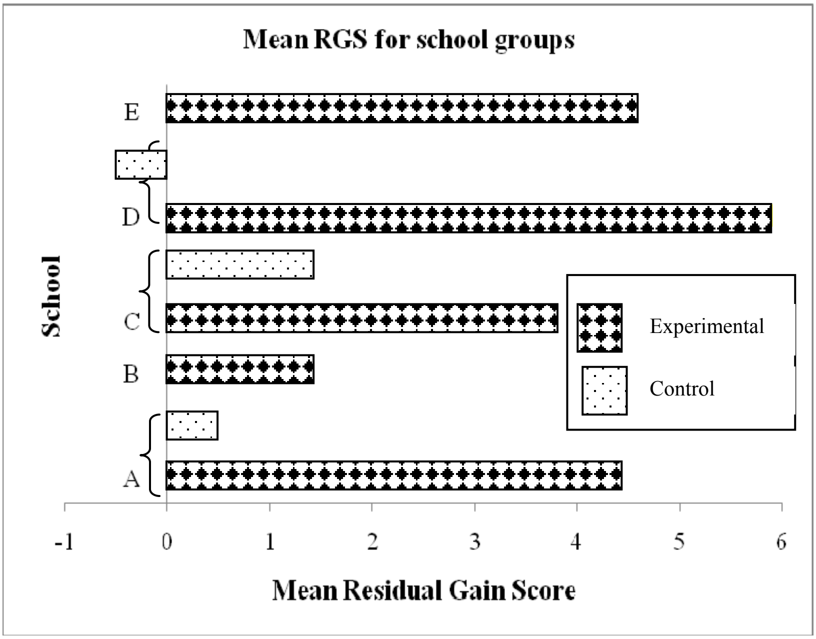

Figure 2. Graph of mean Residual Gain Scores for Control & Experimental groups

In order to determine the effect of the intervention on gender further analysis was done. *Table 6* shows the main finding. The female cohort achieved greater RGS scores than their male counterparts, despite there been no significant difference prior to the *Thinking Science through Topics* programme. *Table 6* also shows that there was no significant difference between the male and female cohorts in the control group. In addition to this there appeared to be no significant difference in the mean Residual Gain Score (RGS) of the group taught by their class teacher or the class that was team-taught by their class teacher and visiting 1st author. This shows that the *Thinking Science through Topics* materials are successful in both scenarios where the trained class teacher must teach alone or when they are teaching in tandem with a CASE facilitator, the 1st author in this case.

Table 6. Mean RGS for gender groups

Group	Gender & (Number)	Mean RGS*	p value
Experimental	Male (57)	3.5494	0.02
	Female (49)	4.2852	
Control	Male (15)	0.5543	0.85
	Female (35)	0.2414	

* = (Post-test score - Predicted Post-test score)

In order to assess the broader effect of the intervention on the student's thinking and exam performance analysis was also conducted on their end-of-year examination result and a set of thinking questions, based on concepts they covered in the *Thinking Science through Topics* intervention. The end-of-year exam was that set by the individual school and therefore each school group sat a different test, hence not standardised. The thinking-type questions were designed by the authors and their aim was to gauge did students have a deep understanding of the concepts that were taught during *Thinking Science through Topics* or was it just a surface knowledge. Their total scores from these questions were converted to a percentage and the mean results of all three assessments are shown for the experimental and control groups.

Table 7. Mean RGS, Mean end-of-year percent & mean Thinking question percent for experimental & control group

Group	Mean RGS	Mean End-of-year exam %	Mean thinking question %
Experimental	3.8895*	62.66	51.58**
Control	0.0027*	60.24	28.18**

*Significant to the 95% confidence level
** Significant to the 99% confidence level

As the information in *Table 7* shows the experimental group out-performed the control group in both the Science Reasoning Tasks and the thinking questions score. The difference in the results for the end-of-year science exam was not significant. However, such a result shows that the *Thinking Science through Topics* intervention programme succeeded in improving students' cognitive and thinking skills. The end-of-year exam with a majority of recall and knowledge questions was mastered equally as well with both cohorts. This result may be more an attribute to the type of exam set and what it is assessing than the actual result itself.

Conclusion

Overall it is evident that *Thinking Science through Topics* set out what it planned to achieve. The intervention was an extension of the CASE programme. Results show that the RGS of the experimental group was higher than that of the control group, implying they did comparably better when exposed to the intervention. The approach involved teachers focusing on thinking skills rather than content knowledge and there is a demand for the student to engage and think. Further beneficial effects shown were that the experimental students performed better than control students in `thinking-type' questions and hence engaging more with the content of the topics.

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A startup tutorial for the controller design of mobile competition robots

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Abstract

A guideline is proposed for preparing quick startup tutorials on embedded controller design of simple competition oriented robots, especially for those who want to have a quick start with freshman level of knowledge of Science and Engineering students. The proposed guideline is parallel to the Problem and Project Based Learning methodology. Robotic Competitions play a significant role to motivate students for learning high technology tracks such as mechatronics and robotics. Microcontrollers are embedded in a typical competition robot to implement intelligent sensors and several intelligent control algorithms. In this paper, C programming language is suggested for the novice robotics competitor, for its medium-level programming character with a fast learning curve. An Integrated Development Environment (IDE), and a hybrid circuit simulation environment is suggested for fast and simple coding and debugging of the microcontrollers and peripheral control circuits. The paper concludes the educational method with a set of sample Proportional, Proportional-Derivative, Proportional-Integral-Derivative and line tracking control applications.

Introduction

Problem and Project Based Learning (PBL) is the new trend in learning methodology developed during the last couples of decades in Science and Engineering Education, as stated by Kolmes (2009). The Accreditation Board for Engineering and Technology (ABET) emphasized this trend in the accreditation criteria for engineering education by the following items:

- An ability to function on multi-disciplinary teams,
- An ability to identify and solve applied science problems,
- An understanding of professional and ethical responsibility,
- An ability to communicate effectively,
- The broad education necessary to understand the impact of solutions in a global and societal context,
- A recognition of the need for, and an ability to engage in life-long learning
- A knowledge of contemporary issues,
- An ability to use the techniques, skills, and modern scientific and technical tools necessary for professional practice.

In parallel to ABET (2008) criteria, EUR-ACE (2008): personal programme outcomes for the bachelor level states that first cycle graduate shall provide *1) Individual and team work* (Function effectively as an individual, and as a member or leader in diverse engineering teams) *2) Communication* (Communicate effectively on intermediate engineering activities with the engineering community and with society at large, by being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions) *3) The engineer and society* (Demonstrate understanding of the societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to engineering practice) *4) Ethics* (Understand and commit to professional ethics and responsibilities and norms of engineering practice) *5) Environment and sustainability* (Understand the impact of engineering solutions in a societal context and demonstrate knowledge of and need for sustainable development) *6. Project management and finance* (Demonstrate an awareness and understanding of management and business practices, such as risk and change management, and understand their limitations)

Kolmes (2009) wrote *the learning approach* in PBL means that learning is organized around problems, which is a central principle for the development of motivation. A problem initiates the learning processes, places learning in context, and bases learning on the learner's experience. The learning is carried through in projects, and it is a unique task involving more complex and situated problem analyses and problem solving because it is also project-based. *The contents approach* especially concerns interdisciplinary learning, which may span across traditional subject-related boundaries and methods. The learning outcomes support the relation between theory and practice since the learning process combines problem solving methods with the analytical approach using theory in the analysis of problems. *The social approach* is team-based learning that considers the learning process as a social act where learning takes place through discussion rich communication, where the students learn to share knowledge and organize the process of collaborative learning. It is a participant-directed learning, which indicates a collective ownership of the learning process and, especially, the formulation of the problem. PBL is a much more demanding method and often requires organizational changes in order to practice more complex projects compared to the other well-known learning methods such as such as active learning, inquiry-based learning, experiential learning, co-operative learning, and case-based learning those not fulfilling all of the learning principles.

Competitions have a very significant role in developing the attention of the competitors on high technology, as proven on robotics field by the DARPA grand challenge competition. The Defense Advanced Research Projects Agency (DARPA) is a military organization with the aim to maintain the technological superiority for the US military from the encouraged and new ideas between the initiator people with fresh point of views. DARPA is well known with many important innovative scientific and technological projects such as ARPANET, the origin of Internet. DARPA started to organize a professional level robotic competition with the aim of carrying robotics into a new dimension by initiating employment of autonomous mobile robot vehicles in human environment. The first DARPA Grand Challenge Competition took place in March 2004. It was open to organizations, business, university and the school teams. From the 106 applicants, only 15 were reported to be ready in the competition field. The best vehicle managed to run only 5 percent of the complete route before failing. The competition closed without any winner of 1 million dollars grand prize, which was transferred to next competition. The next Grand Challenge was hold in

Nevada, on desert and mountain roads on October 8, 2005. From over 132 applicants, 23 finalists competed on a twisting, unpaved course. 22 of 23 vehicles traveled further than the 7.4 miles, a real success compared to the 2004 competition. 2005 DARPA Grand Challenge Program Manager R. Kurjanowicz (2007) evaluated the competition as a great success and explained the primary reason for the success by the composition of the teams —the students, engineers, scientists, and backyard mechanics— all inventors who brought fresh ideas to solve a very difficult technical problem. They were individuals, but learned to work together in teams. Unlike other prize events, the DARPA Grand Challenge set a specific date for the competition, and all the teams spent countless long hours overcoming setbacks to be there for the final event.

The Science and Innovation Club in Eastern Mediterranean University (EMU) has established in 2007 by the seamless efforts of leading students from Arts and Science, and Engineering Departments including a team of robotics hobbyists. This student club collected modest interest in EMU Spring Fair, and started the first ideas of organizing a robotics competition. The first international robotics competition of Northern Cyprus namely the International Joint Robotics Competition (IJRC) by EMU of TRNC, Shiraz University of Iran, Boğaziçi, Süleyman Demirel and Middle East Technical Universities of Turkey held on May 2008 at EMU. IJRC (2008) was composed of a set of intermediate and advance level of competitions. The relatively easier branches —Line following, Car race, Fight (to survive on an elevated platform), and Cooperated Fight— collected quiet many competitors while more difficult categories —Solo and Cooperative Labyrinth Discovery competitions— did not attract any competitors. In overall, the organization can be accepted as a successful initiation of an annual robotics competition, since the goal of IJRC was to encourage the students to involve in robotics competitions. It granted to the participants of the tutorials an opportunity to become familiar with robotics as an interesting field of research and study where exchanging of ideas is very important. IJRC-09 is already in progress for the competitions to take place at Süleyman Demirel University, Turkey.

IJRC applicants are supported to construct their robots by a set of tutorial sessions, demonstrations, competitions and demos, each being only 45 minutes, including the following topics: a) On the Competition, How to get Prepared, and Costs Involved; b) A Simplified Introduction to Electronics (Transistor, diode, LED/LCD-displays, measuring devices etc.); c) Introduction to Suitable Microcontrollers (AVR 8-bit/32-bit, 8051); d) PC Interfacing (Port Protocols, Parallel, Serial, USB, Windows XP/Vista/Linux Port communication); e) Simplified Image Processing (Color Detection, Path Recognition, Object Recognition); f) Programming for Microcontrollers (C, IC Programming, PIC Programming); g) Control (Feed forward, Feedback, On-Off, PID, Servo Control, PM-DC motors, PWM); h) Embedded/HLL Programming (C++ for Microcontrollers, BASIC); i) Sensors (Infrared Detection, Range Finder, Acceleration/Force/Torque/Velocity/Pressure, Shaft Encoders); j) Motors and Actuators (DC, Servo, Stepper, Driving Circuits, PWM); k) Embedded Boards (ICOP, PC104, WinXPe, Linux Embedded); l) Mechanics (Gears, Materials for Gears); m) Dissecting a Robot (Line following, SUMO, CLD). The training modules of the tutorials cover almost all of the technical knowledge the trainees may need for constructing their own mobile robots. In this respect, IJRC creates a very effective extra-curriculum activity opportunity to learn mechatronics principles through PBL.

Mechatronics is a young branch of engineering that boils the mechanics, electronics and control software in the same pot to design and develops various devices, instruments and systems. Billingsley (2006) wrote that mobile robots are a fascinating application of mechatronics. A competition robot is a typical mechatronics device based on three main components: a) Mechanical structure that carries the body and electro-mechanical parts such as actuators and motors, as well as transmitting the desired motion to the necessary elements, b) Electronics that enables usage of several sensory elements, and drivers for actuators, c) Computational power generated by the embedded processor which gives the programmed intelligence to the mechatronics device. Building a competition robot from available components requires a wide range of skills even if it is built by the ready made kits. Some of them are electronics for the motor drivers, power supplies, sensors and microcontroller interfaces; building the mechanical parts such as the platform with a frame to carry the whole system, and the covers to protect the components from the unexpected environmental effects; and programming a microcontroller to get the desired actions from the robot. Two important skills that cannot be developed from reading books and attending tutorials are patience and the willingness to learn. Both are absolutely essential for the competitor to build and prepare their own working robots for the competition as stated by (McComb at all 2006).

In this paper we explain our methodology and procedure in preparing the tutorials to construct embedded controllers for simple competition oriented robots, especially for those who want to have a quick start without any background knowledge about embedded controllers and robotics. The following three sections contains the educational background of the expected and actual audience, social learning approach, the contents including the demonstration of IC programming processes in the tutorials. In the last two sections we evaluated the success of the tutorials and IJRC, concluding on the benefits of the tutorials.

Expected and actual audience of the tutorial

Considering IJRC as an extra-curriculum activity suitable to PBL method, the authors (Bodur 2008, Bodur and Pousti, 2008) are involved in the tutorial series voluntarily to prepare and present the two tutorial sessions on "*Control*" and "*Programming for Microcontrollers*". It was the first IJRC event, open to all students, BS and MS, and there was no information about the distribution of the competitor candidates from the *Art and Science* and *Engineering* Faculties. We started to design the tutorial sessions expecting an audience at least at their third academic semesters, which implies that they have taken freshmen calculus, and physics courses both on mechanics and electricity. We expected some *Art and Science* students to be among the competitors, with enthusiasm and motivation to learn application oriented practice on microcontrollers and control. On the other side, we expected the majority from senior BS engineering students, and even some MS students to attend to our tutorials to determine the feasibility of entering to competitions. For them, the challenge was to transform their accumulated theoretical and conceptual knowledge to practical implementation of a mobile robot in a short period of time.

The attendance lists of both tutorials were consistently around 30 students, which consists of 24 regular attendees who took an attendance certificate for complete set of IJRC tutorials, and some of the IJRC competitors who did not aim to get attendance certificate. Indeed, one of the attendees was a member of the winner of Line-tracking competition. However, it is not possible to claim a contribution of the tutorial on the success of their robot, since the robot was fully working before the tutorial. At the introductory interaction right before the tutorials we observed that most of the trainees were familiar with the computers and microcontrollers, and many of them had prior practice at least on one high level microcontroller programming language such as C or Basic.

Learning and social approach of the tutorial and competition

The tutorial alone is only a small component of the overall competition, and thus we shall consider the social feature of the tutorial together with the competition. The effort for building a competition robot is not in the affordable magnitude by a single student. This fact naturally forces the competitors to work in teams of two or three, which satisfies the team-based learning feature of PBL. The teams contacted us after the tutorial hour to discuss the problems related to their competition robots, which verifies the team based learning process. From the contacts with these teams, we know that they did not assemble only for the competition, but most of them were already very close friends prior to the competition, mostly because they have the same hobbies and preferences.

The learning approach of our tutorials is directly a consequence of the problems defined by IJRC. The design and implementation problem of a competition robot has no trivial solutions, and requires the combinational utilization of the material and intellectual resources to get the best performance in the competitions. Both the design and the implementation require well organized team-project management where learning is an essential component for improving the design to the successful product.

Contents of the tutorials

Microcontrollers are the core of the embedded system to implement the control algorithms required for a mechatronics system as stated by Billingsley (2006). A microcontroller is the dedicated programmable computer in a chip that sends control signals to the indicators and actuators of the robot. It is impossible to control the motion of a competition robot without a microcontroller which works as the computer of the robot. In this respect, a microcontroller is an inevitable item of a successful competition robot. One or more microcontrollers are embedded in a typical competition robot to implement several intelligent control algorithms on collected sensory data. Control theory provides the systematic methods, procedures and algorithms to build stable control systems which shall be implemented by the microcontroller software of the robot. A variety of microcontroller families are suitable for the competition robots, each of them has a different machine or assembly language. A rich literature on some of the suitable microcontrollers is available such as Bates (2008), Ibrahim (2006, 2008), Jivan et al (2008), Predko (2007), Pont (2002), Wilmshurst (2007).

Features of C Programming Language. Many embedded system authorities are in agreement on the benefits of C programming language for the following reasons as listed by Zurell K. (2000). It helps to abstract the architecture and keep from getting lost in opcode sequences and assembly coding. It makes your program portable within and between the microcontroller families, which can be useful to reduce the price as well as to port the application to more improved microcontrollers. It reduces the cost of project by reducing the programming time by available library functions and simplifying the documentation efforts. It reduces implementation time, and allows you to spend more time on algorithm. It reduces the debugging time because C codes are much compact and easier to grasp than assembly codes.

Creating new coding projects in C are an easy and routine task. C is a well standardized mid-level modular programming language and very compact compared to the assembly, making the documentation easier. C is widely used in industry to program microcontrollers. If a designer faces to a problem during the microcontroller programming it can be solved by surfing through the internet and finding available online sources and even discuss with other experienced people.

C is also common in many other fields of science and engineering. Most of the scientists and engineers are familiar with C as a well known programming language. We can expand its benefits further considering the much shorter learning time of C language compared to the assembly languages. With these superior mid-level properties C language is the common language in the embedded system industry, with over 60 percent, followed by all assembly languages and other high level languages such as C++ and Java. C programming language is a mid-level coding language with high level features for accessing hardware. Most C compilers also allow the assembly codes to be embedded into the C source codes.

Along with a C compiler, code developers need an Integrated Development Environment (IDE) and a hybrid circuit simulation environment which support their C compiler. These tools are included to the contents of the tutorial for fast and simple coding and debugging of the microcontrollers and peripheral control circuits.

The control tutorial is carefully filtered from all confusing theoretical knowledge which is not necessary for control of mobile robots. Instead of summarizing the control theory we described the DC and stepper motors with examples. The concepts of open-loop and closed-loop control, the concept of feed back sensors, on-off control, proportional (P), integral (I) and derivative (D) control methods are explained with effects on the control loop stability. Pulse-width-modulation (PWM) and its implementation for a DC motor control are included into the demonstration section of the tutorial. The paper concludes the educational method with a set of sample P, PD, PID and on-off line tracking control applications.

Demonstration of IC Programming. Microcontrollers have different families based on their producers and their goal. Some of the well known microcontrollers for mobile robotic applications are 8051, Motorola M68332 and Microchip PIC16/18. From the large set of suitable microcontroller families, we decided to use PIC16/PIC18 family for its availability in local markets as well as availability of freely distributed educational development tools such as compilers and integrated development environments (IDE). In programming PIC microcontrollers the most important reference is the device datasheet by Microchip (2002). Huge amount of application sheets and sample programs are available in the manufacturers' web site "www.microchip.com". C program can be conveniently coded in MPLAB IDE as a CC8E project. Thereafter, the code needs compilation to HEX file, and the hex code is transferred to PIC16F452 using an IC-programmer-device. Due to the short time allocated for the tutorial we preferred to show the multimedia video of the programming process.

The details of microcontrollers may be quite confusing for a novice competitor. Once the trainee learns how to program a PIC device, the details may be gained by electronics and microprocessor courses professionally. For this reason, the demonstration is focused on anatomy and implementation of a very simple line following robot. The compiled program code is transferred to the microcontroller with the aid of an IC-programmer tool.

The sensors and motors as input/output peripherals should be managed by the microcontroller. The sensors collect the signals from the environment, and send them to the microcontroller for processing. Depending on the result of the processing, the microcontroller sends appropriate signals to the actuators for the next movement.

Coding Example with ADC. A microcontroller usually contains an Analogue to Digital Converter (ADC) to convert analog voltage to digital value. The trainees doesn't need to know the fine details of this conversion, it is enough to know that microcontroller has some pins for ADC applications accessible through some registers. The details are explained in several reference books, and can be accessed on demand. The physical sensors feeds analogue signals to the ADC input of the microcontroller. ADC converts them to the digital values to be processed by the microcontroller to control the system components like motors, LED and counters. Programming an ADC is almost similar for all applications. In the demonstration, a potentiometer produces an analog voltage, and the programmed controller displays the value of this analog voltage in digital form after A/D conversion. The complete coding and designed is available in the tutorial notes.

Control Examples. A microcontroller manages the control of all peripheral components of the robot. The On-Off and PID control are two well known control methods included in to the tutorials. The behavior of a typical mechanical system is simulated with a second order RC circuit in the simulation demonstration. PID is the classical solution to reduce the offset and overshoot of the second order systems. PID and on-off control are applied to the RC circuit only by modifying the coding of the microcontroller.

The demonstrated line tracking robot was implemented as a design project by senior Computer Engineering students, Dundar and Cango (2007). It is made of a toy-car with two dc-motors to move the platform. The applied control is essentially an on-off control. The control function is a combinational Boolean function of five optical sensor inputs, to decide on four motor control output signals: forward, backward, left turn, and right run.

Evaluation of the Tutorials and Competitions

Evaluation the success of a one-shot action is possible with interviews rather than statistical analysis, as Cohen et al. (2005) wrote about the evaluation process in educational research. We may mark our tutorial as a fail considering that only one of 24 attendees could complete the construction of a robot and used it in the competitions. But it may be considered as a great success since that competitor won the first price of the competition. Yet, it can be considered as a fail since that robot was ready to competitions before the tutorials. Thus our approach to measure of success will not based on the number of winners and competing teams attended to the tutorials. First of all, the feedback collected from the attendees indicates that the tutorials were successful to start a motivation among the students to prepare for the next competitions. For example, we see the effect of the motivation in the form of increasing interest to the Embedded System Design course at Computer Engineering Department.

Conclusion

Extra-curricular activities such as a robotics competition may provide an opportunity to apply problem/project based learning methodology in Science and Engineering Education. A startup tutorial for the controller design of mobile competition robots is introduced as a robotic educational technique in this paper. Motivation is one of the most important factors in competitions. We observed that most of the students interested into IJRC robotics competition is from Engineering Faculty. Although training courses are prepared considering both Science and Engineering students, most of the trainees and competitors are engineers.

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Investigation of physics teachers' knowledge and using ability the new learning and assessment approaches

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Abstract

In this research, it has been studied to identify what the opinions of physics teachers in knowing and using new learning and alternative assessment approaches. The universe of research is consisted of teacher who is working in Isparta city. The Teacher Knowledge Form (TKF) was prepared and for determines teachers' personal information. The New Learning and Alternative Assessment Approaches Teacher Questionnaire (NLAATQ) developed by researcher with 5 Likert type has been used to determine the teachers' knowledge level and using situation of new learning and alternative assessment approaches. The data which were obtained with data collection method have been analysed using frequency, percentage, arithmetic average, standard to resort and t-test, suitable for the purposes. The results of analysis have been commented by getting use of SPSS. The results of research, have determined that teachers' lacked in knowledge and the application of the new learning and alternative assessment approaches. The lack of teachers was differentiated according to seniority, school of graduation, age. Another result was that the majority of teachers stated that they all needed in-service training about new learning and assessment approaches.

Introduction

New teaching strategies that emphasise student-centred techniques have been introduced through global trends. In utilising these strategies, students are encouraged to be involved in the learning processes and activities requiring intellectual participation (Chanchalor and Chomphutong, 2004). The teacher-centred learning strategies are described as focusing on the teacher transmitting knowledge from the expert to the novice. In contrast, the student-oriented learning strategies are to focus on the students' learning and 'what students do to achieve this, rather than what the teacher does' (Harden and Crosby, 2000). Alternatively, a student-centred approach is one in which teachers adopt a student-centred strategy to help their students change and reconstruct their views or concepts of the phenomena they are studying, and so the teacher has to focus on what the students are doing in the teaching-learning situation. The teacher must realise that he/she cannot simply transmit the new knowledge or concepts to the students, (Trigwell and Prosser, 1996).

Alternative forms of assessment include authentic assessment, performance assessments, portfolios, journals, and other forms of assessment that involve the active construction of meaning rather than the passive regurgitation of isolated facts. Alternative assessments highlight opportunities for instruction to foster reasoning and thinking with acquired knowledge (Baxter and et al, 1996). In conjunction with the current educational reform movements, there has been an interest in assessing higher-order thinking, reasoning, problem-solving, and conceptual understanding of subject matter. Consequently, implementation of alternative forms of assessment that require thinking skills and are consistent with cognitive theories of learning has emerged as a need (Maeroff, 1991).

Some effective contemporary student-centred teaching and learning approaches such as Constructivism, Discovery Learning (Bruner), IM Theory, Project Based Learning, 5E Learning Cycle Model, Brain-Based Learning, Research Based Learning, Problem Based Learning, Cooperative Learning, Active Learning, Life Long Learning, Mastery learning (Bloom), Kolb's experiential learning model, Predict Observe Explain (POE). And alternative assessment approaches, Rubrics, Concept Maps, Vee diagram, Structural Grid, Diagnostic Tree, Self assessment, Peer assessment, Portfolio, Attitude Scales, Performance based assessment, Student journals, Projects, Reports, Interviews, Concept Cartoons (Airasian,1991 ;Allen, 1997; Bloom,1979; Bruner, 1961; Bybee,1997; Cole and et al, 2002; Dewey, 1938; Dochy and et al,1999; Egan,1972; Karahan,2007; Keogh and Naylor,1999; Klenowski,1995; Kolb,1984; Malinowski and Johnson, 2001; Maypole and Davies, 2001; Novak and Musonda, 1991; Novak, Gowin 1984; Paulson and et al,1991; Ramsden, 1998; Richmond and Cummings, 2005; Shepardson, 1999 ; Silberman, 1996; Stevens and Goldberg, 2001; Stiggins, 2001; White and Gunstone, 1992;).

The purpose of study was to further examine associations among physics teachers' using and knowledge level of new learning and alternative assessment approaches. Based on the purposes of the study, following research questions were formulated and addressed in this study: Is there a relationship between physics teachers' using and knowledge level of new learning and alternative assessment approaches and their ages/seniority/gender?

Material and Methods

"Survey Model" was employed in this research by using the questionnaire, which had been developed by researchers. The Teacher Knowledge Form (TKF) was prepared to determine teachers' personal information. Physics teachers' personal information that age, gender, graduated faculty, length of service (seniority). The New Learning and Alternative Assessment Approaches Teacher Questionnaire (NLAATQ) was utilized to identified participants for the study physics teachers who worked in the secondary schools located in Isparta, province of Turkey were selected to collect data. Data were collected, between 2007 – 2008 educational term. A questionnaire was used as a survey instrument. The items of questionnaire are likert type response format in which the respondents were to choose. To ascertain the reliability of the instrument after modification, it was administered on 20 respondents which were not part of the sample using test- retest method. The reliability co-efficient trough a cronbach alpha yielded an r = 0.97. Face validity of the questionnaire had been evaluated by two independent experts in the field and two experts from the faculty of education. All producers and experts agreed upon appropriateness of each item. The results of analysis have been commented by getting use of SPSS.

NLTAAQ which for prepared to investigate the physics teachers' using and knowledge level of new learning and alternative approaches, two questions was asked to respondents. First question: ''How much information about new learning / alternative assessment approaches?. Answers of this question, likert type format, very good, good, satisfactory, poor, very poor/ non existence. The second question: "What is frequency of using new learning / alternative assessment approaches?" Answers of question, likert type format, very high, medium-high, medium, low, never.

Results

The number of physics teacher reached was 20. The profile of the respondents is as in Table1.

Table 1. Physics Teachers' Profile

		Frequency (f)	Percentage (%)
Graduation			
	Science & Art Faculty	6	30.0
	Faculty of Education	14	70.0
Gender			
	Female	5	25.0
	Male	15	75.0
Age			
	24-28 yrs	0	0.0
	29-33 yrs	1	5.0
	34-38 yrs	6	30.0
	39-43 yrs	8	40.0
	44-over	5	25.0
Seniority			
	-2 yrs	0	0.0
	3-5 yrs	0	0.0
	6-8 yrs	0	0.0
	9-11 yrs	2	10.0
	12-15 yrs	4	20.0
	15-over	14	70.0

As can be seen in Table 1, the distributions of ages heavily pile up on the ages between 34-38 and 39-43 years. Participants' teaching experience varied from 9-11 years to over 15 years. Considering that the seniority of physics teachers heavily piles up on 15-over years. The teachers responding to the survey were female (25.0%) and male (75.0%). Accordingly, as seen in Table 1, (30.0 %) of the teachers graduated Science & Art Faculty and (70.0 %) of the teachers graduated Faculty of Education.

As indicated in Table 2, regarding the level of physics teachers' information of new learning approaches, MI Theory (15.0%), Constructivism, Discovery Learning, 5E Learning Cycle Model, Problem Based Learning, Active Learning (5.0%) were scored as high level of information. Other approaches were scored as good, satisfactory and poor level of information. Moreover, Brain Based Learning (30.0%), Kolb's Learning (20.0%), 5E Learning Cycle Model (15.0%), Discovery Learning and MI Theory (5.0%) were indicated as "very poor/non existence information'' physics teachers. Most of physics teachers' information level of new approaches was scored as satisfactory. Kolb's learning approaches were scored as good (5.0%), satisfactory (25.0), poor (50.0%), very poor (20.0%) level of information.

Table 2: Physics Teachers' Level of Knowledge New Learning Approaches

	Very good		Good		Satisfactory		Poor		V.poor/Non existence	
	f	%	f	%	f	%	f	%	f	%
Constructivism	1	5.0	1	5.0	13	65.0	5	25.0	0	0.0
Discovery Learning	1	5.0	5	25.0	7	35.0	6	30.0	1	5.0
MI Theory	3	15.0	5	25.0	9	45.0	2	10.0	1	5.0
Project Based Learning	0	0.0	4	20.0	13	65.0	3	15.0	0	0.0
5E Learning Cycle Model	1	5.0	2	10.0	9	45.0	5	25.0	3	15.0
Brain Based Learning	0	0.0	6	30.0	6	30.0	2	10.0	6	30.0
Research Based Learning	0	0.0	9	45.0	9	45.0	2	10.0	0	0.0
Problem Based Learning	1	5.0	7	35.0	9	45.0	3	15.0	0	0.0
Cooperative Learning	0	0.0	6	30.0	12	60.0	2	10.0	0	0.0
Active Learning	1	5.0	10	50.0	6	30.0	3	15.0	0	0.0
Life Long Learning	0	0.0	8	40.0	11	55.0	1	5.0	0	0.0
Mastery Learning	0	0.0	6	30.0	10	50.0	4	20.0	0	0.0
Kolb's Learning	0	0.0	1	5.0	5	25.0	10	50.0	4	20.0
Predict Observe Explain (POE)	0	0.0	5	25.0	12	60.0	3	15.0	0	0.0

Table 3. Physics Teachers' Level of Knowledge Alternative Assessment Approaches

	Very good		Good		Satisfactory		Poor		V.poor/Non existence	
	f	%	f	%	f	%	f	%	f	%
Rubrics	0	0.0	1	5.0	4	20.0	5	25.0	10	50.0
Concept Maps	0	0.0	3	15.0	8	40.0	5	25.0	4	20.0
Vee Diagrams	0	0.0	1	5.0	5	25.0	7	35.0	7	35.0
Structural Grid	0	0.0	0	0.0	4	20.0	7	35.0	9	45.0
Diagnostic Tree	0	0.0	1	5.0	7	35.0	1	5.0	11	55.0
Self Assessment	1	5.0	4	20.0	6	30.0	6	30.0	3	15.0
Peer Assessment	1	5.0	3	15.0	9	45.0	4	20.0	3	15.0
Portfolio	0	0.0	6	30.0	9	45.0	5	25.0	0	0.0
Attitude Scales	0	0.0	1	5.0	8	40.0	6	30.0	5	25.0
Performance Based Assessment	0	0.0	3	15.0	13	65.0	3	15.0	0	0.0
Student Journals	0	0.0	2	10.0	8	40.0	7	35.0	3	15.0
Projects	0	0.0	2	10.0	4	20.0	10	50.0	4	20.0
Reports	1	5.0	6	30.0	9	45.0	3	15.0	1	5.0
Poster Presentation	1	5.0	7	35.0	6	30.0	3	15.0	3	15.0
Interviews	1	5.0	9	45.0	8	40.0	1	5.0	1	5.0
Concept Cartoons	0	0.0	0	0.0	11	55.0	5	25.0	4	20.0

As indicated in Table 3, regarding the level of physics teachers' information of alternative assessment approaches, Self Assessment, Peer Assessment, Reports, Poster Presentation, Interviews (5.0%) were scored as high level of information. Other approaches were scored as good, satisfactory, poor and very poor level of information. Moreover, Diagnostic Tree (55.0%), Rubrics (50.0%), Structural Grid (45.0%), Vee Diagrams (35.0%), Attitude Scales (25.0%), Projects, Concept Cartoons and Concept Maps (20.0%), Self Assessment, Peer Assessment, Student Journals and Poster Presentation(15.0%), Poster Presentation and Interviews (5.0%) were indicated as "very poor/non existence information'' physics teachers. Most of physics teachers' information level of new approaches was scored as satisfactory and poor. Rubrics, Diagnostic Tree, Structural Grid and Vee Diagram are the lowest level of information.

Table 4. Physics Teachers' Level of Using New Learning Approaches

	Very high		Medium-high		Medium		Low		Never	
	f	%	f	%	f	%	f	%	f	%
Constructivism	0	0.0	3	15.0	6	30.0	10	50.0	1	5.0
Discovery Learning	1	5.0	5	25.0	2	10.0	9	45.0	3	15.0
MI Theory	1	5.0	4	20.0	7	35.0	6	30.0	2	10.0
Project Based Learning	0	0.0	2	10.0	9	45.0	8	40.0	1	5.0
5E Learning Cycle Model	1	5.0	1	5.0	4	20.0	10	50.0	4	20.0
Brain Based Learning	0	0.0	5	25.0	4	20.0	3	15.0	8	40.0
Research Based Learning	0	0.0	3	15.0	13	65.0	3	15.0	1	5.0
Problem Based Learning	0	0.0	5	25.0	8	40.0	3	15.0	4	20.0
Cooperative Learning	0	0.0	4	20.0	5	25.0	8	40.0	3	15.0
Active Learning	2	10.0	5	25.0	4	20.0	8	40.0	1	5.0
Life Long Learning	0	0.0	3	15.0	11	55.0	5	25.0	1	5.0
Mastery Learning	0	0.0	6	30.0	5	25.0	6	30.0	3	15.0
Kolb's Learning	0	0.0	1	5.0	2	10.0	9	45.0	8	40.0
Predict Observe Explain (POE)	0	0.0	4	20.0	5	25.0	9	45.0	1	5.0

As indicated in Table 4, regarding the level of physics teachers' use of new learning approaches, Active Learning (10.0%), Discovery Learning, MI Theory and 5E Learning Cycle Model (5.0%) were scored as high level of use. Other approaches like Research Based Learning (65.0%), Life Long Learning (55.0%), Project Based Learning (45.0%), Problem Based Learning (40.0%), MI Theory (35.0%), Constructivism (30.0%), Mastery Learning, Predict Observe Explain (POE), and Cooperative Learning (25.0%) were scored as medium level of use. Moreover, Brain Based Learning and Kolb's Learning (40.0%), Problem Based Learning and 5E Learning Cycle Model (20.0%), Discovery Learning, Mastery Learning, and Cooperative Learning, (15.0%) were indicated as "never been used by physics teachers". Most of physics teachers' using level of new approaches was scored as medium and low.

As indicated in Table 5, regarding the level of physics teachers' use of alternative assessment approaches, Peer Assessment, Projects and Reports (5.0%) were scored as high level of use. Other approaches like Interviews (50.0%), Performance Based Assessment (40.0%), Reports (35.0%), Peer Assessment, Projects and Poster Presentation (25.0%), Diagnostic Tree, Self Assessment, Portfolio, Attitude Scales and Concept Cartoons (20.0%) were scored as medium level of use. Moreover, Diagnostic Tree (70.0%), Rubrics and Structural Grid (65.0%), Attitude Scales (55.0%), Vee Diagrams and Concept Cartoons (50.0%), Concept Maps (40.0%), Projects (30.0%), Self Assessment and Portfolio (25.0%), Peer Assessment, Reports and Poster Presentation (20.0%) were indicated as "never been used by physics teachers". Most of physics teachers' using level of alternative assessment approaches was scored as low and never.

Table 5. Physics Teachers' Level of Using Alternative Assessment Approaches

	Very high		Medium-high		Medium		Low		Never	
	f	%	f	%	f	%	f	%	f	%
Rubrics	0	0.0	1	5.0	3	15.0	3	15.0	13	65.0
Concept Maps	0	0.0	2	10.0	3	15.0	7	35.0	8	40.0
Vee Diagrams	0	0.0	1	5.0	1	5.0	8	40.0	10	50.0
Structural Grid	0	0.0	0	0.0	3	15.0	4	20.0	13	65.0
Diagnostic Tree	0	0.0	1	5.0	4	20.0	1	5.0	14	70.0
Self Assessment	0	0.0	6	30.0	4	20.0	5	25.0	5	25.0
Peer Assessment	1	5.0	3	15.0	5	25.0	7	35.0	4	20.0
Portfolio	0	0.0	4	20.0	4	20.0	7	35.0	5	25.0
Attitude Scales	0	0.0	1	5.0	4	20.0	4	20.0	11	55.0
Performance Based Assessment	0	0.0	4	20.0	8	40.0	7	35.0	1	5.0
Student Journals	0	0.0	2	10.0	3	15.0	5	25.0	10	50.0
Projects	1	5.0	2	10.0	5	25.0	6	30.0	6	30.0
Reports	1	5.0	1	5.0	7	35.0	7	35.0	4	20.0
Poster Presentation	0	0.0	2	10.0	5	25.0	9	45.0	4	20.0
Interviews	0	0.0	4	20.0	10	50.0	5	25.0	1	5.0
Concept Cartoons	0	0.0	0	0.0	4	20.0	6	30.0	10	50.0

Table 6 shows the analysis of physics teachers' perceptions about in-service training about new learning and alternative assessment approaches. Accordingly, 40.0% of the teachers indicated that they strongly agree with and 45.0 % of teachers indicated that agree with to participate in-service training. However, 5.0% of the teachers do not agree with and 5.0% of teachers strongly disagree with this opinion. Almost most of the teachers (85.0%) indicated that they want to participate in-service training about new learning and alternative assessment approaches.

Table 6. Perceptions df Physics Teachers About In-Service Training About New Learning and Alternative Assessment Approaches

I want to participate for in-service training about new learning and alternative assessment approaches.	Strongly Agree		Agree		Neutral		Disagree		Strongly Disagree	
	f	%	f	%	f	%	f	%	f	%
	8	40.0	9	45.0	1	5.0	1	5.0	1	5.0

Table 7 shows the analysis of physics teachers' perceptions about new physics curriculum and its applicability. 55.0% of the teachers indicated that new curriculum is applicable. However, 15.0% of the teachers do not agree with and 5.0% of teachers strongly disagree with this opinion. Almost most of the teachers (55.0%) indicated that they believe that the new physics curriculum is applicable.

Table 7. Perceptions of Physics Teachers About New Physics Curriculum

I believe that the new physics curriculums is applicable	Strongly Agree		Agree		Neutral		Disagree		Strongly Disagree	
	f	%	f	%	f	%	f	%	f	%
	0	0.0	11	55.0	5	25.0	3	15.0	1	5.0

The question of the study was if there were any significant differences in the criterion of "knowledge level of physics teacher" related to physics teachers' gender, age and seniority. A one-way ANOVA was carried out in analyzing related data. The analysis related to "knowledge level of physics teachers" criterion depending on physics teachers' gender, age, seniority.

Table 8. "Physics Teachers' Knowledge Level of New Learning And Alternative Assessment Approaches" Related to The Variables of Physics Teachers' Gender, Age, and Seniority.

		Sum of Squares	df	Mean Square	F	Sig.
Gender	Between Groups	120.417	1	120.417	.373	.549
	Within Groups	5808.133	18	322.674		
	Total	5928.550	19			
Age	Between Groups	170.842	3	56.947	.158	.923
	Within Groups	5757.708	16	359.857		
	Total	5928.550	19			
Seniority	Between Groups	80.371	2	40.186	.117	.890
	Within Groups	5848.179	17	344.011		
	Total	5928.550	19			

$p<0.05$

As it is seen on Table 8; gender, age and seniority of the physics teachers are not significant for the criterion of physics teachers' knowledge level of new learning and alternative assessment.

Discussion and Conclusion

According to this study, most of the physics teachers reported that they have lack of information new learning and alternative assessment approaches. Specifically, level of information of physics teachers at alternative assessment very low. Most of physics teachers' using level of alternative assessment approaches was scored as low and never. But, alternative assessment more effective than traditional assessment (Baxter and et al, 1996; Maeroff, 1991).

In general, the findings of this study support the results of other studies conducted in this area (Bridges,2000; Driver and et al,1978; Amer 1994;). Many studies (Birgin and Tutak, 2006; Çakan, 2004;Özsevgeç and et al., 2004) showed that teachers in Turkey don't have enough knowledge and experience about alternative assessment methods.It seems that effective use of new learning and alternative assessment approaches in physics classrooms would be expected from all physics teachers in the future. Some teachers might think that new learning and alternative assessment approaches can be a lot of time at course and teachers noted that they have many problems at application of alternative assessment approaches and they had not adapt new program (Doğan, 2005; Kılıç, E.D., 2007; Yılmaz,2006,). For this reason, most of physics teachers (85.0%) want to participate in-service training about new learning and alternative assessment approaches.

Based on the findings of this survey, the physics teachers' knowledge level of new learning and alternative assessment approaches was independent of their gender, age and seniority.

It is most important for a teacher utilise contemporary learning and assessment approaches. In this way, students become more active participants in the learning process wherever possible and take greater responsibility for their own learning and assessment. These approaches encourage deep level processing of information, make the students efficient problem solvers, and develop lifelong learning skills.

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Guided-inquiry in teaching science

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Abstract

In this presentation, we want to discuss and contrast few pedagogical paradigms that are most effective in science education. We focus in particular on the use of guided inquiry in teaching science subjects. Additionally, we deal with some applications of guided inquiry in lectures and labs. To illustrate how guided inquiry works in real life, we invoke a simple, yet edifying and practical, example from physics. We argue that when properly wielded, guided inquiry becomes a powerful tool educators can use to infuse students with skills which will enable them become experienced learners and independent inquirers. The aim here is to empower the students not only to construct and acquire knowledge on their own but also to master a number of essential skills, most notably creativiry, critical thinking, problems solving, communication, team-work, and responsibility.

Introduction

The roots of the scientific method and scientific inquiry can be traced back to two important dates. First, around year 1000, Ibn-Al-Haytham[1]--[2] was the first to have developed a methodology on the use of equipments to study natural science---optics.[10]--[12] Then around 1600, Francis Bacon and, later on, Rene Descartes had the foresight to lay down the foundations of the Scientific Method. Bacon and Descartes have independently developed the theoretical and experiential paradigms to study natural phenomena and extract quantitative results about them. As a result of their work, we now know that there are two ways of reaching the truth when dealing with natural phenomena:

- through disciplined rational, systematic, and axiomatic reasoning; this is the essence of Descarte's theoretical approach, and
- through experimentation--Baconian empiricism.

These new ideas insisted on the role of the scientist with respect to nature. The value of evidence (experimental or observed) led towards a scientific methodology in which empiricism played a central role. Bacon instituted a new method to reach conclusions: He introduced an inquiry-based method which called for a planned procedure of investigating all things natural; this marked a new turn in the rhetorical and theoretical framework for science. It was Newton who thereafter managed to mathematize the agenda of physics; he developed models by which the validity of theories are tested. Thanks to Newton, the authority of science has been accepted for centuries now.

The fact that scientific reasoning is so often successful is a remarkable property of the universe. So far, scientific inquiry is the best tool available to us humans to extract information from the universe we inhabit, because nature is dependable and predictable and the physical laws are reproducible, most notably in chemistry and physics.

The next logical step is how to educate and train our students to learn the methods of science and how to enable them become science-inquirers in their own rights. That is, what are the most effective teaching methods to produce students who are creative enough to become successful scientists or engineers?

In attempting to answer this question, we will consider and contrast the two essential teaching methods: the ***direct instruction method*** and the ***guided-inquiry method***.

Inquiry-based education

Before 1900, most educators viewed science primarily as a body of knowledge that students were to learn through ***direct instruction***. In this (direct) instruction paradigm, the teacher is a dispenser of knowledge and the role of the students is merely to amass this knowledge from the authority--the instructor.

Around 1910, John Dewey offered powerful criticisms to this perspective; he argued that science teaching gave too much emphasis to the accumulation of information and not enough to science as a way of thinking and an attitude of mind. Science is more than a body of knowledge to be learned; there is a process or method to learn as well. Dewey became a relentless campaigner to reform the educational system; he pointed out that the authoritarian, strict, pre-ordained knowledge approach of the traditional or direct instruction method was too concerned with delivering knowledge, and not enough with understanding students' actual experiences.[5]--[8] Dewey along with others---most notably, Bruner, Shwab, Piaget, Postman, Weingartner---called for the introduction of inquiry based instruction. Bruner argued that Inquiry-based learning was developed in response to a perceived failure of more traditional forms of instruction, where students were required simply to memorize instructional materials that is laden with facts.[3]--[4] He developed the concept of discovery learning which promoted learning as a process of constructing new ideas based on current or past knowledge. Students are encouraged to discover facts and relationships and continually build on what they already know. Inquiry learning can be viewed as a form of active learning where progress is assessed by how well students develop analytical and experimental skills rather than how much knowledge they possess.

Inquiry-based education is a student-centered method of education where the focus is on asking questions and encouraging students to ask questions which are meaningful to them, and which do not necessarily have easy answers. In this method, teachers are encouraged to avoid giving answers (whenever this is possible) in favor of asking more questions. As such, the central aim of inquiry-based learning is the requirement that learning should be based around student's questions and that students work collaboratively to solve problems rather than receiving direct instructions on what to do from the teacher. The role of the teacher reduces, therefore, to helping students navigate their way along the process of discovering knowledge on their own. In this form of instruction, ***the***

teacher is viewed as a facilitator of learning rather than a dispenser of knowledge.

The inquiry-based method was also advocated effectively by Neil Postman and Charles Weingartner.[9] They argued that our educational system is traditional and backward-looking; it produces students who cannot deal with change. They called for the elimination of the traditional classroom organization and the institution of an inquiry system. As mentioned above, this inquiry-based system of education must be student-centered and question-centered: it must consist of relevant questions (selected by the students as worth knowing the answers to) which will help students to develop and internalize concepts which are appropriate to reality; it must take place in a questioning, meaning-making atmosphere in which students ***learn by doing***; that is, the students learn how to become effective learners, while the teacher serves as a guide. This inquiry-based paradigm is aimed at providing the conditions for students to build progressively what they don't know on top of what they do, and for the teacher to understand, through close listening, what the students know and to encourage them to develop their own understanding.

So, by the 1970s, the rationale for inquiry as an approach to teaching science became evident. If students were to learn the methods of science, then how better to learn science than through active engagement in the process of inquiry itself. The fact that scientific reasoning is so often successful is a remarkable property of the universe we inhabit, because natural laws are dependable and reproducible.

The works of Dewey, Bruner, Piaget, Schwab, Postman, Weingartner and others influenced the nature of curriculum materials developed from the 1920s into the early 1970s. Their work led to a reform in education:

- This reform placed as much, if not more, emphasis on learning the processes of science (methodology) as on mastering the subject matter of science alone (contents).
- The underlying aim of these instructional ideas was the commitment to involve students in doing rather than being told or only reading about science.
- The main finding of these new studies is that students don't learn science through direct instruction, rather ***they construct their own knowledge from formal and informal experiences on their own.***

Direct-instruction versus guided-inquiry

Direct-Instruction Method. In the **traditional or direct-instruction method**, the teacher is the authority, the dispenser of knowledge. In traditional instruction classrooms, the role of the student consists essentially in amassing the knowledge and facts provided by the authority--the instructor. Once outside the classroom, the student is be expected to reflect on the material given to her/him in the classroom, to internalize it, and to master it so as to be tested later on. So, the various assessment exams are the main mechanism available to instructors to test their students' level of understanding.

Critics of the direct-instruction method point out that the student is reduced to a passive receiver of information/facts from the instructor. This method is often referred to as the confirmation or verification method. That is, the students are asked or expected to simply confirm a principle through a well prescribed activity when the results are known in advance. The critics contend that this method leaves the student with no room to practice or exercise her/his creativity. Everything is defined from start to finish for the student. In summary, the students end up confirming a principle through a prescribed activity when the results are known in advance.

Guided-Inquiry Method. First, what is inquiry? Inquiry applies to research as well as to teaching. In the realm of scientific research, and according to the US National Science Education Standards (NSES), inquiry is the process by which scientists pose questions about the natural world and seek answers and deep understanding and then formulate explanations of what they observe; in short, inquiry research deals with how science proceeds independently of the educational process. What about inquiry teaching? Inquiry teaching as used in the NSES has no precise operational definition; yet, it is understood to be something that promotes inquiry learning by the students. Inquiry learning requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations (NSES). *Inquiry learning is often described as learning with understanding.*

Now, what is guided-inquiry? It is the process used by the teachers to guide their students through projects by giving them starting questions, prompting new discussions with ideas and methods, or acting as supervisors in other ways. This can be initiated at the beginning of a course with students and followed by open-ended inquiry. The five "ritual" phases of guided-inquiry can by outlined as follows: The students are asked

- to engage with a scientific question, event, or phenomenon, connect this with what they already know, and motivate them to learn more;
- to explore ideas through hands-on activities, formulate and test hypotheses, solve problems, and offer explanations for what they observe;
- to analyze and interpret data, synthesize ideas, build models, and clarify concepts and explanations with teachers and other sources of scientific knowledge;
- to extend their new understanding and abilities and apply what they have learned to new situations; and finally,
- to review, synthesise, and assess, along with their teachers, what they have learned and how they have learned it.

Contrasting Direct-Instruction and Guided-inquiry. The amount of information and instructions given to the learner determine at which level of inquiry the given activity resides. As a result, ***the less is given to the learner the higher the level of inquiry the activity will be.*** To study a problem, one can identify three essential elements that must be addressed:

- **the problem:** one needs to define the problem (for instance, a natural phenomenon) to be studied;

- **the procedure:** to define or prescribe the methodology or procedure to be used to solve the problem (this includes the theoretical framework as well as the experimental procedure); and
- **the solution:** to obtain the results and formulate the solution.

In direct-instruction classrooms, everything is given to the students: the problem to study, the procedure to use, and the results that are expected to be obtained or confirmed. In guided-inquiry classrooms, however, only the problem is given to the students. Each group of students are expected to develop their own procedure and to pursue it relentlessly until they obtain the solution. So the students are asked to navigate on their own in developing assumptions and hypotheses, identify the proper methodology and the experimental procedure(s) to follow until they arrive at the solution. As shown in Table 1, students in traditional classrooms are given everything, whereas guided-inquiry students are given the strict minimum.

Table 1. Types of instructions or information given to the leaner in direct-instruction and guided-inquiry classrooms.

Teaching Method	Traditional Method	Guided Inquiry
Problem	Given	given
Procedure	Given	Not given
Solution	Given	Not given

Illustrative example from physics: The simple pendulum

As an illustration on how to implement the two methods in real classroom settings, let us consider an example from physics: the simple pendulum. The problem consists in finding the mathematical relation which gives the period T of a simple pendulum and express it in terms of the three parameters involved in the pendulum; namely, the length L of the string, the mass M of the bob or a small metallic sphere, and the initial angle θ from which the sphere is released. The solution is well known: the period T depends only on the pendulum's length L and on the acceleration due to gravity g:

$$T = 2\pi\sqrt{\frac{L}{g}}.$$

Let us now examine the practical steps involved in teaching the simple pendulum topic to students in a direct-instruction setting and in a guided-inquiry approach both in lectures and in labs.

The simple pendulum in a direct-instruction classroom or lab: How this topic is dealt with in a traditional lecture and in a traditional lab session? In lecture, instructors traditionally work out the mathematics involved and would derive the expression of T for the students. At best, the students will understand the method as well as the mathematical manipulations involved in the derivation; some students simply end up memorizing the procedure altogether with no real understanding.

In the lab, however, the problem is well defined for students at the start of the session, then a manual (or lab instructions) is given to them. The manual lists explicitly all the experimental steps involved and to be followed sequentially. In essence, the students will be asked to keep two parameters constant, while varying or changing only one parameter at a time. The students will be asked to carry out the various experiments, collect the data and prepare three plots of T versus the various three parameters. From these plots and the supporting data, the students will then conclude that the period is affected neither by M nor by θ; the period depends only on L. From the T versus L plot, they will be able to extract the formula mentioned above. That is, they will conclude that the period T is proportional to the square root of the pendulum's length L,

$$T \propto \sqrt{L},$$

and they should be able to find that the constant of proportionality is given by

$$2\pi / \sqrt{g}.$$

The simple pendulum in a guided-inquiry classroom or lab: In a guided-inquiry setting, the instructor begins by defining the problem—finding the period T of a pendulum in terms of the various parameters—for the students, encourages questions, and then steps aside to allow them to embark on carrying out the various steps of inquiry-based learning till they arrive at the solution; the instructor remains supervising as a mere guide just in case a deadlock arises. At the end, the instructor steps in to help the students reflect on the entire process, helps them internalize the methodology, and then seeks new extensions of the results obtained. In short, *instead of acting like an authority or a sage on the stage, the instructor operates like a guide on the side.*

As hands-on activities are an integral part of inquiry-based learning, the instructor should prepare the necessary components needed to study the simple pendulum; namely, the instructor should prepare a sufficient sets of strings, small metallic spheres, stop-watches, protractors, and rulers.

In a classroom setting, the instructor would define the problem, divides the classroom into small groups of students, prepares enough sets of hands-on components, and then instructs the students to start their inquiry-based investigation of the problem. An important remark needs to be made at this level. If the instructor has enough time (say about an hour) to devote to this single topic of finding the pendulum's period T, I would allow all groups to investigate the connection between T and all of the pendulum's parameters—the length L of the string, the mass M of the metallic sphere, and the initial angle θ. In this case all groups should carry out comprehensive investigations and should be able to derive the formula of T listed above. However, if the instructor has only a limited amount of time to devote to this topic (say only half an hour), I would divide the classroom into three groups and would ask each group to study the dependency of T on a single parameter; i.e., one group investigates the dependency of T on L, another group studies dependency of T on M, and the last group dependency of T on θ. Once they finish, the instructor would need to collect the results obtained by each of the three groups and would reach a conclusion about T with the participation of the entire class. The teacher may consider asking the students questions like these: How will the period T be affected when we go to a different planet? Will the period on this planet be larger or smaller than T on earth?

In a guided-inquiry lab setting, the instructor would define the problem, divides the classroom into small groups of students, and then asks them to develop the experimental method to use, and then decide on which hands-on components they would need to study the pendulum; the lab should be equipped with sufficient sets of hands-on components and equipments. In a (guided-inquiry) lab setting, the instructor does not need to define the various hands-on components needed in the experimentation or measurements phase. He/she needs to leave this task for the students to define on their own. Again, the instructor would simply serve as an observer or a guide to ensure that none of the groups is stuck.

In summarizing the results of the simple pendulum example, we want to note that in direct-instruction classrooms or labs, the students are given everything: the problem, the procedure, and the formula. The students are here only to confirm their teacher's result(s). In a guided-inquiry classroom or lab, however, the students are given the problem only; namely to find the mathematical relation between the period T and the three parameters L, M, and θ. The students are the ones who have to develop the procedure to be used to find the mathematical relation for the pendulum's period, and then to implement it until they find the result; that is, the students investigate a teacher-presented question using <u>student designed/selected procedures, and discovering or arriving at the result on their own.</u>

Two Important remarks. Once the students have finished from the simple pendulum exercise, the following outcomes occur:

- On the one hand, the students from direct-instruction classrooms or labs will not feel a sense of true ownership of the knowledge involved; they would feel that they have merely confirmed someone else's claims or ideas. To some extent, as the critics have contended, the students are treated as passive agents who are involved in verifying the claims of others. This process teaches the students conformity and deference or submission to authority. This method can be boring and inhibits creativity, motivation, and independence.
- On the other hand, in the guided-inquiry classrooms, once the students manage to derive the relation for T, they will feel that they have discovered it themselves; they take ownership of the entire process. They have actively defined the procedure, carried out the measurements, analyzed the data, and came up with the right conclusion. The students here are active participants in acquiring and constructing their own knowledge; they take possession and ownership of the entire process. This procedure empowers the students to become experienced learners and independent inquirers

This illustrative example indicates that guided-inquiry has all the ingredients of an effective and a superior method as compared to direct-instruction. It empowers the students to master a number of essential skills, most notably creativity, critical thinking, problems solving, communication, team-work, responsibility, and independence among students.

Our experience at JSU: Projects IMPACTSEED and NASA tools for teachers.

We have been offering at JSU (Jacksonville State University) two outreach projects that utilized guided-inquiry in their professional development porgrams:

- The first project—IMPACTSEED (IMproving Physics And Chemistry Teaching in SEcondary Education)—is grant funded by the Alabama Commission on Higher Education as part of the No Child Left Behind (NCLB) act. IMPACTSEED aims at helping high school teachers learn and master the various physics topics. Teachers are offered year-round support through a rich variety of programs, most notably a series of make-and-take technology workshops. Through our inquiry-based, hands-on approach, we have identified a number of ways of bringing technology into physics classrooms. A number of technology projects were developed to show students how chemistry and physics connect to the technological devices around us.
- The second projecy—NASA Tools for Teachers—is funded by NASA. In this project, we focus on offering year-round professional development for 6—12 math and science teachers within the context of an inquiry-based, hands-on approach. These efforts are aimed eventually at engaging students and heightening their interest in STEM (Science, Technology, Engineering, and Mathematics) fields and at encouraging them to pursue educational disciplines that are critical to NASA's future engineering, scientific, and technical missions. We have been offering a rich collection of make-and-take technology projects which were designed with a primary focus on classroom inquiry-based, hands-on instruction. These activities are designed to motivate students continue their study of science and mathematics throughout their school career and encourage them to pursue STEM related workforce opportunities.

These projects have resulted from a joint collaborations between JSU's College of Arts and Sciences, the College of Education and Professional Studies, and more than two dozens of school districts. These two projects have impacted ten of thousands of high school students. In both of these two projects, high school math, chemistry, and physics teachers are offered year-round support through a rich variety of programs. We have identified a number of ways of bringing technology into math and science classrooms.[13]--[14] A number of nake-and-take technology projects were developed to show instructors (and hence their students) how to teach science in an inquiry-based, hands-on setting; additionally, and through this series of make-and-take technology projects, we show them how math, chemistry, and physics connect to the technological devices around us. In turn, when the teachers assign these projects to their students, the students will be able to see first-hand—by doing, rather than being told—that math, chemisty, and physics are not dry, abstract subjects. We found this approach to be particularly effective in heightening the students' interest in math and science. As a result of many years of offering IMPACTSEED, we have been able to record measurable improvement in the chemistry and physics backgrounds of freshman students coming to JSU from high schools participating in IMPACTSEED; additionally, we have seen a consistent increase in the number of students majoring in science at JSU, most notably in chemistry.

Concluding thoughts

The discussion outlined above can be synthesized in the following elements:

- Teaching by telling (direct-instruction) does not work for most students.
- Knowledge is personal; students learn best when they are actively involved in constructing their own understanding and when they are doing rather than being told. Guided-inquiry is far superior to direct-instruction.

We currently face a paradoxical situation in the field of science education: The teaching method that was proven not to work—the Direction-Instruction method—is practiced on a massive scale, while the method that was proven to work effectively—the Guided-Inquiry method—is practiced on a terribly much smaller scale. More than 90% of k—16 science education is carried out using direct-instruction, while only about 10% is inquiry-based. This unfortunate asymmetry is attributable to a number of reasons:

- The immense majority of the current generation of k—16 instructors have not been trained, and hence are not prepared, to teach in an inquiry-based setting. Most of them have received training in the direct-instruction method only; *instructors end up teaching in the same way they have been taught.* It will take considerable time, effort, and resources to train the next generation of teachers in inquiry-based instruction.
- In the various fields of science (biology, chemistry, math, and physics), guided-inquiry has been tried and tested on a *limited number of highly "idealized" cases only*. To prepare k—16 educational institutions for inquiry-based instruction, considerable work has yet to be deployed to develop curricula and lesson plans that will make inquiry-based teaching practical in the various fields of science.
- Guided-inquiry works superbly fine for small classes, but becomes quite intractable for large classrooms. This has been a debilitating inhibitor to the expansion of the guided-inquiry method.
- Another important factor that has inhibited the expansion of inquiry-based teaching is the economic factor. Inquiry-instruction is more expensive than direct-instruction, for it requires smaller classrooms and hence more teachers, more classrooms (i.e., more facilities), and more hands-on equipments.

The use of Guided-Inquiry in teaching science is still in its infancy: a lot of work remains to be done to develop field-tested, practical methods, and workable lesson plans and outlines so as to teach entire curricula of all science subjects in inquiry-based settings. This task is too demanding and too important to be left for individuals. To attack this problem effectively and methodically, wholesale resources have yet to be committed and deployed. For this, we need to marshal not only the intellectual might, talents, and resources of numerous institutions of higher learning but also the backing of governmental agencies as well as private organisations.

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Things that we can learn from praxis: attempts to overcome alienated learning within traditional teaching

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Abstract

Despite all criticism in the last decades, traditional mathematical teaching is largely prevalent in Brazil, mostly in schools which attend students from unprivileged social groups. Researchers in sociology of education field have consistently shown that this practice leads students to very restrictive learning processes and then tends to reproduce given social inequities. However in the mathematics education field there have been some alternatives concerning the teaching and learning process, and those alternatives can inspire changes in teaching practice, we would like to avoid a research method that doesn't suit teachers' reality. Therefore we decided to do a research inside a classroom, sharing the teacher's position with the teacher herself, facing the same tensions that she had to face quotidianly. As a result we learned that it is possible to overcome some aspects of traditional teaching without changing the school environment in a very artificial way.

Introduction

Traditional mathematical teaching and learning practices are characterized by memorization, reproduction of standardized procedures and individualized work. Those practices have been strongly criticized in the last decades mainly because they do not consider students reality and the cultural environments of students' families. In consequence, they make school knowledge seem something alien to the students (Carraher et al., 1988 and Boaler, 2000).

Nevertheless, despite all criticism, traditional teaching still prevails around the world and largely in Brazil especially in schools for working class students. This reality reproduces social inequities challenging us to understand why those practices are so prevalent in special in environments that need urgent transformations. In a first gaze to what happens inside schools we recognize pedagogical traditionalism in teachers' performances. Consequently it is quite common for one to attribute to teachers the responsibility for the teaching process as a whole (see, for instance, Anyon, 1981, and Zevenbergen, 2003). Nevertheless, findings from sociology of education field teach us that this is a social phenomenon related to the reproduction of given social conditions even by the unprivileged classes themselves. Researchers from different countries verified that working class students and their families pressure schools reinforcing traditional teaching (Jones, 1989, and Charlot, 1996).

When we take into account this perspective, we find out that this reproductive process is much more complex than it would be if teachers could overcome traditional teaching only by choice. In our understanding, many critical alternatives for mathematics education address their proposals to teachers without considering the strong pressures that the professionals are subjected to while working. That is why we agree with Skovsmose (2006) when he refers to researches that create prototypical classrooms where students are willing to learn. He says that those researches do not mention inherent tensions of school processes, thus they stay far? from real school conditions. Readers of those research reports, such as undergraduates who seek for alternatives to traditional teaching, can be led to the false impression that it is easy to transform school environment if a teacher, even without his/her peers support, adopts a critical framework and changes his/her practice.

However, even considering the difficulties that critical teachers have to face while experiencing innovations; we believe that it is possible to change given conditions at least at a minimum level. Thus we adopted a theoretical and methodological framework that would allow us to keep as close as possible to the work conditions that a teacher is subject in everyday life. To develop our research we chose a regular school in which traditional teaching was prevalent without any contesting movement. During four months we shared the teaching position with a fourth grade teacher who volunteered to participate in the research. In this coteaching process, the teacher and the researcher planned, taught and evaluated together fourteen classes, of one hour and a half in average. All the classes, but the first, were about geometry subjects.

Since the first meeting, the teacher prevented us of the parents who played a strong role in that school. Later we interviewed many of them. They were unanimous in considering that the school and especially the teacher were doing an excellent work. Through co-teaching we learned with the teacher some strategies that were very effective in obtaining students' and families' confidence. We also learned that the parents used students' notebooks to control the teacher's work. They compared their children's notebooks to others from other classes or even from other schools. So, we took those facts into account while proposing changes in teaching. What the co-teachers changed was the way the subjects were presented to the students. Instead of focusing in memorization of shape's names, the common practice in that school, the co-teachers developed many activities in which they allowed the students to creatively think to solve challenges. They also provided many notes and exercises that the students copied in their notebooks. Besides, they managed to link mathematics classes to one social event that occurred during the research: the fathers' day.

Based on our data, we argue that it is possible to promote significant changes in regular schools with school community support. We evaluate those changes taking from Marx (1844) the division of labor and the alienated labor concepts. From this perspective, the co-teachers changed the division of labor inside the class and thus allowed students to take control over their work, experiencing a non-alienated learning. We intend to present a study case that shows how working class students can involve themselves with the teachers' proposals when they are challenged and they can take control over their activities. While recognizing the significance of the process, the students can legitimize the novelties that teachers propose.

From now on, we will briefly describe the coteaching theoretical and methodological approach. Then we will present an overview of the research process with a more accurate description of an episode involving one student. Later we will analyze this episode based on Marxian ideas about alienated labor showing how this research can teach us something about viable alternatives to work in traditional school environments. To protect their identities, we will use pseudonymous for all the participants in the research.

Why adopting coteaching as a research method

Our main purpose was to explore possibilities in teaching that eventually were available in regular schools that serve students from unprivileged classes. From the very beginning we were aware of the fact that schools are structures integrated in a net of other ones that perform production and reproduction of social life (Sewell, 2005). It is likely to say that schools do not work by themselves as if they were independent from society as a whole.

Maybe because we live in a society in which the difference between the poorest and the richest is one of the greatest in the world, we can strongly identify the political role that we perform as teachers, in the way it is described by Freire (1968, 1978). Besides we know through experience that it is quite difficult to find a general theory that could help teachers in a pedagogical matter. In mathematical education, for instance, we could think about applying a method inspired by a constructivist based theory, mathematical modeling, or even by an etnomathematical approach.

We are not denying all these research fields nor others. We acknowledge that each one can brighten at least part of our teaching experiences, as well as do researches from sociology of education field. But many problems arise when we try to import any method that was created accordingly to challenges found in another reality. If so, we run the risk of creating a very artificial environment, or a prototypical classroom in Skovsmose's words, that can work only in very specific conditions.

We needed a research method that would allow us to explore innovations in teaching and, at the same time, would keep the work conditions as close as possible from the regular ones that the teachers have in everyday life. Of course the regular work conditions are changed immediately when we interfere with the school environment in any way and, even worse, when we explicitly intend to explore innovations. Therefore, on one hand we were approaching a traditional school and accepting it's given conditions but on the other, we acknowledged that this interaction would have implications for all people that were involved.

In our understanding the way to deal with this contradiction would be through dialoguing with the teacher, trying to share our perspectives and deciding together each step to be taken.

Facing this challenge, we adopted coteaching as a research method (Roth, 2002; Roth & Tobin, 2002; Roth & Tobin, 2004). Coteaching is a process in which two or more teachers take the responsibility of planning, teaching and discussing the events that they have experienced in the classroom. This approach is based on the idea that what we learn in praxis cannot be prescribed or transmitted, but has its foundation in practice itself (Roth & Tobin, 2004, Lave & Wenger, 1991). It happens partially because when we teach we are immersed in a phenomenological time dimension.

This dimension is related to the here and now, when we have to decide what to do next barely with no time to reflect beforehand. On the other hand, when we are talking about what happened in a past experience we inevitably filter the facts according to our own perception. In this situation prevails the chronological time dimension. Teachers usually plan and teach, but most part of teaching occurs in the classroom. While immersed in that environment for a long period of time, teachers usually produce and acquire what Bourdieu (1983) called habitus, or a system of dispositions that informs how that environment works.

Habitus is updated at each ongoing experience. At the same time, it always incorporates past experiences and helps teachers decide what to do in the very next moment. The acquired habitus is what differentiates a veteran teacher from a newcomer. Because habitus is produced in practice, it is usually acquired without conscious decisions. Then, if we want to better understand teaching processes, we have to take into account what teachers say and mainly what teachers do. Video camera is the tool we have to collect data from the classroom events even in a specific perspective. This is why it is a very important resource in our research.

An overview of the research

From May to September 2005, Vanessa (the teacher) and I co-taught 14 classes. When I arrived at the school, Vanessa had already planned a class about division operation, so we decided that the first class would be as it had been planned. For the next ones, Vanessa asked for help in geometry, a subject that she would like to learn more.

In the first class, Vanessa introduced me to the students as a visitor teacher that would spend some classes with them. After asking each student to introduce him/herself, to the camera, I placed it up in the back wall pointed to the front in order to record mainly teachers' movements. In the following classes we used on additional camera, which was pointed to a group of students. At the beginning, the students played with the camera a little but it was not a problem during the entire coteaching process.

In that first class Vanessa conducted a type of dialogue with the students which would be frequently performed by her during most of the classes that we would co-teach. It took place mainly in contexts which she seemed to want to emphasize something or to check students' memories about a subject that they should already know. The following excerpt is illustrative of this type of dialogue:

1. Vanessa: For what (purpose) I use the division operation?
2. Students (in chorus): To divide…
3. Vanessa: What, to divide what?
4. A group of students (in chorus): Into equal parts.
5. Vanessa (while gazing and pointing upon a group of students): In parts, what, guys? … In equal parts.

This type of dialogue is mentioned in literature. Mortimer & Aguiar (2005), for instance, categorize it as "interactive / of authority". The teacher usually leads the students through a sequence of questions and answers to reach a specific point of view. Vanessa starts by throwing a question to the entire class (turn 1). The students answer in chorus as if they knew the script beforehand (turn 2). Vanessa continues by changing the question and waiting for a complement of the previous answer (turn 3). At this point the students offer different answers and then Vanessa points to a direction in which supposedly somebody answered according to the teacher's expectation (turn 4). At the end, Vanessa repeats what they said (turn 5).

We have two different and complementary comments about this dialogue. First, as that categorization mentioned above shows, it indicates an interaction between teacher and students in which the teacher puts herself in an authoritative position. She knows what has to be said and she controls all the dialogue by checking the answers and choosing the one that is considered the correct. It means that there is one correct answer and no space for alternatives.

We could take this practice as exemplary of traditional teaching. The relationship with school knowledge is shown as something that students have to deposit in their minds as it was presented by the teacher. Sometimes, the teacher can evaluate what students memorized and by doing this she updates what students could forget if they were left on their own.

We knew from the beginning that we would experience many situations in which traditional teaching is manifested in school practice. And yet we were trying to explore alternatives in which the students could have at least some possibilities to think creatively. In practice it would be by proposing challenges and questions of more than one answer.

However, in our experience with Vanessa, we found out that we could interpret those dialogues in a different way. Based on parents' testimony we can say that Vanessa knew how to get students' and parents' confidence. It was as if she represented the teacher who corresponded to their expectations. In the interviews the parents said that they used to evaluate teachers' work by talking to their children and, mainly, by looking at their notebooks and comparing those notebooks to others from other classes at the same school or even from other schools. They also said that they considered the teaching in that school as a high quality one. Vanessa taught thirty-six students, ten years old in average, in a very harmonious way in our perception. So, we consider that she created a friendly environment and the students were confident enough to deal with novelties.

When planning the second class, Vanessa thought it would be a good idea if we taught how to identify the polygons presented in the faces of solid. This then became the subject of this geometry class. We also taught how to design any regular polygon by using the protractor. In the third class, we taught how to design an unfolded pattern to build a tetrahedron. The students had to use the protractor again, this time to design a regular triangle that would be the base for the tetrahedron.

Planning the fourth class, we decided to take a step further. We built many paper-made polyhedra: tetrahedron, square-based pyramid, pentagon-based prism and hexagon-based prism. Then, we challenged the students to find a way to reproduce one of the polyhedra. Each student could choose the polyhedra that she/he would reproduce as well as the way to do it. We thought the students would destroy the polyhedra and unfold it to find out its unfolded pattern. While planning, we discussed this issue and we decided to let them do whatever they might consider necessary to achieve their goal. Nevertheless none of them adopted this strategy. In this class the students took control over the activity in the sense that they had to decide each action to be take.

In the fifth coteaching class, the students had to imagine any product and they had to plan and to build the box that would pack the imaginary product. Again they had to decide everything: the box's shape and size, what to write on the box, how to beautify the packing, etc.

The sixth coteaching happened on June fifteenth. The fathers' day would be in August, but we decided to propose to the students to build a box that would pack the fathers' gift. That decision was based on the idea that we would not have enough time to build the box and the gift. Winter break would start on the fifteenth of July and the students would return to school in the beginning of August. The fathers' day in Brazil is always on the second Sunday of August. Therefore we spent six classes to plan the box with the students, to make several prototypes until reaching the best model possible and to build the gift. The gift was a rocket made by five matches and one piece of paper. Each box had the shape of a pentagon-based prism or a hexagon-based prism; depending on each student's choice. It was used to wrap the rocket, as well as to be its target. The fathers received the gift at home and were invited to play with their children by trying to throw the rocket into the box (figure 1).

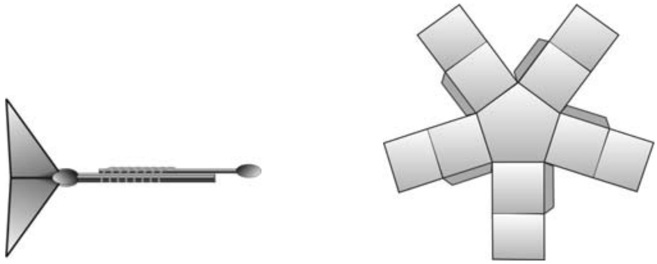

Figure 1: the rocket and an unfolded pattern for the box

In the beginning of the twelfth coteaching class, many students said that their fathers liked the gift a lot. Several of them said that their parents doubted that they were the builders of the gifts. In that class, Vanessa announced that the students would build a game with which they would play later. The game would be about fractions. The first step would be to build some dice that were needed for the game.

In order to build the dice, the teachers invited the students to find out all the possibilities to draw an unfolded pattern that could be used to build a die. There are limited unfolded patterns that result in a die. Applying the same challenge to groups of teachers we found out that it is not an easy task finding all these possibilities. In that class the students found ten of the eleven possible unfolded patterns.

Vanessa drew the eleven unfolded patterns in the chalkboard before starting the thirteenth coteaching class. The students were invited to choose one of those unfolded patterns and to build a cube by using the chosen one, as well as to color of the faces of the cubes using three colors only. During the building process, each student had to find out where to paint each of the three colors they would use following this rule: each color would be painted in two opposite faces of cube. Each student had also to find out where to draw seven tabs. Those tabs were enough to fold and to glue the cubes' faces in a way that each edge would result either from a fold or from a gluing.

In the fourteenth and last coteaching class, the students played the game using the dice they had built.

A student fighting to reach his goal no matter how long it takes

In the thirteenth coteaching class we could record Túlio working in his unfolded pattern for 13 minutes and 37 seconds. Actually, when we started videotaping him, he had drawn already the six squares that would compose his unfolded pattern and four tabs (figure 2).

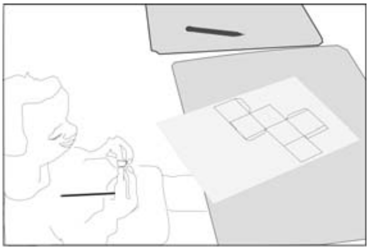

Figure 2. Túlio working in his unfolded pattern

Túlio had drawn a miniature of his unfolded pattern, cut it and folded it. Using this miniature he was finding out where each tab that he was drawing in his sheet would be. He was keeping a pencil between two of his fingers while exploring the miniature. He was late comparing to his peers; almost all the students had finished their cubes. He still had to find out where to draw three last tabs and what color would be used to paint each square.

Túlio spent 24 seconds after this moment holding, moving and looking at the miniature. Then, he drew one tab and got back to the miniature. After 40 seconds, he drew one more tab, the sixth one. Once more he explored the miniature for a while. He opened the miniature, and looking at the drawing in the sheet he positioned the miniature as if he was trying to align the correspondent squares: those in the miniature with the ones in the drawing. After 57 seconds, he drew the seventh tab. In fact the obtained unfolded pattern was not according to the given rules because it would only be possible to finish it by gluing two tabs together.

Túlio counted the seven tabs and referred back to the miniature. Then I kept holding the camera and suggested he should draw another miniature, this time including the seven tabs that he had drawn in the sheet. Túlio took a piece of paper that was under the desk. As it was terribly wrinkled I suggested him to use part of his sheet. He accepted the suggestion. After several minutes, he had the second miniature and was exploring it as he did with the first one.

Túlio explored this second miniature for more than one minute. I asked him what he had discovered and he said that there was one tab that was wrong. I replied showing him that two tabs were encountering (in the same edge) and suggested he should change one of those two tabs to another place.

Túlio leaned over his sheet and remained in this position constantly exploring his second miniature. After 3 minutes and 30 seconds examining at the miniature, opening and folding it several times, he cut one tab using his scissors. One minute later, he told me that he thought no more tabs were needed. He opened the miniature-unfolded pattern and folded it again showing it to me. Túlio and I explored the miniature until we found the edge where there was no tab to be glued. Soon afterwards, I helped Túlio find the position where the last tab had to be drawn in the sheet. Then I told him he had now to decide which squares he would paint with each color.

Then, Túlio pick the miniature up once more but after a few seconds he looked at me and announced his plan: instead of using his miniature he would cut the unfolded pattern, fold it and mark each pair of opposite faces with a smudge of the same color.

When a student undertake the work

Túlio could have gotten help from any classmate if he would have liked to. The students were organized in groups, each one of six students. In his group, all his pairs managed to solve the challenge before him. So, if his purpose was to do the task, mainly to satisfy the teachers, he could get rid of it quickly. Nevertheless, he persisted in facing the challenge that was given. We chose to show Túlio in action not because he was a brilliant student but because he was determined to solve the challenge despite all difficulties.

Túlio's determination to work has nothing to do with characteristics that we attribute to traditional teaching. Instead of performing monotonous activities based on reproduction of standardized procedures, it seems that he was working conscious to what he would like to achieve. In our perspective what makes the difference is allowing the students to decide how to solve the challenges given. During the coteaching, at the same time that the teachers were conducting the geometry classes they focused in offering the students opportunities to act creatively. This little change in the way the teaching process is conducted has a political dimension, as we will explain.

Traditional teaching reproduces the work organization model in which modern capitalism is based in the sense that a few people decide what to be done by all the workers in a work place. Marx noticed that: "What characterizes the division of labor in the automatic workshop is that labor has there completely lost its specialized character" (Marx, 1847/1933, p.121). The alienated labor is the consequence of this way of organizing the production process. When a worker performs the same task day after day, thousands of times, he / she do the activities alienatedly. There is no need of any expertise considering that most workers have to perform mechanical tasks following what was previously planned according to somebody else's interest. The worker does not recognize himself / herself in the product of his / her labor. So the labor is exchanged by money. There is no pleasure in such situation, the job becomes the worker's misery.

Something similar occurs to students when they have to perform tasks that are meaningless to them. They just follow a curriculum that is planned without their participation, without considering their cultural background, the history and the interests of their social class. The school is seen as an institution that is always preparing them to a distant future without taking into account the present. Again there is no space for pleasure and the school becomes the student's misery. Indeed, Marx's considerations about alienated labor are perfectly transposable to alienated learning, as shown by Lave & Mcdermott (2002).

It is plausible to think that the pressures in favor of traditional teaching that most teachers are submitted to are linked to the way the work is organized in society. We agree with it when we take what Marx teaches us seriously: "the same men who establish their social relations in conformity with the material productivity produce also principles, ideas, and categories, in conformity with their social relations" (Marx, 1847/1933, p.93). In the case of working class students, their parents tend to expect from school the same treatment that they are submitted to in their work places. It makes more comprehensible the fact that they themselves reinforce the reproduction of alienated learning.

When the teachers change the way the work is organized inside classroom they are inviting the students to experience possibilities to act with conscious of the process in which they participate. The students can choose between keeping in a very dependent-on-others situation or assuming their duties and acting according to objectives that they percept as meaningful. This experience of being empowered opens new possibilities to act and it can influence students' behavior inside school and outside as well. This idea of influencing student's identities is what we consider the political dimension of teaching.

Túlio was not an isolated case. Most students in that class seemed to enthusiastically engage in the proposals during the coteaching. Besides all challenges, the fathers' gift was a strong motivation for this engagement in the activities. If we would put what the co-teachers did in principles, those principles would be: to translate the concepts to be taught into challenges; to let students decide how to organize their work in order to solve the challenges; to provide notes and exercises related to the concepts on the agenda; to explore possibilities to link the curricular concepts with events that are meaningful to the students' community.

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An overview of mathematical word problem solving strategies and their usability

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Abstract

The aim of this study was to investigate the different strategies of different mathematical word problems which require representation standards and to identify which strategy is functional for pre-service teachers to teach their primary grade students. For this study, 150 senior class pre-service teachers of Primary Mathematics Education Department were chosen. Ten mathematical word problems which selected from the five sub-learning areas were given the pre-service teachers to solve in different ways. The strategies of pre-service teachers were categorized by using content analyze. Analysis sub-units have been obtained by determining the different strategies. We had interviews with pre-service teachers who used extreme strategies. We discussed which strategy is useful to apply with their primary grade students and why they chose this strategy. Findings revealed that participant pre-service teachers are lack of using strategies. In general, the participant pre-service teachers do not apply more than one strategy and they use traditional strategies instead of extreme strategies.

Introduction

We believe that if we want students to understand mathematics, it is more helpful to think of understanding as something that results from solving problems, rather than something we can teach directly (Hiebert, 1997, p. 25).

Problem solving is important for students. They don't use this only in mathematics. If they learn how to solve problems they can use this in their real life. And if they find different solutions they can execute these strategies to other lessons and also to their real life.

Posamentier and Krulik (1998) defined problem as a situation that a person can meet, which requires resolution, and also the path to the solution, is not known immediately. In Agenda for Action NCTM stated that, problem solving must be the focus of school mathematics (NCTM, 1980, p.1). The emphasize on problem solving was continued with Curriculum and Evaluation Standards for School Mathematics The mathematics instruction will aim to make students suitably skilled problem solvers. Making students familiar to different problem solving strategies and allowing them to practice these strategies is one of the important goals in mathematics education. Problem solving is seem to have a critical role in a good instructional program (NCTM, 1989).

Posamentier and Krulik (1998) associated the main handicap of the successful problem solving in mathematics curriculum with the weakness of teachers' problem solving training. With respect to his views, teachers receive a defective training of problem solving strategies and also, they are not able to combine the problem solving skills with their regular teaching problems. Teachers need to be aware of different representations of problems for encouraging their students. Posamentier and Krulik (1998, p.3) stated that, problem solving can be thought of in three different ways:

1) Problem solving is a subject for study in and of itself,
2) Problem solving is an approach to a particular problem,
3) Problem solving as a way of teaching.

He concluded that, teachers' problem solving ability has an integral part in teaching. Firstly, teachers should know which problem solving strategies are available for a problem, then, when and how to use them. Also, not only mathematical problems but daily life experiences require different strategies. Every teacher, who aims to make students skilful problem solvers, should have a collection of strategies.

Strategies for solving problems are identifiable methods of approaching a task that are completely independent of the specific topic or subject matter. Strategy goals play a part in all phases of problem solving: understanding the problem, solving the problem and reflecting on the answer and solutions. Strategy and process goals are;

- Develop problem analysis skills-to improve students' ability to analyze an unfamiliar problem, identify wanted and needed information, ignore nonessential information and clearly state the goal of the problem.
- Develop and select strategies- to help students acquire a collection of problem solving strategies that are useful in a variety of problem solving settings and to select and use those strategies appropriately
- Justify solutions-to improve students' ability to asses the validity of answers
- Extend or generalize problems-to help students learn to go beyond the solution to problems; to consider results or processes applied in other situations or used to form rules or general procedures (Wan de Walle, 2004, p.54).

Posamentier and Krulik (1998) make a conscious effort to label the strategies and to use these labels as much as possible. These strategies are "working backwards", "finding patterns", "adopting a different point of view", "solving a simpler, analogous problem", "considering extreme cases", "making a drawing", "intelligent guessing and testing", "accounting for all possibilities", "organizing data" and "logical reasoning".

We take into account these strategies then prepare ten questions which require representation standards.

Standards are descriptions of what mathematics instruction should enable students to know and do. They specify the understanding, knowledge, and skills that students should acquire from prekindergarten through grade 12. The Content Standards—Number and Operations, Algebra, Geometry, Measurement, and Data Analysis and Probability—explicitly describe the content that students should learn. The Process Standards—Problem Solving, Reasoning and Proof, Communication, Connections, and Representation—highlight ways of acquiring and using content knowledge (NCTM,2000,p.30).

Instructional programs from prekindergarten through grade 12 should enable all students to,

- create and use representations to organize, record, and communicate mathematical ideas
- select, apply, and translate among mathematical representations to solve problems;
- use representations to model and interpret physical, social, and mathematical phenomena (NCTM, 2000,p. 67).

Representations should be treated as essential elements in supporting students' understanding of mathematical concepts and relationships; in communicating mathematical approaches, arguments, and understandings to one's self and to others; in recognizing connections among related mathematical concepts; and in applying mathematics to realistic problem situations through modelling (NCTM, 2000, p.67).

As we touch upon before, we prepared ten questions which require representation standards. Questions are selected from the five sub-learning areas (numbers, geometry, algebra, measurement, statistics and probability).

Questions which prepared were given to 150 senior class pre-service teachers of Primary Mathematics Education Department of Gazi Education Faculty of Gazi University. We want them to use different strategies for every question and think which strategy is useful. We gave them one hour to solve questions. The questions solved by them in different ways. Then we categorize solutions using content analyze.

A central idea in content analysis is that the many words of the text part classified into much fewer content categories (Weber, 1990, p. 12). In our research the analyze unit is the pre-service teachers' strategies for each question. Then we count frequencies for each unit. The frequencies are shown in tables (Table 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9 and 1.10).

For reliability and validity, the analyze units shown to 5 mathematic educators. We plan to interview with participants who use extreme strategies. But they do not find extreme strategies for all questions. So we interviewed with randomly selected 6 pre-service teachers. We asked them which strategy is useful to apply with their primary grade students and why they chose this strategy. Some of the interviews are given under the solutions.

Table 1.1 Frequencies for question 1

Strategies	1	2	3	4	5	6	7	8	9	10	W
Frequencies	129	6	17	0	3	4	45	1	1	1	22

Question1.In a room with 5 people; Aydan, Neslihan, Mehmet, Selçuk and Gizem shakes hands with everybody else exactly once. How many handshakes are there?

In the first question, pre-service teachers use 9 alternative solution strategies. As shown in Table 1.1, first solution which called *visual representation strategy* used by 86 percent of the pre-service teachers. Solution of a participant for this was given below;

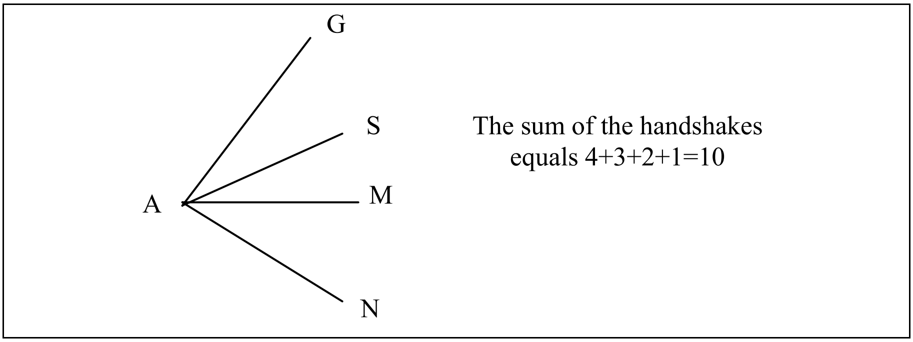


Figure 1.A participant's solution

The second, *accounting for all the possibilities* used by 4 percent of the pre-service teachers. Solution of a participant for this was given below;

	A	S	G	M	N
A	X				
S		X			
G			X		
M				X	
N					X

$$\frac{n.(n-1)}{2} = \frac{5.4}{2} = 10$$

Figure 2.A participant's solution

The third strategy used by 11 percent of the pre-service teachers, they *adopt a different point of view*. Solution of a participant for this was given below;

The room with five people, each of whom will shake four other people's hands. 5.4=20 but we must divide by 2 to eliminate the duplication hence $\frac{20}{2} = 10.$

But it is interesting that nobody used the fourth strategy.

The fourth one *is looking for a pattern*. The fifth one is *organizing data* and 2 percent of pre-service teachers used it. Solution of a participant for this was given below;

Organizing Data					
Number of People	5	4	3	2	1
Number of Handshakes	4	3	2	1	0

The sum of handshakes is 10.

Figure 3.A participant's solution

The sixth one is a combination of *solving a simpler problem with visual representation, organizing data, and looking for a pattern*. If we combine this, it becomes a geometry problem, in which the answer is the number of sides and diagonals of an "n-gon". 3 percent of pre-service teachers used this strategy.
Solution of a participant for this was given below;

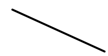
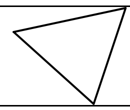
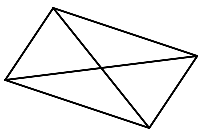
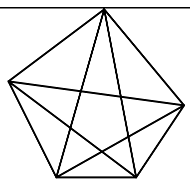
Number of People	Number of handshakes	Visual Representation
1	0	.
2	1	
3	3	
4	6	
5	10	

Figure 4.A participant's solution

$$d = \frac{n.(n-3)}{2}, where\ n > 3$$

$$d = \frac{5.2}{2} = 5$$ Number of diagonals, 5+5=10 total handshakes.

The seventh one is using *combinations formula* and 30 percent of the participants used the strategy. Solution of a participant for this was given below;

$$_5C_2 = \frac{5.4}{2} = 10$$

The eighth strategy includes a combination of accounting for all the possibilities and visual representation. The ninth strategy shows Cartesian

multiplication of clusters. The tenth strategy combines adopting a different point of view and visual representation.
T: Yes Can, in the first question which strategies did you use?
C: I used visual representation, combination formula and also the other.
T: The other?
C: I wrote all people's names than below the names I wrote who had shaken hands. I found 20 handshakes. But I noticed there are same handshakes. I remove them and find 10.
T: Which strategy is useful to apply with your primary grade students?
C: I think the first one, visual representation
T: Why?
C: As I remember, curriculum suggests using visual representations firstly. In the beginning of the lesson I use visual representations because students can understand them easily. Then I ask this question which contains more people. And I ask them how to solve this. Then I say we need a formula and give combination formula and also remind them to use this in tests for being quick.

Table 1.2 Frequencies for question 2

Strategies	1	2	3	Y
Frequencies	94	68	2	23

In this case, 62 percent of the participants solved the second question by *solving a simpler analogous problem* strategy. The second strategy called *another point of view* used by 45 percent of the pre-service teachers. In the third solution 1 percent of the pre-service teachers applied *logical reasoning*. Also 15 percent was not able to find the correct answer.
T: Yes Burcu, in this question which strategy is useful to apply with your primary grade students? Why?
B: I m good at using formulas. We learned like this and also I use this in my lessons.
T: Can you say the teachers' experiences are important to select the strategy?
B: I think….for example I do like this.

Table 1.3 Frequencies for question 3

Strategies	1	2	3	4	W
Frequencies	85	16	48	27	38

The third question is a geometry problem. In the first strategy 57 percent of the pre-service teachers used only algebraic formulas. The second strategy is simpler analogous problem and 11 percent of the pre-service teachers used solving a simpler analogous problem strategy. The third one is another point of view strategy, and it is used by 32 percent of the pre-service teachers. The fourth one is a visual representation involving Pisagor theorem and used by 18 percent of the pre-service teachers.

Table 1.4 Frequencies for question 4

Strategies	1	2	3	W
Frequencies	43	88	57	21

The fourth question's first strategy is using the visual representation by combining with the basic principle o multiplication and 29 percent of the participants applied this strategy. The second strategy is used by 59 percent of the pre-service teachers which is including the combination formula. The third strategy is a combination of visual representation and organizing data. 38 percent of the pre-service teachers applied this strategy.

Table 1.5 Frequencies for question 5

Strategies	1	W
Frequencies	144	6

The fifth question was including one strategy. This strategy includes different approaches. Each of these approaches doesn't mean a different strategy. We tried to find if participants are aware of this. Findings revealed that pre-service teachers used different approaches as different strategies. In the interviews they noticed that different approaches do not mean different strategies.

Table 1.6 Frequencies for question 6

Strategies	1	2	3	W
Frequencies	65	25	83	32

In the sixth question 43 percent of the pre-service teachers made a pair of lists. The second strategy is using a visual representation, for example a calendar. 17 percent of the pre-service teachers used this strategy. The last strategy is another point of view including their common multiple and 55 percent of the pre-service teachers used this.

T: Yes Ada, in this question how many strategies did you use? Which strategy is useful to apply with your primary grade students?

A: I use three strategies. When I solve by first strategy, I think that students will not solve in this way. If they have a calendar they will . And drawing a calendar is more visual. And I use this for a month only. If I need the second month I don't use this strategy. I use the third one. And I want in exams to use the strategy which I use in lessons.

Table 1.7 Frequencies for question 7

Strategies	1	2	Y
Frequencies	31	145	5

In the seventh question 20 percent of the pre-service teachers used visual representations, 97 percent of the pre-service teachers used algebraic formulas. We paid attention to the problem, this problem was chosen from curriculum and pre-service teachers were aware of the solution strategies. Findings revealed that, giving a perspective of different strategies will be helpful for pre-service teachers.

Table 1.8 Frequencies for question 8

Strategies	1	2	3	4	W
Frequencies	58	57	53	8	15

In the eight question 39 percent of the pre-service teachers used organizing data strategy. 38 percent of the pre-service teachers used visual representation. 35 percent of the pre-service teachers used algebraic formula. 5 percent of the pre-service teachers used a combination of visual representation and solving simpler analogous problem strategies.

Table 1.9 Frequencies for question 9

Strategies	1	2	W
Frequencies	70	134	15

The ninth question is a permutation question. The first strategy includes the formula. Pre-service teachers who are familiar with probability can solve this in the manner; P (3+5) + P (1+5) + P (2+4) + P (2+6). Nobody solve this question using the second strategy. We can look this problem from a different point of view. The probabilities of getting an odd number on the left spinner and an odd number on the right hand spinner (and two evens) are not done by them. The third strategy is accounting for all possibilities by setting up an organized sample space. An interesting point is very huge percent (%86) couldn't solve the question or solve incorrect. When we look at the problem, probability of each number was not equal on the first spinner. Most of the participants did not pay attention to this point. Because they overlook the first spinner has four equal regions.

Table 1.10 Frequencies for question 10

Strategies	1	2	3	W
Frequencies	20	0	6	129

The last one is a geometry question. In the first strategy 46 percent of pre-service teachers find volume of a cylinder then multiply with ten. In the second strategy 89 percent of pre-service teachers find high of ten cylinders then find volume. In general the pre-service teachers use both of the strategies. But no one use another strategy.

T: Yes Ahmet, in this question how many strategies did you use?

A: Two

T: Which strategy is useful to apply with your primary grade students?

A: I think it is same. I can use both of them
T: Why?
A: It is not same but same….If we use a representation they can see two drawings are same only different is process.
T: Process?
A: The operations, algebraic operations are different. If I have to choose one I will choose the second one because of operations. It is shorter than the first.

Findings revealed that participant pre-service teachers are lack of using strategies. In general the participant pre-service teachers do not apply more than one strategy and they use traditional strategies instead of extreme strategies. Participants mostly use visual representation strategy and algebraic formulas. Interview results showed that participants used these because of the following reasons;

- Curriculum,
- Operational Simplicity ,
- Time for solving ,
- Complexity of problem,
- Level of the class,
- Experiences of teachers,
- Beliefs of teachers,
- Ability of teachers,
- Solving the problem during the instruction or evaluation ,
- Type of the exam(open-ended or multiple choice)
- If the numbers in the problem are small, they use visual representation but if the numbers are big they use formulas.
- If they don't remember the formula for the questions they use other strategies.

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Cognitive strategies used by pre-service physics teachers

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Abstract

Cognitive strategies enhance students' learning. The purpose of this study was to identify pre-service physics teachers' cognitive strategies used in their learning. The participants of the study included 16 pre-service physics teachers enrolling in an elective course in Middle East Technical University. The pre-service physics teachers answered the question that what strategy or strategies they used to study. The results of the study indicated that the number of cognitive strategies used by the pre-service physics teachers were very limited. Some of cognitive strategies used by them were ineffective. The reasons why the pre-service physics teachers were not good at strategy use were also discussed.

Introduction

Cognitive strategies improve students' learning (Garner, 1990). They are used to make cognitive progress (Flavell, 1979). Scraw, Crippen and Hartley (2006) define cognitive strategies "as a wide variety of individual tactics that students and instructors use to improve learning" (p.112). For example, when reading a text, writing important points of the text is a cognitive strategy.

Several researchers noted the importance of good strategy use in academic learning (Pressley, Goodchild, Fleet, Zajchowski, & Evans, 1989). Pressley et al. (1989) describes the characteristics of good strategy users as follows;

> Good strategy users know many strategies and much information about when and where to use them. They are reflective and have low anxiety. They possess beliefs about themselves and performance that are compatible with good strategy use (e.g., that they can do well by using the right approaches). These beliefs motivate use of strategies. Good strategy users can combine strategies proficiently and often execute strategic sequences automatically (Pressley et al., 1989, p.301).

Many studies addressed strategy instruction to help students to learn effective strategies used in their learning process (Levin, 1986; Lin, 2000; Moely, Hart, Santulli, Leal, Johnson, Rao, & Burney, 1986; Pressley, 1986).

Cognitive strategies is divided into two parts: deep-processing strategies such as explaining, reasoning, organizing, summarizing and elaborating and surface-processing strategies such as memorization and rehearsal strategies (Weinstein & Meyer, 1986, as cited in Salovaara, 2005).

Effective strategy use depends heavily on metacognition. Metacognition is generally described as thinking about thinking (Jacobs & Paris, 1987). According to Schraw and Moshman (1995) taxonomy, metacognition has two main components: knowledge of cognition and regulation of cognition. Knowledge of cognition refers to what is known about our cognition. It includes three subcomponents: declarative knowledge, procedural knowledge and conditional knowledge. Declarative knowledge involves knowledge about ourselves as learners and what factors affect our performance. Procedural knowledge consists of knowledge about strategies and other procedures. Finally, conditional knowledge includes knowledge of why and when to use a particular strategy. Regulation of cognition includes metacognitive activities that promote control one's thinking or learning. It consists of three components: planning, monitoring and evaluation (Schraw & Moshman, 1995). Planning includes the selection of appropriate strategies and the allocation of resources. It consists of goal setting, activating relevant background knowledge, and regulating time. Monitoring requires self-testing skills to control learning. Evaluation requires assessing the products and regularity processes of one's learning (Scraw, Crippen & Hartley, 2006). It is seen clearly that knowledge of cognition provides learners with knowledge about how, when, and why to use strategies. On the other hand, regulation of cognition enables students to select appropriate strategies and make suitable change in strategy use according to demands of situations.

Some researchers have discussed why learners do not use strategy for effective learning. Garner (1990) proposed five reasons why strategic knowledge is not employed to improve learning process. The first reason is poor cognitive monitoring (metacognition). Because learners who have problems related to their metacogniton do not aware of that they are not learn, they are unlikely search for strategy remedy. Monitoring learning must be conscious process so that the learner can detect any problems and deal with them by changing old strategies or supporting them with new ones. The second reason is primitive routines for task-completion which can inhibit use of learning- enhancing strategies. If students get impression that unstructured strategies must be disguised in instructional settings, they unlikely employ these learning-enhancing strategies. Another reason is knowledge deficiency about task demands in a particular setting. The fourth reason is students' attributions and adopted goals. If learners think that being strategic will not make any difference in performance, they unlikely employ strategies demanding more time and effort. Students' goal orientations can also affect strategy use. The studies showed that students having mastery goal orientations use more strategy that those having performance goal orientation. Last reason was minimal transfer of strategic activity to new and related situations. Some strategies can be welded to the situation where they are obtained (Garner, 1990).

Purpose of the Study

The purpose of this study was to identify pre-service physics teachers' cognitive strategies used to study physics topics covered in the physics course, High School Physics Curriculum Review I.

Course Description

The course of “High School Physics Curriculum Review I” is a three credit elective course at Education Faculty at Middle East Technical University. The purpose of the course is to offer the students conceptual understanding of the physics topics covered at 9th and 10th grade Turkish High School Physics Curricula and emphasizes the common misconceptions about these topics. Six chapters are studied during the course. These chapters are properties of matter, geometric optics, force concept, kinematics, Newton’s laws of motion, and work and energy. Handouts emphasizing the essential parts of the topics and including some conceptual questions are used to revise the important concepts about these topics. In addition to handouts, there are misconception lists and tables for each chapter. Misconceptions list involves common misconceptions and learning difficulties about the topics, and tables present some quantitative values, ranging from minimum to maximum, for some physics concepts to increase their common sense. Moreover, for each chapter, the related questions asked at the University Entrance Exams in Turkey in the previous years are given as homework. Then, the questions which could not be solved by the students are solved and discussed in the following lessons.

The participants of the study consisted of 16 pre-service physics teachers enrolling in an elective course in Middle East Technical University. They are 6 male and 10 female pre-service physics teachers from different grades, ranging from sophomore to senior.

Procedure

To investigate pre-service physics teachers’ cognitive strategies, the students were requested to answer the question of “What strategy or strategies did I use to study?”. The students answered the question three times in their journals as a requirement of the course. Firstly, they reported their cognitive strategies after they finished properties of matter and geometric optics chapters. After they studied force concept and kinematics chapters they wrote their strategies for studying these chapters. Finally, after Newton’s laws of motion, and work and energy chapters were covered, they expressed their strategies for these chapters.

Results

This part includes pre-service physics teachers’ strategies expressed in their journals. Some of students said that they did not use any strategy to study. On the other hand, the students, claiming use strategy, generally expressed similar strategies for all chapters. “Reading handout before lesson” and “solving physics problems given as homework” were the most frequent strategies.

The maximum number of strategies used by one student was 4 in the first journal; 7 in the second journal; and 7 in the third journal.

The number of students who expressed that they did not use any strategy was 4 in the first journal; 2 in the second journal; and 3 in the third journal.

Table 1 indicates strategies used for studying properties of matter and geometric optics chapters and their frequencies.

Table 1.The strategies expressed in the first journal and their frequencies

Strategy	Frequency
Reading handout before lesson	8
Solving physics problems given as homework	8
Taking note the important points during lesson	5
Generating questions about points were not understood	2
Studying from different textbooks	1
Making internet search for supporting lack of knowledge	1

Table 2 shows the strategies expressed in the second journal to use for studying force concept and kinematics chapters and their frequencies.

Table 2. The strategies expressed in the second journal and their frequencies

Strategy	Frequency
Reading handout before lesson	6
Solving physics problems given as homework	5
Taking note the important points during lesson	4
Generating questions about points were not understood	1
Studying from different textbooks	1
Making internet search for supporting lack of knowledge	2
Discussing concepts with the classmates and instructors	1
Studying with music	1
Studying by writing important points	1
Learn topic enough to explain others	1
Watching well- known professors' lectures or demonstrations from internet	1
Review studied topics	2
Make research for lack of knowledge	1
Finding different definitions of concepts	1
Solving different type questions	2

Table 3 presents the strategies used for studying Newton's laws of motion, and work and energy chapters and their frequencies.

Table 3. The strategies expressed in the third journal and their frequencies

Strategy	Frequency
Reading handout before lesson	5
Solving physics problems given as homework	3
Generating questions about points were not understood	1
Studying from different textbooks	2
Making internet search for supporting lack of knowledge	1
Discussing concept with the classmates and instructors	1
Summarize important points	1
Studying by writing important points	1

Table 3 *(Continued)*

Strategy	Frequency
Learn topic enough to explain others	1
Watching well- known professors' lectures or demonstrations from internet	1
Make research for lack of knowledge	1
Finding different definitions of concepts	1
Solving different type questions	1
Studying with visual materials	1

Conclusion and Discussion

The results of the study indicated that the participants of this study used similar strategies for different chapters although we would expect that they change their strategy choices because effectiveness of a particular strategy generally changes across different contents. Although the number of strategy increased in the second and third journal compared to the first journal, it was limited. Moreover, some of the students' strategies could not be considered as deep level cognitive strategies. Furthermore, some participants expressed that they did not use any strategy.

One reason why the pre-service physics teachers' strategy use is limited might be that they might think that studying physics topics covered in the course which are not new for them did not require learning-enhance strategy use. Another reason may be they did not have enough knowledge about strategies and strategy use. Third reason may be deficiency in students' metacognition. If they have not enough metacognitive knowledge related to their cognitive strategies and do not monitor effectiveness of a particular strategy used a particular task, they are unlikely good at strategy use.

Asking students what strategies they used to study can help students to be aware of their strategies and also improve strategy use. It also provides information about students' strategies, which can be used to identify the problems in strategy use.

Several researchers suggested strategy and metacognitive training instructions to make students to be strategic learners. For example, Schraw (1998) suggested using "strategy evaluation matrix" to improve students' strategy use and metacognitive awareness and to encourage students to actively construct of knowledge about how, when, and where to use strategies. This matrix consists of information about how to use several strategies, the conditions under which these strategies are most useful, and a brief rationale for why one might wish to use them. Each row of the strategy evaluation matrix intended to promote explicit declarative (column 1; the name of strategy), procedural (column 2; how to use strategy), and conditional (columns 3; when to use strategy and 4; why to use strategy) knowledge about each strategy. One use of strategy evaluation matrix suggested by Schraw is asking students either individually or in a group to complete each row over the course of the school year.

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Determining the learning styles of primary school teachers

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Abstract

Since constructivism is based of basis of student-centred education, the different properties of individual are searched in order to improve the learning quality. The learning styles are researched on individual differences basis. In this study, the learning styles of the teachers are surveyed by branches. The teachers are the most important elements in the education. Their role of creating learning environments for students appears with constructivism. The learning styles of the teachers are also important in managing learning process. In this study, learning styles of 223 primary school teachers in different branches in Turkey were determined. Learning styles were defined by Kolb's learning style inventory and distributed based on branch. The correlation between teacher branches and learning styles was measured by Chi-Square test. The correlation with learning styles was also researched based on gender. Consequently while 48% of teachers have converger learning style, 24% of them have assimilator, 18% have accommodator, and 10% have diverger learning styles. If branches are examined, a similar distribution will be observed. The correlation between learning styles and branches was measured by Chi-square test, and no correlation was seen (Pearson Chi-Square=0.332, p>0.01). In the same way, no correlation between genders and learning styles was seen (Pearson Chi-Square=0.052, p>0.01).

Introduction

Every individual can learn but rate of learning varies from person to person. According to Özden (1999), studies have shown that individual's learning rates, their capacities and styles are different from each other (Şirin and Güzel, 2006). As a result, there are several researchers started to deal with individual differences. For example; cognitive styles (Witkin and Goodenough, 1981; Riding, 1991), problem solving styles (Kirton, 1987), thinking styles (Sternberg, 1997; Cana-Garcia and Hewitt, 2000), and motivational styles (Adar, 1969; Hofstein ve Kempa, 1985) are some of the areas of researches about individual differences. One of the most important points of individual differences is learning styles.

There are several studies about determination of learning styles. Kolb, Dunn&Dunn, Gregorc, McCarthy, Felder&Solomon, Felder&Silverman and Grasha are some of the people who improved learning styles inventories. Kolb's learning styles inventory is used in Turkey most commonly among other inventories (Koçakoğlu et al, 2006).

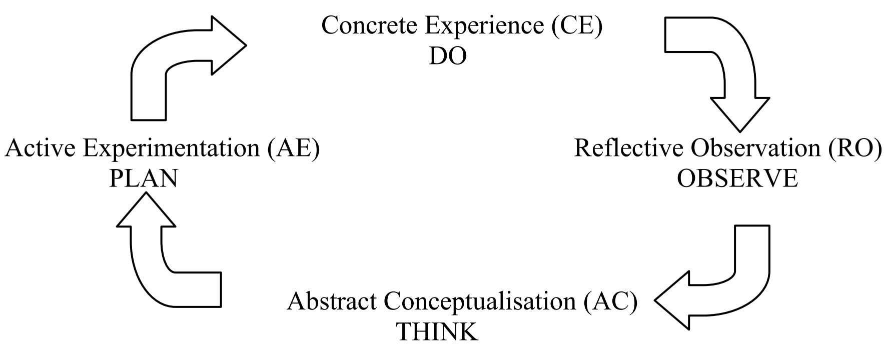
The purpose of this study is to draw a general framework of Kolb's learning styles, to determine learning styles of teachers who work in Turkey, and to determine the correlation between their branches, genders and learning styles.

Kolb's Learning Styles

Kolb's experiental learning theory (1984), is based on four basic stages of learning cycle with four different learning styles or preferences (Şirin and Güzel, 2006). Sadler-Smith (2001), explain Kolb's four-stage learning cycle as follows;

> Kolb (1984) described learning as a four-stage process consisting of concrete experience, observation and reflection, formation of abstract concepts and generalisations and the testing of the implications of these concepts in new situations. Kolb suggested that pairs of these activities may be represented as polarities with a dialectical tension between concrete experience and abstract conceptualisation (a comprehension dimension) and between reflective observation and active experimentation (a transformation dimension). Kolb suggested that individual learners have particular strengths which form the basis of their preferred 'learning style' and that an individual's style may be identified by assessing her or his position on each of these two bipolar dimensions using a self-report inventory (the Learning Styles Inventory; Kolb, 1985).

Healey and Jenkins (2000), demonstrate Kolb's experiental learning cycle in the following figure as;



Concrete Experience:	Where the learner is actively experiencing an activity (e.g., a laboratory session, field class)
Reflective Observation:	Where the learner is consciously reflecting back on that experience
Abstract Conceptualization:	Where the learner is being presented with/or trying to conceptualise a theory or model of what is (to be) observed
Active Experimentation:	Where the learner is trying to plan how to test a model or theory or plan for a forthcoming experience

Figure 1. Kolb's experiential learning cycle (based on Jenkins, 1998)

Kolb’s learning styles are determined with four dimensions stated in the cycle. The component of Concrete Experience and Reflective Observation (CE/RO) is diverger; the component of Abstract Conceptualisation and Reflective Observation (AC/RO) is assimilator; the component of Abstract Conceptualisation and Active Experimentation (AC/AE) is converger; the component of Concrete Experience and Active Experimentation (CE/AE) is accommodator that defines the learning style. Figure 2 shows Kolb’s learning styles in a diagram;

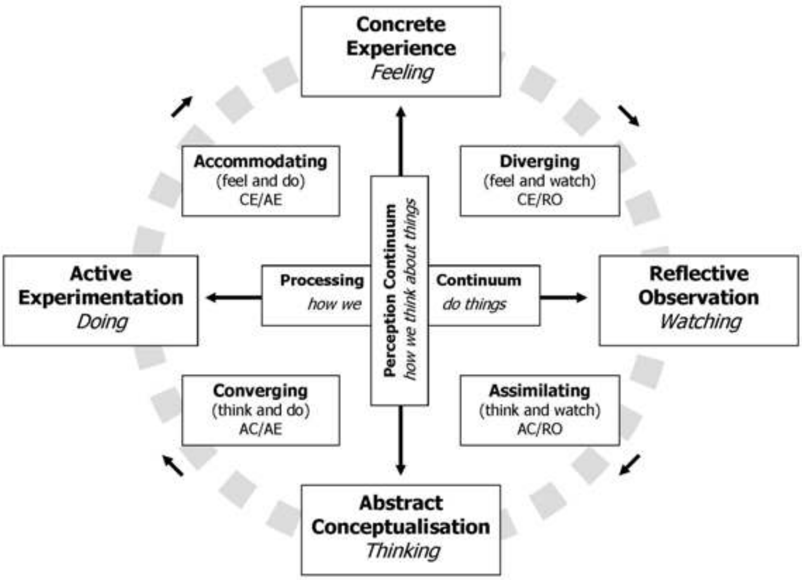


Figure 2. Kolb’s learning styles
(retrieved from http://www.businessballs.com)

Characteristics of Kolb’s learning styles that Kolb associates with problem solving abilities to describe are explained by Healey and Jenkins (2000) as;

- **Divergers** view situations from many perspectives and rely heavily upon brainstorming and generation of ideas.
- **Assimilators** use inductive reasoning and have the ability to create theoretical models.
- **Convergers** rely heavily on hypothetical-deductive reasoning.
- **Accommodators** carry out plans and experiments and adapt to immediate circumstances.

It is normal for the individuals, who have these learning styles defined by Kolb, to have optimum learning in the different learning environments. Healey and Jenkins (2000) specify that; the diverger, in observing and wide range information gathering environments; the assimilator, in the environments where the recognized logical theories are presented; the converger, in the environments where practical applications of concepts and theories are provided; the accommodator, in the environments which give hands-on experience, learn optimum.

Method of Research

Research Model: In this study correlative survey model that is one of the types of single survey is used. Correlative survey model is used for determining the change between two or more variables with respect to their existence and degree (Karasar, 1998). By using this survey method 223 primary school teachers' learning styles were determined. The participants work in different cities in Turkey. During the survey, the teachers who participated in teacher training programs including the topic learning styles conducted by Ministry of National Education were used as a research group.

Data Collection Instruments: In this study Kolb's Learning Style Inventory improved in 1984 by Kolb is used for determining learning styles of teachers. This inventory was adapted by Aşkar and Akkoyunlu (1993), and study about validity and reliability was conducted.

Kolb's Learning Style Inventory consists of 12 items and each item has four options related to relevant item. The participants range those four options according to their learning preferences. The inventory is graded with its own points. After grading, the participant's learning style is determined as diverger, assimilator, converger or accommodator.

Data Analysis: After determining the learning styles of teachers, data was transferred into Excel format and it was analysed by SPSS statistic program. In this study, the correlation between learning styles of teachers and their branches, and the correlation between learning styles and gender were examined. In order to analyse and interpret data, Pearson Chi-Square test was used.

Findings

Findings about teacher's learning styles: Findings about 223 teacher's learning styles are shown in Table 1:

Table 1. Frequency of teacher's learning styles

Learning Styles	Participants	
	Frequency	Percentage
Assimilator	54	24.2
Converger	107	48
Accommodator	39	17.5
Diverger	23	10.3
Total	223	100

When Table 1 is examined, it is seen that about half of the teachers within population is found as converger (48 %). The total number of teachers who are assimilator and accommodator together reaches the total number of teachers who are converger. The lowest number of teachers learning style is diverger.

Correlation between teachers' learning styles and their branches is tested by Pearson Chi-Square. The teachers who participate in the study have 5 branches. Those branches are; classroom teachers, social-science, Turkish, math and science & technology. Table 2 shows the results of Pearson Chi-Square test about correlation between teachers' learning styles and their branches.

Table 2. Pearson Chi-Square test results about correlation between learning styles and branches of teachers

Branch	Learning Styles				Total
	As.	C.	Ac.	D.	
Classroom teacher	10	24	13	5	52
Social Sciences	9	28	7	9	53
Turkish	9	21	8	4	42
Math	17	26	6	3	52
Science & Tech.	9	8	5	2	24
Total	54	107	39	23	223

Pearson Chi-Square$_{(12)}$=13,519, p=0,332, p>.01

According the Chi-Square test there is no significant correlation between branches and learning styles of teachers. This finding indicates that different branches have no effect on determining learning styles of teachers.

Table 3 shows the findings of correlation between dominant learning styles of teachers and their gender.

Table 3. Pearson Chi-Square test results about correlation between learning styles and gender of teachers

Gender		Learning Styles				Total
		As.	C.	Ac.	D.	
Female	N	19	24	13	2	58
	%	32,8	41,4	22,4	3,4	100
Male	N	35	83	26	21	165
	%	21,2	50,3	15,8	12,7	100
Total		54	107	39	23	223

Pearson Chi-Square$_{(3)}$=7,745, p=0,52, p>.01

When table 3 is examined, it is seen that teacher's gender and their learning styles are homogenously distributed. According to the results of Chi-Square test, there is no significant correlation between gender and learning styles of teachers. The numbers of female who have assimilator and accommodator learning styles are higher than the numbers of male. On the other hand, the numbers of converger and diverger learning styles are higher in male than female. The number of male who have diverger learning style is four times higher than the number of female having diverger learning style. It is seen that genders of teachers have no effect on determining the learning styles.

Discussion and Conclusion

Teachers' dominant learning style is found as converger. This outcome is different from some researchers' findings. The researchers like Aşkar and Akkoyunlu (1993), Ergür (1998), Kılıç (2002), Gencel (2006), Demir (2006), Hasırcı (2006), Çaycı and Ünal (2007) denote the dominant learning style in Turkey as mostly assimilator. On the other hand Ateş and Altun (2008), show that majority of the students (%63.8) have converger learning style. Research of Ateş and Altun was conducted on Computer and Teaching Technologies Department students. For this reason the students who attend to this analytic settlement requiring department have converger learning style. As found in this research, the fact that the majority of the teachers have converger learning style can be grounded by their deductive analysis necessities.

Research findings demonstrate that there is not a significant correlation between teachers' learning styles and their both branches and genders. Entwistle (1981), claim that teachers' teaching styles are the reflection of their learning styles (Evans, 2004). Because of this, it is expected that there is a significant correlation between teachers' branches and their learning styles. The fact that in research conclusion no such a relation can be found, gives the thought that even if they have different branches and different learning styles, teachers apply a similar teaching method. This teaching method can be said the traditional teaching method in which the teachers are active information transmitters and the students are passive information recipients. Therefore, the teachers are required to be informed about learning styles and specify their learning styles. This way, it will be possible for the teachers to determine the teaching approaches proper to learning styles of students and organize teaching of lesson according to this. Thus, teaching lessons with a monotype method will be prevented.

A significant correlation between learning styles and genders of teachers could not be found. Although there are researches pointing that learning styles are related with the genders (Ergür, 1998), there are more researches pointing that there is no relation between learning styles and genders (Gencel, 2006; Demir, 2006; Arslan and Babadoğan, 2005; Ateş and Altun, 2008). Therefore it can be said that the learning styles, which Kolb specified based on the experimental learning theory, are related with especially the experiences of individuals gathered through their social life rather than their genders.

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Electromagnetic induction: a proposal for a teaching/learning path

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Abstract

The researches on learning of electromagnetic phenomena (EM) have revealed some difficulties related to a partial understanding of electromagnetic induction, to a not complete knowledge of the different situations producing induced currents or in contrary related to a wrong use of the Lenz law. In the framework of a research for a curricular teaching/learning path in vertical perspective, according to MRE model, a study dedicated to the specific knot of the electromagnetic induction to students of middle school has been carried out. On the same knot three different strategies are implemented in parallel classes of the same school: a Prevision Experiment Comparison (PEC) explorative strategy, a Problem Solving Method (PSM) and a semiotic mediation on artefacts. In this paper data of the learning path based on the PSM are discussed according with the detailed grid of research questions split from the main problems underlined in literature.

Introduction: learning knots about electromagnetic induction

The main students' difficulties are related to the concept of field as superposition (Rainson et al, 1992), sources of fields (Maloney et al, 2001; Guisasola et al, 2004), fields representation and systems (Guisasola et al, 2004; Borges et al, 1998), field lines and trajectory (Tornkwist et al, 1993), the sources of time depending fields (Guisasola et al, 1999; IPN Kiel, 1985), the electromagnetic induction (Thong et al, 2008; Galili et al, 1997; Stefanel, 2008). In some examples of the CSEM assessment test (D. P. Maloney et al, 2001), authors show that the majority of students explained the idea that motion of either the loop or the magnet is necessary to generate an induced current. Many students do not distinguish electrical and magnetic effects and that they do not recognize Lorentz force or that there are moving charges inside the conductor.

The researches have also revealed learning difficulties related to the application of Lenz Law (E. Bagno et al, 1997). Students often have problems in determining the versus of the induced field, probably because of an incorrect interpretation of textbook sentences like "The induced current resists its cause", because this is interpreted as opposite versus of induced field.

Other problems are related to: the fact that induced current varies proportionately with the current that induces It, that there must be contact between the magnetic flux and the coil for any induced emf, or that Coulomb or electrostatic potential difference is present in an induced electric field (W. M. Thong et al, 2008). The researchers suggested there were five areas of deficiency in students' knowledge structures: 1. Often the student's knowledge structure does not include central relationships (e.g. Maxwell's equations) in any form, neither mathematical nor qualitative. 2. There is an over-emphasis on subsidiary information (i.e. Ohm's law). 3. They have difficulty retrieving even the partial information that they store. 4. Most students seem to represent the relationships only in mathematical form and do not have access to more qualitative representations. 5. Students hold many inaccurate ideas in electromagnetism and erroneously interpret the central relationships (Bagno et al, 1997; Stefanel, 2008).

Several studies in literature (Guidoni, Durban) suggest the necessity to work for curricular proposals in a vertical prospective. For this reason, in the context of the MRE, a study dedicated to the specific knot of the electromagnetic induction to students of middle school has been carried out. In this work data of the explorative strategy are discussed according with the detailed grid of research questions split from the main problems underlined in literature.

Context, research questions and situations

This work is based on a brief research experimentation (6 hours) conducted with 19 pupils of the same class of the 3rd year of Middle School (13 year old students). The experimentation involved in total 60 students that never studied the topic of electromagnetic induction before, but received by the same teacher an introduction to magnetic phenomena, according with a pre-requisite path (Fedele et al, 2005; Bradamante F, PhD dissertation, private communication). The class group consists of 19 students: 4 of them are foreign and have some problems in communication, 6 students have a low level of marks in science, the others a high one. The class may be considered of a middle level.

The session is based on Problem Solving Method (Michelini 2005, Watts 1998). The proposed activities, that presuppose an experimental investigation, are presented as a play: the play of solving a well defined and concrete problem to be carried out personally with the sources at disposal.

According to previous researches, we decided that an effective angle of attack may be those of field and field lines and a spontaneous exploration of phenomena.

A second part is based on an experimental explorative learning path to re-examine and consolidate the concepts of magnetic field, Its representation through field lines, magnetic flux and Its variation as responsible of electromagnetic induction in Its interpretation.

The main research aims in the first part are spontaneous reasoning in problem finding, own problems and approaches in operative exploration, relationship between explicit presentation of a systematic organization of case studies and complete synthetic vision of induction law.

The main research questions of the experimental path carried out are:

does the observation of the field lines configuration help in recognition the vectorial nature of magnetic field, in reasoning in terms of field to give an operative meaning to Faraday-Neumann-Lenz Law to overcome conceptual knots and understand electromagnetic induction?

The explorative situations faced in the path carried out are listed in Table 1.

Table 1. The situations in the path of the second session

▪ The space around a magnet: the magnetic field representation through field lines. ▪ Two or more magnets in the same space: magnetic field vector and superposition of magnetic fields. ▪ A coil in a magnetic field: all the situations generating electromagnetic induction.

Strategies and methods

In an activity of 6 hours for each class having the same teacher and with the same pre-requisite path done before, three different strategies are implemented in parallel.

A) Experimental explorative learning path: in a first class the situation path is offered with CLOE conceptual labs approach (Michelini, 2005) in which an explorative hands-on situation path is proposed using stimuli worksheets (Martongelli, 2001; Michelini, 2003) and a strategy based on SPPEA cycles (Situation, Prevision, Planning, Experiment, Analysis). These worksheets were organized in a path for students, done in previous researches (Fedele, 2005; Bradamante, 2005; Michelini, 2006). Rogersian interview followed the activity to clarify interpretative spontaneous ideas and type of reasoning.

B) Learning path based on the Problem Solving Method (Michelini, 2005), in a second class. In this work results of this case study are analyzed and presented.

C) Artefacts as tool for semiotic mediation (Bartolini Bussi et al, 2002), as learning path in a third class. In the class this research refers to, the SPPEA strategy is applied as follows: we used 6 worksheets, each of them containing more or less 3 problems on open experimental situations, in which we propose to observe the phenomenology and give hypothesis and previsions to be used to plan an experimental exploration with available materials or others to be searched. In the analysis of that experimental exploration, students are asked to give an interpretation or an operative explanation of phenomena.

The work methodology was always an active personal involving of all the students, in small fixed groups, chosen in the way that they consisted of students of all the levels.

The curricular path and Its research questions

The approach followed in the present work is those based on Problem Solving Method (B) and CLOE explorative Labs to re-examine and consolidate the experience of the activity of Problem Solving.

The session of is organized as follow: in the first part tasks and rules are presented. Students have a challenge: “Building an electromagnetic induction motor, maximising induction”. Resources available are: physics textbooks of different levels (someone more descriptive, others with formalism, one treats electromagnetism but not electromagnetic induction); Internet sources and web sites regarding phenomena linked to electromagnetic induction, historical aspects, technological applications; various laboratory equipments to build experiments on their own hands (magnets of various shape and size, pieces and objects made of different materials, wires, coils, bobbins with different number of coils, galvanometers) and some artefacts based on electromagnetic induction. Students have to find the problem to solve starting from the task of using the resources available in a free manner, conducting a preliminary feasibility study. Like real researcher, each student has a budget (120 €) to use to seek theoretical (30 €) or technical (10 €) advice by teacher, but he cannot spend any more. The resources presentation is very important because is a way to obtain the student involvement according with their own way of thinking and interpretative point of view of the problem. The presentation has to stimulate interest, curiosity, creativity: it is a panorama of suggestions and flashes with references to the available sources, as an implicit suggestion of the main modalities to face and solve the problem, even if no one of them is really described. In this way the activity is presented as a play and each student feels free to choose a modality according to his way of thinking and attitudes.

In the next part each student studies the problem on his own, plans the modality of work, does a study of practicability exploring all the sources at his disposal, writes his project. In the next part students work in small group of 4-5 of them, discussing the personal projects, choosing one or two of them to execute (depending by time and way of execution), assigning tasks to each component of the group, carrying out the experiment, writing notes for a group report. In the last 50 min each group write a report of the activity. As homework, each student has to write a critical report based on his reflection about the work done, valuations, proposals.

The explorative path begins with a pre-requisite analysis by means of an explorative experimental activity of magnetic interaction phenomena: the recognition of a property of the space around a magnet, as those able to orient a compass or a ferromagnetic needle, used as space property explorers (Bradamante et al, 2006). The magnet is recognized as source of this space property and magnetic field lines are drown as a representation of that property, distinguished by the force producing the starting motion of a free explorer. By means of the same magnet explorer (i.e.: compass) the magnetic field lines produced by more magnets are drown. The identification of the field as a vector is analyzed as a new aspect as regards the superposition of field. The electromagnetic induction is explored starting from the observation that we may have a current in a wire also when there are no generator in the circuit and the concept of flux and the role of flux variation are build (Table 1).

In Table 2 the research question of the activity of re-examination and consolidation of the experience of Problem Solving are split according with the main situations of the learning path.

Table 2. The detailed research questions

1- Are the reasoning in terms of property of the space around a magnet or still in terms of interaction between objects (systems) and magnet? 2- What students identify to be around a magnet? 3- Do students recognize an explorer?

4- Is the planning proposal based on explicit/implicit hypothesis?
5- Do students take in account the contribution of earth magnetic field in orientation of compasses? 6- Does earth magnetic field considered as responsible of the orientation of compasses?
7- Which explanation students give for the change of orientation? 8- Does the idea of superposition of field emerge?
9- Do students recognize the parallelism of needles far from a magnet? 10- Do students describe lines and/or compare them in the various situations? 11- Is the description concerning the states or the process of change of direction? And, when the process is identified, is the new field lines path recognized as a characteristic that the magnet produces? 12- Do students recognize the superposition or does the role of earth magnetic field disappear?
13- Do students recognize field lines as dependent from the source or interpret them as a structure of the space independent from It? 14- Do students associate field lines path to the magnet? 15- Do they recognize the magnet as a source?
16- Is the field lines structure and Its symmetry recognized in the three dimension space? 17- Is an exploration planning proposal based on explicit/implicit hypothesis in terms of field? 18- Are the use of an explorer and of the field lines an effective angle of attack for the reasoning in terms of field? 19- Which angles of attach are effective for the reasoning in terms of field in the conceptual reconstruction of the phenomenology?
20- Are field lines considered as an autonomous entity or associated to the magnet as source? 21- Do students connect the orientation of needles when there are no magnets with the problem of superposition? 22- Is the description of field reduced to a part of space around the magnet or is Its infinite extension recognized? Is the platform of needles a conceptual reference tool for field idea or produce the idea that the field is limited? 24- How students give meaning and role to the field lines?
25- Is the principle of superposition recognized and used to explain the changes in the field lines? 26- Is each magnet recognized as source of the field described by field lines? 27 - Is the new pattern considered as a composition point by point or only as a new configuration? Is the change of field lines configuration globally or locally considered?
28- Do students recognize that the current is due to the field changes? 29- Are student describing the process using field lines?
30- Do students individuate all the situations that generate induced current? 44- Are these situations only described or included in a unitary interpretative framework? Which one?
31- Are field lines and Lorentz law used as tool to understand and interpret the phenomenology of electromagnetic induction? 32- In which way students use field lines to understand the induction?
33- Is the role of the flux recognized? 48- Do students propose a path of the space or look only at the lines shape?
34- Is there the phenomenologycal/descriptive recognition of the action (the change done) with the induced current? 35- Which is the interpretative model used to explain the birth of an induced current?
36- Is the speed of flux variation recognized as condition the intensity of induced current depends on? 37- Which interpretative model is used to explain the phenomenon in this case?

Data analysis

For analyzing data of the activity based on Problem Solving Method we used a monitoring observation grid in which, for each student, the following main categories of attitudes and behaviours are monitored:

if student studies proposed problems only from a theoretical point of view, if he is absorbed in his work, if looks around, if immediately uses the objects at disposal, if he asks suggestions to teacher, if he takes advice from other students, if he examines the textbooks and the web resources, if he uses materials in a random way or chooses them with a criterion, if concocts the material and leave It without using, if he starts the realization of the experiment and perseveres with the same modality, if he gets tired and passes to other materials, if often looks at the clock, if controls the work of other students.

For group activity following attitudes and behaviours are monitored for each group:

if the group chooses a method, if fixes intermediate aims, clarifies individual positions, decides to manage time, fixes role for each component of the group, if the roles are functional, if there are coalitions within the group, if there are mediators, if there is tension in the group, if students pay attention to the others.

For each member of a group:

if student proposes a method of work, if he underlines emerged criteria, summarizes the though of the others, summarizes the work done, if he opposes or forms a coalition with the others, mediates the conflicts, if he supports his own point of view, if controls the time, takes down notes, if he shouts to be eared.

Collected data are obtained analyzing students reports of experimental activities, research reports, critical reports on the work done written by students at home after the activity, comments emerged during the final discussion.

For analyzing data from experimental part we did a classification of answers in a priori classes, statistical analysis of standard answers, qualitative case study for special interpretative models, comparison with quantitative and qualitative data and control using Rogersian interviews.

In this work we give results of data analysis on the base of detailed research questions, so that conceptual development associated to the curricular learning path is highlighted.

Results

In the first part of individual work: 7 students analyze first the textbooks and after the experiments; 3 first the web sources, after the textbooks and at the end the experiments; 2 students the web sources and after the experiments; 5 students the experiments and after the textbooks, but not in a deep way; only one student consults only the textbooks and not experimental materials. Among students who consult textbooks: 5 analyze only one of them and ask advice to the teacher. It was suggested to look at more sources; 12 students read the descriptive parts to understand the phenomenon and skip the formalism; in particular 9 students look at the definition of electromagnetic induction, 3 how to obtain It experimentally and after they try to reproduce that experiments. The students who consult Internet, usually stop at the first result of the query research even if not satisfying, so It was suggested to try to consult more websites. A students jams in consulting the textbook that doesn't treat electromagnetic induction. The work has been most of all individual, even if sometimes students take advice from the others, 6 students seek advice to teacher. all the students, except 3 of them, analyzes the objects before choosing those to use. No one concocts the material and leave It without using, starts the realization of the experiment and perseveres with the same modality, gets tired and passes to other materials, often looks at the clock.

From the analysis of students reports It emerges that: 10 students write the definition of electromagnetic induction that they have found; 1 inserts formula too (Faraday-Neumann-Lenz Law); 5 students write their personal new elaboration of the concepts, what they have understood; these students start from the experiments they did to explain the phenomenon, so they give their interpretation; 1 student explain the birth of induced current using the Lorentz Force that "pushes electrons", other 3 students say that "into pole pieces of a magnet, a pole attracts the electrons, the other one repels them, so we have a current in the wire"; 1 student says that "the magnet creates energy"; 1 student individuates the rotation of a coil into pole pieces of a magnet as the only responsible of induced current "only if there is a rotation there is Lorentz Force"; 1 student that "magnetic field generates he current" and describes all the situations in which he observes induced current (for him magnetic field is what that is the flux); 3 students individuate that the velocity with which they move the coil is important to generate a stronger intensity of current; 1 student writes that "a varying magnetic field, generated by a varying current) generates an induced current"; 3 students recognize that "the versus of induced current depends on the magnetic pole I bring near to the coil"; 1 student writes of perpetual motion; 3 students recognize that "the effect depends on the number of coils in the bobbin"; 1 writes of a "moving of energy"; 6 students bring as examples the artefacts; 3 students don't recognize the situations in which they have an induced current, but only he fact that there is a current.

For the group work, students divide into 4 groups, two of 5 students and two of 4 students.

From the analysis of group reports It emerges that: in 5 cases students refer to the movement of the magnet to generate an induced current; in 2 cases they say that "there is a current since I move the magnet"; in 2 cases there is the recognition that the velocity of the movement influences the intensity of the current; in 2 cases also that "the versus of the current change if I bring near to the coil the other magnetic pole"; in 2 cases students write that "If I rotate the coil, Lorentz Force moves the electrons and I have electrical energy"; in 3 cases there is written that "magnetic poles attract or repels the electrons"; in 3 cases students write that "the magnet generates energy", "a magnetic field generates electricity", "a magnetic field generates an electromagnetic flux". All the groups refers that "a flux variation causes an induced current". A group refers of Faraday-Neuman Law too. All groups give the definition of electrical motor, writing of the transformation of mechanical energy in electrical energy through the rotation. In 1 case there is the recognition that the number of coils influences the intensity of current. All the groups brigs the examples of the artefacts as experiments that they have performed.

Following data refers to a recorded discussion with a group, whose members couldn't write their considerations and experimental results: "only if I bring the coil inside or outside of the pole pieces of the magnet, I have induced current; if I move the coil inside the pole pieces, I have no current, but, if I rotate It, I have current again".

Conclusions

The usual reproductive way of learning influence the explorative problem solving work of students, they often copy in an dogmatic way the statements from the textbooks and after, in an empirical way, perform some experiments and recognize one or two situations in which the maximum signal on the galvanometer is obtained. During the work emerge an important need to become familiar with a responsibility in planning experimental exploration and report results. A structured research plan is very rare in their work: this can be understood, but a common attitude to conclude with partial local information appear to be a need at methodological level.

It emerges an electrostatic interpretation of the current through the potential ("magnetic poles attract or repel the electrons").

Students have difficulties in organizing structured investigation or elaborate explorative path; when they find something that works, they write It as a result of a research. The local and partial vision of the phenomena obstacle their interpretation of the induction cases in a unique framework.

Some students have the need to refer in a book-way, coming out the context.

Data results from individual reports may be divided in two categories:

- statements of a declarative type about the nature of electromagnetic induction in terms of definition,
- report about two case studies in which they find electromagnetic induction in the form of a current seen on a galvanometer or through a led that lights up.

No planning emerges, there is only a referring about local cases, only a list of cases and sometimes they forget some aspects. Usually there are observative-phenomenological descriptions. No attempts of generalization, and this means the attitude to declare found results only, and this responsibility in connection with scientific exploration of a big range of situations interpretable through the same process, is a potentiality improved by PSOF Method.

About the group work, It emerges that the students who effectively do an organized investigation and explore all the situations, describe them without inferring.

Sometimes there are some conclusions, but without the description of the experiments done or with only a drawing by which we can deduce the type of the experiment done, that in general is only one.

It emerges that the observation of the field lines configuration help in recognition the vectorial nature of magnetic field, in reasoning in terms of field to give an operative meaning to Faraday-Neumann-Lenz Law.

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Using project based learning model at solar energy and applications topic

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Abstract

Nowadays, increasing of the utilization of renewable energy resource is due to its economic and developing positive attitude to environment. Turkey is the one of the countries in the world which has potential of solar energy. The teaching of solar energy and applications (SEAs), with new learning strategies and as connected with life, is important for expected goals. The aim of this research is determine the effects of student's attitudes and achievements which was done project based learning (PBL) model at SEAs topic in high school. Research was conducted with control group and experiment group. While the SEAs topic was being given to control group by traditional method, the topic was given by PBL model the SEAs to experiment group student. The field trip was prepared to The Renewable Energy Resources Center (RERC) at The Suleyman Demirel University. After the field trip the experiment group was prepared project about the SEAs topic. The SEAs Achievement Test (SEAAT) and The Environmental Attitude Scale (EAS) were given both groups, as a pre-test and post-test. Collected data's were evaluated by using SPSS. The results of research, the student's, who were in PBL model, attitudes and achievements, are more than the student's who were in traditional method was determined. At the results EAS and semi-constructed interviews, the students have developed positive attitude to environment and the SEAs topic.

Introduction

Renewable energy resources (solar, hydroelectric, biomass, wind, ocean and geothermal energy) are inexhaustible and offer many environmental benefits over conventional energy sources. Each type of renewable energy also has its own special advantages that make it uniquely suited to certain applications (Kaya, 2006). Most of the renewable energy comes directly or indirectly from the sun. Sunlight or solar energy is used for many commercial and industrial purposes in heating, lighting and electricity production (Morgil and et.al 2006). The project based learning and the field trip are will be effective to constructing of knowledge of students at the teaching of solar energy and applications topic.

Project-based learning (PBL) is an instructional model that covers the problem solving skills of the students, ensuring working on their own to construct information and to finalize their studies in a realistic manner (Cole and et. al., 2002; BIE, 2008). The PBL approach engages learners in exploring important and meaningful questions through a process of investigation and collaboration. Students ask questions, make predictions, design investigations, collect and analyze data, use technology, make products, and share ideas (Krajcik and et al., 1999).The outdoor field trip is defined as a teacher-led student excursion away from the physical classroom. It is considered to be a valuable learning experience because the activities during the trip provide a hands-on experience to complement traditional classroom teaching (Flexer and et al., 1984). Field trips are an important component, or teaching methodology, of an educational program. They are usually taken to provide students with opportunities that they do not or cannot receive in the classroom. Field trips may be taken to museums, cultural events, or to the outdoors. However, while their value is known, field trips are not used by all teachers (Orion and et al., 1994).

The Solar Energy Applications at the Renewable Energy Resources Center (RERC). Solar Chimney**;** one of the Application of Solar Energy**:** The solar chimney offers a method for the large scale generation of electricity from solar energy. Ambient air is drawn into the glass collector. This is warmed by solar energy and rises up the chimney. The current of rising warm air drives a turbine. The capital cost is high but running costs are very low, the fuel is free and the power station has a long lifetime. The technology could become the cheapest method for the large scale generation of solar electricity (Schlaich, 1995).

PV stands for photo**v**oltaic; Photo means light and voltaic refers to volt, a unit of electrical force. Hence photovoltaic activity is the process where electricity is generated, using light. Solar panels that use PV chips are designed to do just that whenever the sun shines on them(AES,2008).

The aim of this research is determine the effects of student’s attitude and achievement which was done project based learning model supported by prepared according to constructivist approach the field trip.

Materials and Method

The aim of this research is determine the effects of student’s attitude and achievement which was done project based learning model. Research was conducted with control group and experiment group. The Gülkent High School the latest class students in Isparta City were divided into two groups which are control and experiment group. The study was done in 2007-2008 educational term while the topic of "Solar Energy and Applications” was being given to control group by traditional method; the topic was given by project based learning model to experimental group student. The Renewable Energy Resources Center (RERC) was selected at The Suleyman Demirel University for the field trip. After the field trip the experiment group was prepared project about The Solar Energy and Applications Topic at their school. At the end of the project, each group made an oral presentation of their final product to the teacher and their peers who then made critical comments on their projects. The Solar Energy and Applications Achievement Test (SEAAT) and Environmental Attitude Scale (EAS) were given both groups, as a pre-test and post-test.

Materials. The Solar Energy and Application Achievement Test (SEAAT): The purpose of this test was to measure the achievement of students about The Solar Energy and Applications topic. SEAAT included 30 questions. 29 questions was multiple-choice, one was open-ended question. Cronbach alfa reliability coefficient was 0.75.

Environmental Attitude Scale (EAS): Berberoğlu and Tosunoğlu (1995) were developed Environmental Attitude Scale. This scale was applied to 639 students. EAS is consisting of four dimensions that energy consumption, the size of population environmental problems Nuclear energy. SEAS was included 21 item. Cronbach alfa reliability coefficient was 0.70.

Data Analysis. The data were analyzed using SPSS 13.0 statistics program. Paired samples t-test was used to investigate significant differences between pre-test and post-test in the groups. And then the semi-structured interview protocol was used for determining students' views about this application. The interviews results were evaluated.

Findings and Discussion

Table 1. t-Test results of the SEAAT pre-test scores of the two groups

	N	X	S	sd	t	p
Experimental Group	16	29,62	8,11	32	,087	,931
Control Group	18	29,38	7,61			

[$t_{(32)}$=0.87, p>.05]

SEAAT pre-test results showed that in the beginning of the application the experimental group who was done the project based learning model scores from the control group which was subjected to traditional method X=29.62 and 29.38 respectively. t-test results indicated that the difference in the pre-test mean score was not statically significant.

Table 2. t-Test results of the SEAAT post-test scores of the two groups

	N	X	S	sd	t	p
Experimental Group	16	87.81	7.91	32	15.34	.000
Control Group	18	42.94	8.99			

[$t_{(32)}$=15.34, p<.05]

SEAAT post-test results showed that at the end of the application, students in the experimental group who were applied the project based learning model scored higher than the students in the control group who participated traditional method X= 87.81 and 42.94 respectively. And t-test results indicated that the difference, in the post-test mean score was statically significant.

Table 3. t-Test results of the EAS pre-test scores of the two groups

	N	X	S	sd	t	p
Experimental Group	16	74.81	4.59	32	0.65	.517
Control Group	18	73.83	4.11			

[$t_{(32)}$=0.65, p>.05]

EAS Pre-test results showed that in the beginning of the application the experimental group who was done the project based learning model scores from the control group which was subjected to traditional method X=74.81 and 73.83 respectively. t-test results indicated that the difference in the pre-test mean score was not statically significant.

Table 4. t-Test results of the EAS post-test scores of the two groups

	N	X	S	sd	t	p
Experimental Group	16	94.06	7.37	32	7.26	.000
Control Group	18	77.50	5.89			

[$t_{(32)}$=7.26, p<.05]

EAS post-test results showed that at the end of the application, students in the experimental group who were applied the project based learning model scored higher than the students in the control group who participated traditional method X= 94.06 and 77.50 respectively. And t-test results indicated that the difference, in the post-test mean score was statically significant.

The interview has been done with students about the field trip and project based learning model. The data was determined which results of interviews as follows:

This question addressed to the students in the study was “Did you draw attention the solar energy and applications’’ When we examine the responses to that question, we found that most of the students stated that yes, because their cost is very low and using of they is very suitable for our country. I did not know that its usage area was very much.

This question addressed to the students in the study was “Are you thinking is this field trip providing the benefit for your project ’’ When we examine the responses to that question, we found that most of the students stated that yes, we think that we learnt how work most of solar energy applications at place. Now, we can prepare different project. We think that, the field trip will be a useful our project.

Conclusion

At the end of the research, the student's who were in project based learning model, achievements are more than the student's who were in traditional method was determined. Project-based learning is an effective educational approach and offers the opportunity to apply theoretical and practical knowledge, and also to develop the student’s group working, and collaboration skills (Close, 2003; Frank and Barzilai, 2004; Marx, and et al 1997; Polman, 2000). PBL accommodates and promotes collaboration among students, between students and the teacher. For PBL to be effective, the school must give students change to involve team projects frequently. Placing students in a group and assigning them a task does not guarantee that the students will engage in effective collaborative learning behaviour. At the results of SEAS and EAS and semi-constructed interviews, the students have developed positive attitude to environment and The Solar Energy and Applications topic. Students thought project based learning is an interesting and enjoyable learning method, and that it offers a more flexible and nurturing way to learn. Their attitudes helped students increasingly become more self-motivated and independent learners, which will help students, continue their learning practices once they leave school.

Before the project is started, the field trip which was to RERC useful for learning solar energy and applications topic. The similar results from different studies were cited; Gennaro (1981) and McKenzie (1986) found that most students who have been prepared for field trips by their teachers concentrate better and learn more from the experience. Storksdreck and Falk (2003) have found evidence that pre- and post-visit activities support not only the field trip itself, but also subsequent learning experiences that provide evidence for long-term impact of a science museum visit. This is a viable learning strategy and should be encouraged by physics teachers.

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Teachers' beliefs, attitudes and intentions about using Geometer's Sketchpad in their mathematics classroom

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Abstract

In this study, we sought to examine the influence of grade 10 to 12 mathematics teachers' beliefs on their intention and actual usage of Geometer's Sketchpad (GSP) in their classrooms. The theory of planned behaviour (TPB) and the innovation diffusion theory (IDT) were used to examine the influences of teachers' attitudes, subjective norms and perceived behavioural control on their intention to use GSP in their classrooms. The study adopted the co-relational research design. Both correlation statistics and regression analyses were used to analyse the data. By using stepwise regression analyses it was possible to identify the most important belief predictors and their weights for the different constructs. This study found that the beliefs about the perceived usefulness in combination with the beliefs about the level of technology proficiency are the most important predictors of teachers' use of Geometer's Sketchpad.

Introduction

Researchers agree that technology can be used effectively as a cognitive tool for teaching and learning in the classroom (Bruce & Levin 2001; Bransford, Brown & Cocking 2000). With respect to mathematics teaching in particular, researchers have argued that technology has the potential to enhance instruction (Connell, 1998; Roschelle, Pea, Hoadley, Gordin & Means, 2000). In fact Dede (2000) indicated that technology can be used to strengthen student learning and enhance pedagogy. With this in mind, we introduced The Geometer's Sketchpad (GSP) to mathematics teachers. The Geometer's Sketchpad was originally designed for teaching geometry in secondary schools. The programme allows learners to discover patterns, to explore and to test conjectures by constructing their own sketches. The Geometer's Sketchpad is a powerful teaching and learning medium. This programme has been reported to (a) enhance mathematics teaching; (b) help with conceptual development; (c) enrich visualisation of geometry; (d) lay a foundation for analysis and deductive proof; and (e) create opportunities for creative thinking (Sanders, 1998).

However, teachers' attitudes and beliefs have been identified as barriers to their use of technology for instruction (Hew & Brush, 2007), and problems can emerge when teachers' beliefs are ignored because "Beliefs and values that teachers hold drive many of the choices they make in the classroom" (Cuban, 2001, p. 169). Cuban (2001) argues that beliefs influence what and how teachers choose to teach and what innovations they endorse or reject. In addition, "teachers' beliefs and principles are contextually significant to the implementation of innovations" (Munby, 1984, p. 28). We therefore need a deeper understanding of the nature of beliefs that influence the behaviour of a teacher and how these beliefs manifest.

Theoretical framework

The theory of planned behaviour (TPB) (Ajzen & Madden, 1986) links a person's behaviour to his/her beliefs. The TPB emerged after extensive research into and modification of a previous theory. As seen in figure 1, it explains human action and suggests that human action is guided by behavioural beliefs, normative beliefs and control beliefs (Ajzen & Madden, 1986). Together, these three factors will determine the behavioural intention, and therefore in the end also the actual behaviour. Ajzen (1991) explains that behavioural beliefs (BB) are beliefs about the likely outcomes of behaviour and the corresponding judgements about these outcomes, while normative beliefs (NB) involve the expectations of other people and motivation to comply with their expectations. Control beliefs include beliefs about both internal and external factors that may facilitate or impede performance of behaviour. Internal factors include skills, abilities and emotions, while external factors include environmental factors. The external control beliefs include beliefs about infrastructure, support staff and access to computers. These three considerations can produce a positive attitude towards the behaviour, and will result in perceived social pressure and give rise to perceived behavioural control (Ajzen, 1991).

Information technology (IT) researchers have also developed several models to explain software utilisation, for example the innovation diffusion theory (IDT). This model explains that the main characteristics that determine the acceptance and use of a technological innovation are the relative advantage or usefulness, the complexity and the compatibility of the innovation (Rogers, 1995). According to the IDT, behavioural beliefs also include beliefs about the perceived relative advantage, the complexity, and the compatibility of technology with the innovation. The compatibility beliefs are beliefs about the consistency of the technology use with the teacher's existing values, practices and experiences. Stols (2008) combined the TPB and IDT, which resulted in the model in figure 1. This model has the potential to improve our understanding of teachers' use of technology in general, and in their classrooms for instruction.

Research aim

The aim of this research is to examine the influence of grade 10 to 12 mathematics teachers' behavioural beliefs, normative beliefs and control beliefs on their intention and actual usage of The Geometer's Sketchpad (GSP) in their classrooms.

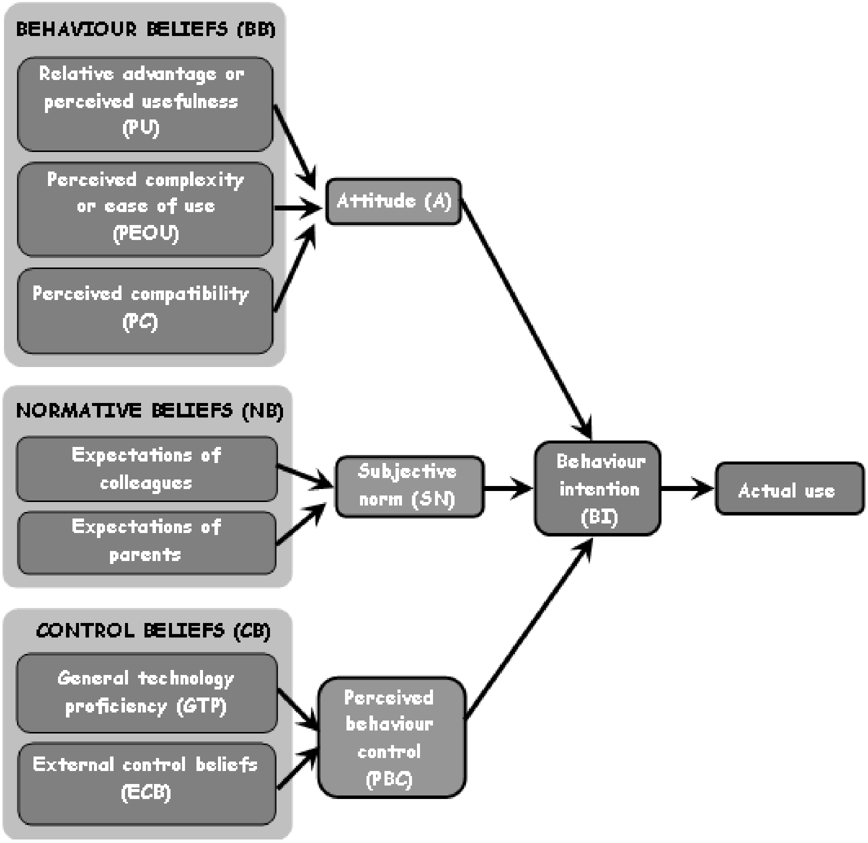

Figure 1. Combined model

Research design

The study adopted the co-relational research design. This design finds the statistical relationship between two or more variables. Both correlation statistics and regression analyses were used to analyse the data. The correlation statistics were used to correlate the beliefs to their respective direct measures of the constructs in figure 1. By using stepwise regression analyses and finding the values of R squared, it was possible to identify the most important predictors and their weights for the different constructs.

Participants and procedure. The study was done in South Africa using two samples of teachers. The first sample consisted of 12 high school teachers from 7 different schools in semi-urban areas, while the second sample consisted of 12 high school teachers from 8 different urban schools. However, data was obtained from only 22 teachers who represented a variety of cultures and experiences. Male and female teachers were included in the samples.

Questionnaire. The first step in this research was to examine publications to identify possible salient beliefs of teachers regarding the use of educational software. Stols (2008) reviewed 53 publications that were selected for their relevance. He used the constructs of the combined model (see figure 1) to analyse, organise and cluster the factors which can influence teachers' decisions to use technology. A 7-point Likert scale was used that varied for example from "unlikely to likely", and from "definitely false to definitely true".

Workshops. Teachers must know and understand the advantages, limitations, functions and complexity of a software package to be able to know what their belief about it is. Therefore, the first author conducted a workshop on the use of GSP in the mathematics classroom before the teachers completed the questionnaire. The workshop covered geometric transformations, transformations of graphs of functions, and Euclidian geometry. In essence, the workshop integrated the development of computer skills and mathematical discovery. In developing mathematics activities and materials, we followed the guidelines of (a) addressing worthwhile mathematics with appropriate pedagogy; (b) taking advantage of technology; (c) connecting mathematics topics; and (d) incorporating multiple representations (Garofalo, Drier, Harper, Timmerman & Shockey, 2000). For example, the workshop covered transformation geometry, which is a new topic in the South African curriculum that uses hands-on activities.

Results and discussion

Descriptive statistics, correlation and regression analyses were used to analyse the data. In the following correlations ** indicates a significance at the 0.01 level (two-tailed) and * a significance at the 0.05 level (two-tailed). The most important predictors and their weights were identified by using stepwise regression analyses.

Influence of behavioural beliefs (BB) on attitude (A). According to the TPB model, behavioural beliefs will produce a positive or negative attitude towards the behaviour. Behavioural beliefs also include, according to the IDT, beliefs about the relative advantage (usefulness), complexity (perceived ease of use), and compatibility of GSP.

Table 1. Summary of the Pearson correlation coefficients between behavioural beliefs (BB) and attitude (A) with N = 22

	A	PU	PEOU
PU	0.889(**)		
PEOU	-0.137	-0.219	
PC	0.816(**)	0.902(**)	-0.301

Table 2. Summary of the regression analysis for attitude (A)

Predictor	R	R square	F	Sig.	df
PU	0.885	0.784	65.300	0.000	1

The highly significant correlation of 0.902 between the perceived usefulness (PU) and perceived compatibility (PC) of using GSP for teaching indicates that these teachers think about the usefulness of GSP in terms of the pedagogical compatibility (see table 1). Ertmer (2005, p. 36) argued that "if we truely hope to increase teachers' uses of technology, especially uses that increase student learning, we must consider how teachers' current classroom practices are rooted in, and mediated by, existing pedagogical beliefs" (Zhao & Cziko, 2001, p. 17). Zhao and Cziko (2001, p. 17) use the perceptual control theory (PCT) to explain this phenomenon in terms of a hierarchy: "Since technology use is at a lower level of the hierarchy than pedagogical beliefs and teaching approaches, and because lower level goals are easier to vary, it is no surprise that many teachers adopt technology without changing their pedagogy."

From the regression analyses, however, it emerged that the most significant predictor of attitude towards the use of GSP is the perceived usefulness (PU) of it (see table 2). The implication is that the perceived compatibility (PC) does not directly influence the attitude but rather works through the perceived usefulness (PU) to influence the attitude. The perceived ease of use (PEOU) of GSP had a negative but insignificant influence on the attitude towards its use.

Influence of normative beliefs (NB) on subjective norm (SN). Normative beliefs (NB) refer to the perceived behavioural expectations of important individuals, leaders, groups or colleagues. The theory of planned behaviour assumes that these normative beliefs in combination with the person's motivation to comply with them influence the subjective norm (SN).

Table 3. Summary of the Pearson correlation coefficients between normative beliefs (NB) and subjective norm (SN) with N = 22

	SN
NB (colleagues)	0.363(*)
NB (parents)	–0.017

The correlation coefficient of 0.363 between subjective norm and normative beliefs (colleagues) is significant at the 0.10 level of significance only.

Table 4: Summary of the regression analysis for subjective norm (SN)

Predictor	R	R square	F	Sig.	df
Colleagues	0.363	0.132	3.196	0.088	1

From tables 3 and 4 it is clear that the expectations of the parents or the colleagues did not have any significant impact on the subjective norm of these teachers. This is understandable because in a normal schooling context teachers have the authority to make their own decisions in the classroom. They act relatively independently within their classrooms and have considerable autonomy over their teaching activities (Hu, Clark & Ma, 2003). The pressure from peers or colleagues to use technology for instruction is therefore limited.

Influence of control beliefs (CB) on perceived behavioural control (PBC). Perceived behavioural control is about the presence of factors that may facilitate or impede performance of the behaviour, and the perceived power of these factors (Ajzen, 1991). In the context of this article perceived behavioural control relates to factors influencing the extent to which teachers feel able to use GSP in the classroom. Control factors include both internal factors and external factors. Technology proficiency is an internal factor that can influence the perceived ease of use and the perceived usefulness of technology.

Table 5. Summary of the Pearson correlation coefficients between control beliefs (CB) and perceived behavioral control (PBC) with N = 22

	PBC	GTP
GTP	0.754(**)	
ECB	0.498(*)	0.536(*)

Table 6. Regression analysis for perceived behavioural control (PBC)

Predictor	R	R square	F	Sig.	df
GTP	0.754	0.568	22.391	0.000	1

Both the general technology proficiency (GTP) of the teacher and the external control beliefs (ECB) relate to the perceived behavioural control (PBC). A strong positive, statistically significant, correlation of 0.754 was found between perceived behavioural control (PBC) and the general technology proficiency (GTP) of the teachers. A weaker but significant correlation of 0.498 exists between perceived behavioural control (PBC) and the external control beliefs (ECB) beyond a teacher's direct control. Table 6 shows that the general technology proficiency (GTP) of a teacher explains 56.8% of his/her perceived behavioural control (PBC).

Influence of attitude (A), subjective norm (SN) and perceived behavioural control (PBC) on behaviour intention (BI). According to tables 7 and 8, a positive, statistically significant, correlation was found between attitude (A) and the behaviour intention (BI) (0.551) and both perceived usefulness (PU) and the perceived behavioural control (PBC) (0.677). However, from the regression analyses it emerged that the most significant predictor of behaviour intention (BI) is perceived behavioural control (PBC).

Table 7. Summary of the Pearson correlation coefficients between attitude (A), subjective norm (SN), control beliefs (CB) and behaviour intention (BI)

	BI	A	SN
A	0.551(*)		
SN	0.233	0.394	
PBC	0.677(**)	0.781(**)	0.218

Table 8. Summary of the regression analysis for behaviour intention (BI)

Predictor	R	R square	F	Sig.	df
PBC	0.671	0.451	13.942	0.002	1

Actual use in the classroom. Using the average score for behaviour intention (higher than 4 on the 7-point Lickert scale), 14 teachers intend to use GSP in their classrooms. Three months after the workshop we managed to contact the teachers. Only 3 of the 14 teachers that intend to use GSP did not use it in their classrooms. No teachers with less than 10 years of teaching experience used GSP in their classrooms. All the teachers with a teaching experience of between 10 and 25 years are using GSP in their classrooms.

Table 10. Summary of the responses in the questionnaire about the different constructs of the TPB (7-point Lickert scale was used.)

	N	Minimum	Maximum	Mean	Standard deviation
Behaviour intention	20	1.67	7.00	5.5833	1.73332
Attitude	22	5.00	7.00	6.5114	0.66134
Pedagogical compatibility	23	4.00	7.00	5.8261	1.00689
Perceived ease of use	23	3.29	6.43	4.3602	0.70496
Perceived usefulness	22	4.86	7.00	6.3214	0.60799
Teaching strategy	20	4.00	6.43	5.3929	0.70881
Subjective norm	23	4.50	7.00	6.1739	0.77765
Normative beliefs (col)	23	3.50	7.00	5.5833	1.00722
Normative beliefs (par)	23	2.50	7.00	4.9167	1.42697
Control beliefs	21	2.90	6.90	5.1333	1.03795
General technology proficiency	23	1.20	5.50	3.6435	1.17892
Perceived behavioural control	20	2.00	7.00	4.9333	1.94245

Interpretation of results

The TPB proposes that peoples' belief-based factors (behaviour beliefs, normative beliefs and control beliefs) have an effect on their behaviour intention and can be correlated with their actual behaviour. This study found that, in the context of teachers using GSP in their classrooms, the subjective norm that forms part of the normative beliefs did not make a significant difference. However, predictor variables for attitude towards behaviour and perceived behavioural control might shed light on grade 10 to 12 mathematics teachers' intention to use GSP in their classrooms. This study found that the actual use of GSP in the classroom will be influenced by the perceived usefulness or relative advantage (PU) and the general technology proficiency (GTP) of the teachers. These two factors combined will influence the behaviour intention and the end behaviour of grade 10 to 12 mathematics teachers to use The Geometer's Sketchpad (GSP) in their classrooms. In the questionnaires 14 teachers indicated that they intended to use GSP in their classrooms. The reason 3 of these 14 teachers did not use GSP after 3 months in their classrooms was that the use of GSP was not compatible with their teaching style. This emerged from their responses to the question: "Describe the most effective way to teach mathematics." These teachers believe that the most effective way to teach mathematics is to "be patient, repeat, and drill", "explain, explore, and give lots of exercises", and "explain and drill". Unlike the other teachers who are using GSP these responses represent a more traditional approach while the use of GSP, in general, promotes a more constructivist approach. A study by Ertmer (2005) confirmed the importance of these findings: "If we truly hope to increase teachers' uses of technology, especially uses that increase student learning, we must consider how teachers' current classroom practices are rooted in, and mediated by, existing pedagogical beliefs." We can therefore conclude that they did not use it because their teaching style was not compatible with the use of GSP.

These results suggest a simplification of the original model in figure 1. From the regression and the correlation analyses, it emerged that these teachers based their decision whether to use GSP on their beliefs about the relative advantage (usefulness) of using GSP in relation to their existing teaching practices (see figure 2).

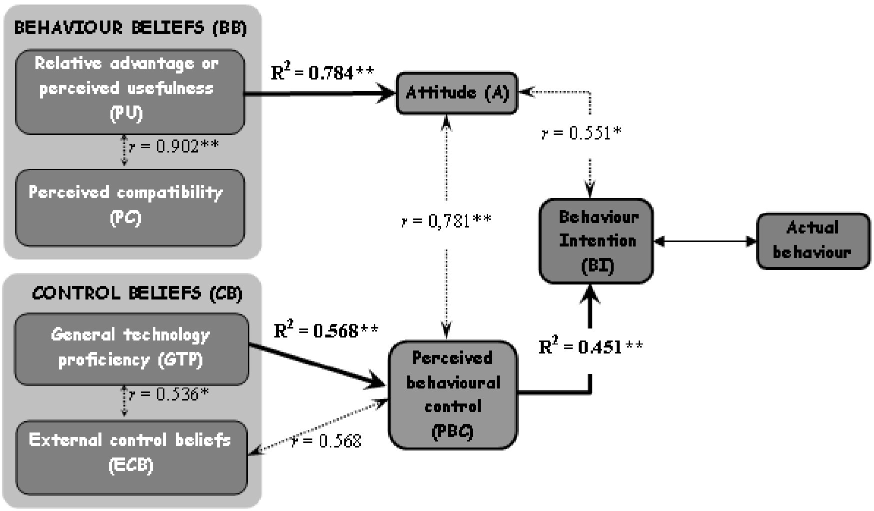

Figure 2. Simplified model (GSP): The dotted line indicates the Pearson correlation coefficient

Conclusion

Teachers' actual behaviour is influenced by perceived usefulness of the technology to make their life in the classroom easier. However, if teachers do not have the general technology proficiency to use it in the classroom it will not be used. A way to improve teachers' use of GSP in their classrooms is therefore to firstly ensure that the teachers have general computer proficiency and secondly to let them experience the advantage of using the software. Lastly, in line with our findings, Ertmer (2005) proposes that when considering ways to change teachers' practice, particularly regarding the use of technology, you have to take teachers' pedagogical beliefs into account. He proposes that you introduce teachers to the types of technology uses that can support their immediate needs (Ertmer, 2001) in order to increase teachers' confidence to use technology. These findings will be able to focus the attention of the district officials on what aspects they will have to consider if they want teachers to use GSP in their classrooms.

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Role and effect of reproducible computing technology in statistics learning

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Abstract

This paper describes a new educational technology (hosted at http://www.wessa.net and http://www.freestatistics.org) that supports non-rote statistics learning based on electronic documents ("Compendia") that allow students to reproduce and reuse computations. It is explained why the acceptance of this new technology is important and how this relates to usability and student satisfaction. Furthermore it is described how reproducible computing plays various roles in the learning process that leads to true understanding (of statistics). Some guidelines are provided that can be used by the educator to improve learning environments based on reproducible computing. Finally, this new technology allows us to objectively measure various types of actual learning-related activities that are otherwise unobservable. These measurements open the prospect of new types of research without the need to resort to reported measurements that can be shown to be highly misleading.

Introduction

The importance of the pedagogical paradigm of constructivism is undisputed (Eggen and Kauchak 2001) and its role in mathematics education has been a subject of careful study for more than a decade – this may be illustrated by the work of Von Glasersfeld (1987) and Smith (1999). Moreover, the role and effect of social constructivism in computer-assisted science education has received quite some attention in the academic community in recent years. One such example of particular interest is the work of Moreno et al. (2007) which focuses on the methodological and pedagogical aspects of course design and the use of a learning environment (Moodle 2008) in combination with other software for the purpose of simulation and visualisation of complex processes which must be assimilated and understood by students. The authors also discuss a list of requirements for computer-assisted learning environments based on proven pedagogical theories.

Obviously, this paper is much less ambitious and rigorous. On the other hand, it resembles the work of Moreno et al. (2007) in two ways. The first similarity is the educational technology: we introduce our newly developed Reproducible Computing Technology which has been seamlessly integrated into the Moodle virtual learning environment and discuss the role and effect of technology on learning based on experience and empirical research. The second resemblance is the emphasis on social constructivism and collaboration as a pedagogical framework which leads to non-rote learning of complex or abstract concepts. In this respect, we provide some guidelines that have been found to be of critical importance from a pedagogical point of view.

Finally, this paper brings together some highlights of most of our previous work that is related to Reproducible Computing in Statistics Education. In this sense, we avoid all technicalities and focus exclusively on the verbalized interpretation of our research.

The compendium and reproducible computing

Compendium. The Compendium is defined as a document where each (statistical) computation is referenced by a unique identifier (URL) that points to an object that contains all the information that is needed to recompute/reuse it. This definition implies that there is a complete separation of text and computing which has many benefits from the technological and pedagogical points of view (Wessa 2008b). The so-called Compendium Platform provides the functionality that is associated with the creation, retrieval, maintenance, and exploitation of computational objects that have been stored.

Any statistical computation that is generated through the so-called R Framework (Wessa 2008a), can be submitted to the CP where it is permanently stored in a web-based repository. Each stored computation is associated with a unique URL which can be easily inserted into any document. These links can be used by the reader of the document to view and reuse the meta information of the computation with a simple click.

The meta information is hosted at http://www.freestatistics.org and plays the role of a free web repository (Wessa and van Stee 2008). The reader can use all the features of the repository through an ordinary web browser. The following features have been implemented so far:

- read the meta information that is associated with a particular computation (including: data, parameters, computational source code, computed result, log file with computer responses at each line of code)
- read/submit comments about the computation in a threaded, hierarchical forum (which is attached to the computation's meta data)
- navigate through a hierarchical tree of inter-dependent computations with parent-child-relationships
- exactly recompute the archived computation by re-submitting the meta data to the R Framework
- reuse the archived computation in "derived" work by changing the underlying data, parameters, and/or computational source code
- search computations that satisfy certain criteria (dates, keywords, names)

Reproducible Computing. In order to allow *all* students to archive, reproduce, and reuse statistical computations one must make sure that the design of the statistical software is exclusively based on meta data. In addition, it should be possible to create, maintain, and publish such software with a minimum cost and human effort – while still being flexible, scalable, and secure. This is only possible if the computing environment (hardware and software) is embedded in a a comprehensive framework that incorporates the business model (Wessa 2008a).

In other words, the use of Reproducible Computing (RC) technology should be easy (c.q. it should be accessible to *all* students – even if they don't have many technical/programming skills). On the other hand, it should also be possible to perform *any type* of statistical analysis quickly and cheaply. The RC technology that was developed meets both – seemingly incompatible – requirements because it is based on an easily accessible web-based user interface which wraps the underlying computational code (based on the powerful, statistical R language).

The role and effect

Constructivism. The role of RC in a socially constructivist statistics course is of utmost importance – if not a conditio sine qua non. The reason for this strong statement lies in the undisputed fact that empirical results that are presented in publications (including papers, empirical research articles, course texts, and handbooks) are not truly reproducible (de Leeuw 2001). If academically trained statisticians have difficulties with the reproduction/reuse of empirical results how can we possibly expect our students to be able to learn from or interact with the examples that we provide them? The answer is simple: we can't.

Individual constructivism requires students to be able to experiment with the subject under study such that knowledge can be constructed. Social constructivism requires students to be able to communicate about statistical computations and the associated interpretations. In addition, many pedagogical theories require students to engage in collaborative activities in order to be motivated to learn and to gain a better understanding of the complexities (and different points view) that are related to statistical analysis. How can we assume that all of this is possible if the empirical results that we provide our students with are simply printed tables and pictures? Even if students have statistical software and data sets available it is very difficult for them to engage in experimentation, communication/collaboration, or critical checking of underlying assumptions. Every statistical analysis should be presented in such a way that there is a direct and unambiguous relationship between the (course) text and the computing infrastructure (which includes the hardware, the software, and all the meta data about the original computation).

There are various ways in which our RC technology can be employed to create truly constructivist learning environments. One such approach is described in Wessa (2008c) where it is shown (based on preliminary results) that there is a very strong relationship between constructivist learning activities (c.q. the submission of verbal feedback in peer reviews about a series of assignments) and the exam scores (c.q. a proxy for desirable “learning outcomes”) in which the questions assess conceptual understanding rather than rote memorization.

Before the introduction of the CP and RC, students found it very difficult to participate in peer review activities because of a variety of problems – most of which have nothing to do with the conceptual understanding of statistics. Some examples of difficulties that have been overcome with the introduction of RC are as follows:

- students were unable to identify the parameters that were used in a computation
- the data that was analysed was not available nor properly defined/described
- the effect of outliers in the data could not be assessed (robustness of results)
- an exact reference to the algorithm/method that was used in analysis was not available
- the analysis was incomplete and did not show any diagnostics about the underlying assumptions of the analysis

Due to these – mainly technical – difficulties it was nearly impossible for students to communicate (provide feedback) about computations from peers and learn from each other's mistakes. Statistical results need to be communicated precisely, with reference to all information that is necessary to (re)compute it.

From this it can be concluded that RC plays the role of a *catalyst that supports effective, constructivist learning activities* such as: peer review, experimentation, critical thinking (about the validity of underlying assumptions), communication, and collaboration.

Attitudes. Statistics is more than applying mathematical techniques to empirical data. This may be a trivial statement for some statisticians – however, many educators treat statistics as a "special case of mathematics" which leads them to use a mathematical approach to teaching. Moreover, in most statistics handbooks it is explained how statistical methods are computed (computational formulae) and why these methods are valid in certain circumstances (proofs). Such an approach however implicitly assumes that students already have an active interest in learning statistics for the purpose of empirical research and possess two of the – arguably – most important attitudes of a good statistician (or scientist): a healthy amount of scientific curiosity and a true commitment to critical thinking. If students are curious (in the scientific sense) then this may motivate them to learn and understand the mathematical aspects of statistics. If we also accept the importance of a critical attitude within the context of non-rote learning of statistical concepts then it is obvious that the computer-assisted learning environment should be supportive of critical thinking and related learning activities. Isn't it true that critical thinking about a statistical analysis is only possible if one is allowed to challenge results (in peer review), experiment (with parameters and data), communicate (about the interpretation of results), and collaborate in research? Our answer to this question is obviously, yes.

In this context it is interesting to have a look at some empirical results from an undergraduate, constructivist statistics course in which RC was extensively used (as a tool to engage in critical thinking). At the start of the course almost all (of a total of 240) students reported that they strongly disliked critical thinking (Wessa 2008f). On the other hand an explorative data mining study (Wessa and Baesens 2009) found very strong evidence that (based on a learning experiences survey at the end of the course) students' satisfaction (in terms of perceived software usability) was most strongly related to learning activities that are related to critical thinking. This came as a pleasant surprise and implies that constructivist learning (through RC and critical thinking) can be associated with a high student satisfaction. Even if critical thinking is not a pleasant activity, it can nevertheless be perceived as a very useful form of learning which yields high satisfaction.

From this we may conclude that (if certain usability criteria are satisfied) RC may help in *fostering critical attitudes* within the setting of a socially constructivist learning environment.

Acceptance. The acceptance of technology (by students) is an important factor that predicts the effectiveness of the pedagogical approach and its underlying learning technology. In Wessa (2008f) it is shown that RC can have a high level of acceptance even if the required learning effort is perceived to be very high and the learning activities go against the initial preferences of students (c.q. they dislike critical thinking). This however, does by no means explain *how* technology acceptance is related to information/system quality, ease-of-use, usefulness, relative advantage, and intention to use. These relationships are important because they provide us with guidelines for the creation of successful technology-based learning environments. The work of Poelmans et al. (2008) investigates these relationships based on a comprehensive database based on the implementation of RC technology in three statistics courses. Even though the effects may be different for female and male students (Milis et al. 2008), the empirical findings clearly highlight the importance of system and information quality as important predictors of the intention to use the RC technology. In other words, the quality of the course materials (texts, assignments, etc...) and the quality of the computer system (incl. software and hardware) are of utmost importance. In addition, it is important to understand that new technology only results in an increased use if it provides a “relative advantage” over previous/old methods of learning. In this case, RC allows us to convert “passive” documents (which can only be read) into “active” environments (“Compendia”) where students can interact with the subject under study and (indirectly) with their peers.

A special remark needs to be made about error messages that are produced by the statistical software. Before the introduction of the CP and underlying RC technology, students were required to solve computational problems by correctly reading/interpreting error messages. As a consequence, most students reported that they had difficulties with solving erroneous computations – in many cases it took days before these problems were fixed.

Since the introduction of the RC technology all error messages have – while still available – become obsolete. The reason is that students are instructed to archive all computations that contain error messages in the web-based CP and report the URL in the forum of the Moodle learning environment. Thanks to the RC technology the educator can click on the link and reproduce, reuse, and fix the computation quickly and provide feedback to the student. This has not only resulted in a substantial improvement of productivity – it has also provided us with valuable insights into the nature of commonly made mistakes.

It can be concluded that RC greatly *enhances the usefulness* of ordinary documents and is therefore well-accepted by students. Note however, that RC technology can never be seen as a replacement for high quality content in educational Compendia.

Research. The technology of RC has the potential to change our ability to do research about the relationships between learning outcomes (as measured by exams) and the learning activities that are associated with constructivism, computing, communication, and collaboration. The main reason for this is the fact that every computer-assisted activity within the CP can be accurately measured. This includes various important activities that – have never been observed before and – are related to the actual use of the R Framework and the Compendia:

- archived computations are registered, including all the meta data
- clicks on the link of an archived computation, including referer information and identity of the user (if the link is contained in the learning environment)
- reproduced computations, including meta data and identity of the user (provided user logs on to the system during the same browser session)
- reused or derived computations, including all changes and the identity of the user (provided the user does not opt to remain anonymous)
- all parent-child relationships between original and derived computations, including the identity of each computation's owner (if no anonymity was requested)

These measurements are valuable for the purpose of educational research and provide us with new insights about the value of self-reported activities as is shown in Wessa (2008d): several types of biases and measurement errors occur – in quite unexpected ways – when reported activity data are used instead of actually measured activity levels. One example relates to (a subgroup of) male bachelor students who have been found to highly exaggerate their performance – unlike their female colleagues. In the light of such findings, it is not surprising that statistical relationships between learning outcomes and reported activity measures, yield extremely low predictive power. Without implying or assuming anything about the quality of the underlying data, this may explain the typically low determination coefficients in (otherwise excellent) studies such as O'Dwyer et al. (2008).

It may be concluded that RC provides *new opportunities in educational research* based on objective measurements that are otherwise unobservable.

Final discussion

Role of Reproducible Computing. As explained before the new RC technology plays important roles for students, educators, and educational scientists. This is a non-exhaustive list of such roles:

- RC is a catalyst – if not a necessary requirement – for various constructivist learning activities which yield better learning outcomes (in terms of exam scores)
- RC fosters critical attitudes provided that the underlying technology enjoys an adequate usability standard
- RC greatly enhances the usefulness of educational documents (with quality content) which leads to a high level of technology acceptance

and increases actual use – in addition, error messages have become obsolete
- RC provides new opportunities in educational research based on objective measurement of – otherwise unobservable – learning activities

Other criteria. On the one hand the role and effect of RC technology is clear. On the other hand, it is important to emphasize the fact that the successful implementation of this new technology is only possible if the learning environment in which it is embedded meets several quality criteria. A few important criteria may illustrate this:
- the course must be designed carefully – this relates to the structure of the course and the quality of the course's resources
- continuous monitoring, and quality control is absolutely necessary – the courses that we have implemented have been continuously improved and upgraded which is not limited to the learning resources but extends to the statistical software, and the computational repository
- the role of the educator is important and closely related to perceived usability and learner satisfaction
- timely and adequate (quality) feedback from the educator and peers is necessary
- the difficulty level of assignments must be carefully balanced and contain elements that are easy enough to provide encouragement, while still posing challenges to more advanced students
- allow/encourage collaboration between students while still maintaining a healthy degree of competition
- support various learning styles by offering problem-based assignments and worked-out cases simultaneously

Challenges. While this paper emphasizes the benefits of RC in statistics education it should be noted that the introduction of this new technology poses certain challenges from an ethical point of view. Our main concern is related to the fact that the details about learning activities of students are monitored and – to a certain degree – available to other students or even third parties. Activities of individuals and social interaction between students are browsable and searchable through the CP's search engine.

Future research. In the near future many new features will be available in the CP and the R Framework. One of the most promising highlights is the feature that allows educators/scientists to extract data and analyse the data contained in the repository. Several types of data mining techniques are currently under development for the purpose of quality control and educational research.

Another important improvement relates to the ability for advanced users to use the R console (or any derived user interface thereof) and connect to the CP directly. An open source R package is currently under development and will be made available to the academic community. It is hoped that this will lead to more scientific articles (or other scientific documents) that are fully reproducible and reusable. Sooner or later, such documents will be used in education which effectively bridges the "insurmountable" gap between the practice of scientific research and academic education.

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Impact of MBL usage on concept learning and graph interpretation skills in physics

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Abstract

Utilization of Microcomputer Based Laboratory (MBL) supports opportunities for data collection, displaying, retesting, analyzing, interpreting, and graphing physical quantities such as position, velocity, acceleration, temperature, light, force, pressure, and current. The ease of real-time data collection encourages students to become more active participants and facilities interpretation of graphs. The purpose of this study was to determine the effects of MBL usage on students' learning of physics concepts and their graph interpretation skills. The participants of the study were 37 tenth graders (organized in to the experimental and control group). Treatment was continued four weeks. The experimental group involved the use of an inquiry- oriented activity (Predict-observe-explain format) by using MBL. The control group involved the use of an inquiry-oriented activity without the supports of MBL. Data were collected through the use of conceptual understanding test and graph interpretation test before and after the instruction. The results showed that MBL usage facilitated conceptual understanding and increased graph interpretation skills.

Introduction

Reform movements in educational systems can be more effective when technological tools are integrated in teaching and learning. Various technological tools have been using for improving science teaching and learning for a while. According to the National Science Education Standards, technological tools provide students and teachers opportunities to conduct inquiry experiments so these tools are an important role in the contemporary reform of science education. These tools, for instance MBL, are useful and help to increase the quality and effectiveness of education, raises the attractiveness of lessons, and accesses the technological development (Ozden, 2000). When used in science laboratories, computers can provide students with the results of their investigation immediately and help students reshape their original hypotheses, test new hypotheses, and display new results (Friedler, Nachmias & Linn, 1990).

Scientific reasoning skills contain the ability to characterize a scientific problem; set up a hypothesis; design an experiment; predict, observe, explain and analyze data; interpret the results. All these abilities are possible for using MBL technology in the class. Many approaches have been suggested about using technologies in schools as a tool for teaching and learning. Microcomputer –Based Laboratory is any laboratory in which the computer is used to investigate and explore phenomena. Computer interface devices enable the computer to detect many physical properties in the real world when used with appropriate equipment. In addition, it becomes a powerful laboratory instrument for collecting, analyzing and interpreting data. The laboratory allows students to interact with physical phenomena while exposing their own preconceptions about the subject. It allows them to develop inquiry, interpretation and intellectual skills. (Friedler, Nachmias, 1987)

Microcomputer Based Laboratory (MBL) is a technological tool composed of a computer, an interface device, probes and sensors. MBL allows immediate real-time data collection and provides graphical representations of the collected data. This situation provides plenty of time for data analysis and interpretation of results (Thornton & Sokoloff, 1990). The fundamental question is "why do we need to introduce MBL technology into schools?" By implementing tool use in the science curriculum, students are given opportunities to understand the nature of science and scientific knowledge not from the traditional science textbook but through genuine inquiry made possible by the use of graphing calculators, computers, and data collection tools (Reid-Griffin, 2002). According to Thornton (1987), students can gain first-hand knowledge of physical phenomena, construct the theories themselves necessary to understand the physical world, and formulate their own questions, further engaging them in the learning process with the help of MBL. In other words, students can spend extra time afforded from using MBL to develop their skills to interpret scientific data (Reid-Griffin, 2002).

Importance of graphing in science education

Padilla, McKenzie and Shaw (1986) emphasized that graph construction and interpretation were important skills for science students. They listed four line-graph construction skills: drawing and scaling axes, assigning manipulated and responding variables to the correct axes, plotting points, and using a line of best fit. Furthermore, they provided four other line-graph interpretation skills that students acquire: determining the X and Y coordinates of a point, interpolating and extrapolating, examining relationships between variables, and interrelating the results of graphs. There have been many studies showing that science students have difficulty with these graph skills, especially with interpretation (Mokros & Tinker, 1987; Pedilla, Mc Kenzie & Shaw, 1986). In consequence, one of the main factors which makes the MBL, together with appropriate, a powerful laboratory instrument for collecting and analyzing data is its ability to do real-time graphing.

Place of MBL in science education

Plenty of research has been done to determine the effects of MBL technology in the classroom environment. Brasell (1987) proposed that although Kinematics was more difficult unit, (MBL) real-time graphing could motivate and encourage students. Because real- time graphing of data on computer screen was fast and dynamic, MBL brought in motivation and dynamism (Brasell, 1987).

Nachmias and Linn (1987) examined the effect of use of MBL and explicit instruction on student's critical evaluation skills. Middle school students participated in the research in two phases. In phase one, 125 students used MBL in the fall semester during 54 activities about heat, temperature, and energy. In phase two, 124 students used a newer version of MBL software and hardware. The results from phase one reported significant improvement in students' abilities to detect invalid data due to scaling errors, probe setup errors, and calibration but no significant differences for probe sensitivity and experimental error. On the other hand, the results from phase two presented significant improvement in graph scaling, experimental variation and probe sensitivity, but no significant differences for probe setup or calibration. These results showed the importance of instruction emphasizing critical evaluation of scientific data. The MBL environment in the classroom gives an opportunity to evaluation of scientific data.

Mokros and Tinker (1987) suggested four possible reasons for MBL effectiveness:

- ❖ MBL uses multiple modalities,
- ❖ MBL pairs in real-time events with their symbolic representations,
- ❖ MBL provides genuine scientific experiences,
- ❖ MBL eliminates the drudgery of graph production.
- ❖ Thornton and Skoloff (1990), for instance, stated different benefits of using MBL in an experiment:
- ❖ MBL gives opportunity for data collection and display.
- ❖ Students can get data in real-time and gain the data quickly.
- ❖ MBL gives another opportunity for retesting.
- ❖ MBL is not complicated.
- ❖ MBL leaves more time on analyzing and interpreting.

The aims of the research done by Friedler and others (1990) were to try a newly designed module to foster scientific reasoning skills, and to assess its value the MBL environment. They found out that during activities, students succeeded in acquiring observation and prediction skills. Svec (1995) revealed how students perceived graphics as pictures in his study on interpreting and summarizing graphics. He emphasized that interpretation of a graphic was more important than drawing it. Casey (2001) stated that MBL increased the available time for analyzing, evaluating and interpreting data. MBL gave more opportunities for problem solving, critical thinking, and reflection.

Nicolaou T. C., Nicolaidou Z. C., Zacharia Z. Z. and Constantinou C. P. (2007) investigated the outcomes of MBL using in fourth grade students' conceptual understanding of melting and freezing. They also examined the participants' ability to construct and interpret graphs. The participants of the research were 65 fourth graders. The experimental group involved inquiry-oriented activities with MBL, the first control group involved use of inquiry-based curriculum without MBL, and the second control group involved the use of traditional laboratory methods. Data were collected via conceptual test before and after the study. The results showed that a statistically significant differences between the experimental group and both control groups in students' ability to interpret and construct graphs. MBL supported significant benefits towards helping students overcome a range of difficulties in interpreting of graphs. This study illustrated that MBL could be integrated in activity sequences guiding to significant improvements in both conceptual understanding and graphing ability.

Purpose of research

The purpose of this study was to determine the effects of MBL usage on students' learning of physics concepts and their interpretation of graphs.

Methodology

Experimental design was utilized for this study. The research was carried out during the instruction of Kinematics concepts in the fall of 2007 and lasted four weeks. Participants of the study were 37 students from two tenth-grade classes in one of the high schools in Istanbul. They had not had any experience with MBL technology before. One of the classes was chosen randomly to become experimental group and then, the students in this group were taught how to use MBL technology. Skill Survey test was applied before the instruction to make sure that the students in the experimental group learned MBL technology. The experimental group worked on the laboratory activities by using MBL with motion detector during the instruction for four weeks. The students collected data by using sensors which were connected to the computer and by receiving immediate feedback on the computer screen about the results of various modes of representation. The control group, on the other hand, performed the same activities with usual laboratory equipment. The students in both groups followed the predict-observe-explain format by working as small groups under the supervision of the same teacher. Same teaching methods were used in both groups during the instruction.

Kinematics Concept Test (Beichner, 1996) including 20 multiple-choice questions was applied as pre-test and post-test to examine the effects of MBL usage on the participants' conceptual understanding. Additionally, the outcomes of MBL usage on the participants' graphic interpretation skills were investigated by using Graph Interpretation Test (Risley, 1993) containing 52 matching questions before and after the instruction. The participants completed each test in 45 minutes. They were also asked to explain the reasons behind their choices in the tests. However, the students did not make enough declarations; therefore, these parts were not taken into account in data analysis.

Results and discussion

While paired t-test was being performed to measure the groups within themselves, independent t-test was performed to compare the groups with each other. The control group achieved little higher score related to concept learning than the experimental group before the instruction ($\overline{X}_{\text{control-pre}} = 16.8$, $\overline{X}_{\text{experimental-pre}} = 15.6$, df = 35, t = 1.71, p = 0.05). There was not any significant difference between the concept learning scores of two groups after the instruction ($\overline{X}_{\text{control-post}} = 16.7$, $\overline{X}_{\text{experimental-post}} = 16.6$, df = 35, t = 0.16, p = 0.44). Paired t-test scores showed that there was not any significant increase in the control group's performance through the instruction (average mean $\text{difference}_{\text{control}} = -0.10$, df = 18, t = -0.20, p = 0.42). However, the experimental group's performance improved significantly through the instruction in terms of concept learning (average mean $\text{difference}_{\text{experimental}} = 1.00$, df = 17, t = 2.30, p = 0.01). The reason for the little improvement might be the students' high good prior knowledge of kinematics concepts. The findings presented that MBL usage facilitated conceptual understanding. This result is in line with the results drawn from the similar studies (Friedler, Nachmias & Linn, 1990; Nakhleh & Krajick, 1993).

Regarding graphic interpretation skills, while there was not any significant difference between the groups' performances before the instruction ($\overline{X}_{\text{control-pre}}$ = 44.6, $\overline{X}_{\text{experimental-pre}}$ = 43.6, df = 31, t = 0.90, p = 0.18), there was a significant difference between the groups' performances after the instruction ($\overline{X}_{\text{control-post}}$ = 42.8, $\overline{X}_{\text{experimental-post}}$ = 46.4, df = 31, t = -2.14, p = 0.01). According to the paired t-tests, unlike the control group's scores, graphic interpretation scores of the students in the experimental group got significantly better through the instruction (average mean $\text{difference}_{\text{control}}$ = -1.79, df = 18, t = -1.18, p = 0.13; average mean $\text{difference}_{\text{experimental}}$ = 2.86, df = 13, t = 3,38, p = 0,00). More detailed analysis illustrated that the students in the experimental group could convert acceleration versus time graphs to velocity versus time graphs, calculate velocity values from distance versus time graphs, interpret velocity versus time graphs accurately, calculate displacements from velocity versus time graphs, and compute changes in velocity from acceleration versus time graphs at the end of the instruction. Furthermore, the students could compose acceleration versus time graphs themselves, determine the sign of acceleration accurately, convert velocity versus time graphs to acceleration versus time graphs and interpret distance versus time graphs. However some students could not learn to convert acceleration versus time graphs to velocity versus time graphs.

The students in the experimental group could reproduce many concepts such as acceleration, instantaneous acceleration, instantaneous velocity, change of velocity and displacement. The findings demonstrated that MBL usage had positive effects on the students' graphic interpretation skills. This result is consisted with the results presented by Mokros and Tinker (1987), and Svec (1995).

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A proposal for the connection between experiment and modelling for first formation of primary school teacher

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Abstract

The transition between the mere description of a phenomenon and its scientific interpretation-understanding is favoured by the reference to or the construction of models. Modelling is fundamental for the development of a scientific approach to problems in primary school teachers since it helps identifying the relevant variables and the relations between them, formulating hypotheses, and designing experiments suitable to explore and prove such hypotheses. This contribution presents a path of computer-aided didactical activities highlighting the connection between laboratory experiments and dynamical modelling using VnR addressed to teachers in first formation of the Education Faculties of the Universities of Modena-Reggio Emilia and Udine.

Introduction.

Separate and not interacting disciplinary and pedagogical groundings are not adequate for teacher formation, but it is also necessary a professional education allowing the revision of the disciplinary methods and tools for an effective learning process (Shulman, 1986). Such problem is more relevant in the case of primary school teachers, because they suffer from scarce scientific cultural foundations and the integration of the disciplinary and pedagogical competences is often left to their professional experience on the field.

Such integration can be recovered, during the formation process, through the didactic design, and, in particular, through the proposal of experiential situations as occasions to learn to build the cultural framework (both epistemological and methodological) to manage the children questions, starting from reality and its complexity, and to organize conceptual references and structured reasoning. The personal involvement in this approach to reality, allows teachers in first formation to experience the needs and the ways to identify variables, relations and dynamical structures of the phenomena, and to learn, finally, to think by means of models. The ability of modelling, fundamental in the scientific field, is fundamental in the teacher formation process too, also as instrument to acquire epistemological knowledge.

Such kind of methodology has been followed in the computer-aided didactical path reported in this paper, based on a previously designed path, experimented with a pilot small number of students (Corni et al, 2008). The activities refer to an experimental approach to physical phenomena with an analysis on a descriptive plane, followed by a modelling phase of revision of the whole phenomenology oriented to the individuation of relevant quantities and relations, and of design, comparison and discussion of interpretative models using the VnR software tool (ASE, 2002; Lawrence, 2004). The objective of the research work is the investigation of the effectiveness of VnR as modelling tool for primary school teacher in first formation in terms of learning to think by means of models.

Details of the activities.

The aims of the didactical path are:

- to acquire a scientific approach to phenomena, up to their analysis and interpretation in terms of models;
- to describe models in terms of variables and relations and to represents them with VnR;
- to analyze models in terms of elementary model structures
- to reflect upon models to recognize their limits as well as their fields of application and transferability.

The path is composed of three activities. Students, after a preliminary phase of laboratory work (activity 1), were asked to perform stimulus experiments to be observed and interpreted in terms of variables and relations (activity 2). At the end (activity 3), they were invited to participate to a workshop in which they shared results and reflected upon models and modelling.

Activity 1: Preliminary laboratory work. The aim of the activity is to improve the basic competencies to perform experimental exploration/investigation. Some experimental activities, relevant also from a methodological point of view, were proposed: the measurement of physical proprieties, the exploration of phenomena, the calibration of self-made measurement tools.

Students performed measurement of mass and volume in order to calculate the density of solid, liquid and gas samples (8 hours). The aim was to became familiar with measurement, sensitivity and precision handling, selection, calibration and zeroing of some measurement tools (analytical and digital balance, calliper and ruler, scaled cylinders).

Then students performed experiments of search for relations (3 hours each); typical experiments were:

- Pressure and volume of air in a syringe
- Motion on an inclined plane
- Oscillation characteristics of a mass-spring system
- Equilibrium of a bar
- Plane mirror reflection
- Calibration of a dynamometer
- Calibration of a densimeter
- Calibration of a flute glass

The students were supplied with worksheet containing aims, materials, measure instruments, task. The data collected had been organized in graphs and tables in order to make it easier to recognize regularities and relations between the variables. At the end of the activity students were asked to write the results in form of experimental report.

Activity 2: Experiments and modelling. Aims of the activity are:

- to get used to interpret a phenomena in terms of models
- to individuate variable and relations in the different phenomena
- to recognize/distinguish state system and process quantities
- to use VnR to represent models
- to recognize some physical concepts that recur by analogy in different contexts.

This activity was planned in the two university sites in order to reach further specific aims: in Modena and Reggio Emilia with more than 60 students focused on the role of peer to peer methodology, on the order of the experiments and the analysis of recurring approaches and difficulties; in Udine, with a smaller number of students (12), attention was drawn to the learning process and the abilities, the conceptual knots and the learning styles.

In MO-RE students formed 16 "experimental groups" of 4 people each, in UD 4 experimental groups of 3 people each, which had to perform 3 experiments (18 hours in total) involving the same basic physical concepts.

For each of the following experiments the activity consisted in two steps: the design and the execution of an experiment (step 1, 4 hours); the analysis of the relations among the variables involved in the experiment and the construction of a model of the experiment employing VnR (step 2, 2 hours).

The three experiments, which students had to perform were:

- water flow between two cylinders connected by a pipe (communicating vessels);
- charge redistribution between two parallel capacitors connected through a resistor;
- transfer of thermal energy between hot water contained in a vessel immersed in an insulating basin containing cold water (bain-marie).

To support the students to perform the requested activities three work-sheets A, B, C were offered.

Students, at first individually, planned each experiment with the help of the instructions given in the worksheet A:

- Task: study the evolution with time of the process specifying the different initial conditions and the adopted parameters.
- Materials
- Measurement instruments
- Planning hints:
    - Initial analysis of the task
    - Designing of one or more procedures
    - Feasibility study with the available resources
    - Expected results
    - Job subdivision within group members
    - Carrying out of the experiment
    - Compilation of the diary
    - Data report
    - Results discussion and conclusions

Then, in the "experimental group", they had to select the more suitable procedure, discussing the different approaches and alternatives, and to perform the experiment.

After the execution of the experiment a final report of the activity was required, containing the following information (worksheet B):

- Actual scheme of the experiment with operating choices
- Data representation (table, graph, other)
- Explanation of the data
- Interpretation of the data
- Possible evaluation of the interpretation given

Following the Worksheet C students, at first individually then in group, had to reflect on the relevant variables involved in the experiment and had to build the VnR model of the specific experiment, guided by the following questions:

- which are the relevant quantities?
- which are their relations?
- are there other quantities that can be considered and how they affect the previous ones?
- how can you explain with a drawing or with words? How can you represent it using graphs, icons, etc.?

Then, Worksheet C required to fill in the table below, preparatory to the construction of the model with VnR.

Description of the physical quantity	Corresponding variable symbol	Is it a free quantity or dependent on other physical quantities?			
		free		dependent	
		It varies during the experiment (variable)	It is fixed at the beginning of the experiment, then it does not change (parameter)	Variables from which it depends (list the symbols)	Relation with the listed variables (use the symbols)

The Worksheet C ended stimulating a reflection on the recurring elementary structures in the VnR model, on the way the model has been built, the possible extensions of the model to other contexts, and how the model helped to understand the phenomenon. The VnR models had to be saved both in the individual version and in the group version after the discussion.

Activity 3: Workshop. The aims of the activity are to summarize the different solutions adopted by the experimental groups, to highlight the recurring basic concepts, and to recognize the analogies between the VnR models.

In Step 1 the students had to build the more general and exhaustive model for each experiment (1 hour), while in Step 2 they compared the three general models to evidence analogies and differences (1 hour).

Step 1: at least one delegate from each experimental group participated in one of the three "reporting groups" (one for each experiment), with the task to build the more general and exhaustive model for the specific experiment, taking into account all the contribution coming from the different experimental groups. For this task they followed the worksheet WS1 (similar to the worksheet C of the activity 2)

Step 2: the students from each reporting group of Step 1 formed three transversal “discussing group”. Following the worksheet WS2 they had to find out the physical concepts transversal to the three experiments (i.e. capacitance, resistance, flux, difference of potential) as well as their specifications in the three contexts (i.e. thermal conductivity instead of resistance). Then they had to compare the three models in terms of elementary model structures, recognizing that they are very similar and made of recurring structures (i.e. structure representing the capacitance, the difference of potential, the feedback) and why they could result slightly different in different cases. At the end they had to collect their conclusive ideas and reflections on the properties and power of models (i.e. how they can be generalized, how they can help to make predictions).

Monitoring and assessment.

The evaluation of the activities of the path was performed in different ways.

1) The interaction among the members of the groups and among the groups during the workshop were observed and recorded by two observers, one involved in conduction of the activities and the other with this specific task of observation.
2) The students’ process of planning and conducting the experimental work was obtained from the analysis of the individual and group worksheets A and B related to the Activity 1, while the students' analysis oriented to modelling was deduced from worksheet C, both individual and group, and from the VnR models of the students related to Activity 2.
3) The results of the process of interaction and discussion in the two workshops and in the different reporting groups and discussing groups, were deducted from worksheet WS1 and WS2.
4) At the beginning of the activities the students’ initial competence in terms of ability to manage variables and relations, both in mathematical and in natural language had been tested. The students were requested to answer a test in containing the following questions (1 hour):

   The questions of the test in had the following structure:
   - How can you explain that a quantity is related to another one?
   - Can you make an example?
   - How can you write the relation with a mathematical expression?
   - How can you explain the relation in words?
   - How can you represent the relation on a two-axes graph?
   - How can you represent the relations in symbols (either invented)?

   The previous structure was repeated for each of the following relations:
   - generic relation between quantities,
   - direct proportionality between two quantities,
   - inverse proportionality between two quantities,
   - direct and inverse proportionality among three quantity at the same time,
   - comparison between two quantities,
   - rate of change of a quantity depending on the value of another one

5) Finally a test out, on the basis of the test in, evaluated the students' improvement, in particular whether they spontaneously represent the relations between variables using the VnR symbols and rules.

Results.

A preliminary qualitative analysis of the whole corpus of collected data highlighted some students' difficulties, behaviours and perspectives which can be synthesized as follows.

Understanding and interpretation. In the beginning students' tendency was to perform the experiments and to collect data, either qualitative or quantitative, aiming at a satisfactory description of the phenomena. In the following, stimulated by the above described modelling activity, the perspective gradually changed into a more thoughtful behaviour favouring explanation of the results and interpretation of phenomena.

Variables. The considerable lacks of the students in science groundings resulted essentially in the description of phenomena in terms of generic "variables", showing difficulties to distinguish system parameters, state variables and process variables. In the activity of modelling with VnR students made mistakes in the choice of static operators (i.e. sum and product, subtraction and quotient), and showed particular difficulties in dynamic modelling, with the use of the "grow" relation to describe the rate of change of a quantity.

Ability in building models. Students, also thanks to a collaborative peer discussion, built VnR models as more effective and correct as they performed the three experiments of activity 2 and recognized recurrent elementary concepts. This improvement took place in any order the experiments were performed.

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Design and use of computer-aided instructional tools in a teacher training environment

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Abstract

Information and Communication Technologies (ICT) instigate enormous technological enhancement in information support of education. ICT make technology-based education and training easier to design, develop and deliver. Introduction and development of ICT-mediated teaching tools in teacher-training environment obtain greater importance as the future teachers would be prepared in advance to the application of ICT in their forthcoming teaching practice. Current paper is aimed to introduce a simple and at the same time an effective methodology allowing the inexperienced (in the field of ICT) instructors to design professional electronic computer-aided instructional tools applicable for virtually all teaching disciplines with multimedia exposure and structured navigation and search options. Proposed methodology is based on text marking-up techniques but doesn't actually require knowledge of any programming language. An attempt to classify the computer-aided teaching tools available for use in teacher-training environment is undertaken as well. The practice of putting together professional e-textbooks is introduced along with some issues of hands-on experience on implementing proposed methodology in teaching practice.

Introduction

ICT is at the very core of the knowledge-based society and its impact creates a significantly different environment for education. Technology-enhanced learning including knowledge and content development tools and applications help us preserve, develop and disseminate knowledge, improve learning and education systems and strengthen the creativity of society. The information support of education obtains more and more new forms and thus play growingly decisive role in contemporary systems of education from secondary to tertiary level. ICT enable individualization of learning process according to learner needs considering their current knowledge, experience, preferences, customs and learning styles. Nowadays teaching environment includes variety forms of computer-aided instructional tools (CAIT). The main advantages of CAIT in comparison with traditional instructional tools could be classified in terms of both *functional* and *technical* viewpoints

The functional (or didactic) advantages are, but not limited to, the following

- CAIT provide opportunities for learners to plan individually the time place and pace of learning and accordingly gain more efficiency in instruction;
- Possibilities to work with digital models and simulations of objects and processes that are hard to or even impossible to demonstrate actually;

- Possibilities to take advantage of unique teaching materials and artefacts such as manuscripts, pictures, museum exhibits, etc;
- Possibilities of objective automatic and on-demand control of knowledge and skills gained at any certain period of learning;
- Possibilities for providing more individualized education by means of adaptive systems that are adjustable to learners' personal abilities and behavioural manners.

As far as the technical point of view, the following advantages are evident:

- Increasing ease of design and implementation;
- More simple updating and development;
- More effective dissemination (especially via Internet)

Didactical characteristics of CAIT based on hypertext

Traditional textbooks are linear tools by their functionality. This mean that the textbooks are being used mostly according to "from the beginning to the end" scenario. This strategy is dictated by the principle of *programmed* instruction. The main assumption of programmed teaching is that the predefined sequences of instruction suppose practically automatic or even forced choice of the most appropriate step for a trainee (work with theoretical material, taking a checking test etc.). The specific features of such a scenario, in accordance with which the study material offered, are defined by this principal pedagogical strategy.

Situation is being changed revolutionary with the implementation of *hypertext* technology in design of CAIT. Distinctive feature of the hypertext is the presence of special *hyperlinks* opening alternative ways of learning and leading the reader in a certain direction. There are *static* and *dynamic* documents based on hypertext technology (HTML-pages). The contents of dynamic HTML-pages can be changed by the user's specific actions such as pressing buttons, inputting certain character set, etc. This feature of dynamic HTML-pages open an opportunity to offer adjustment of the teaching material offered to a trainee, depending on his/her actions and thus making hypertext-based CAIT a flexible and self-adjustable system. The main didactic principles of such systems are defined by the fact that users are free to choose any link in the document and thus any of possible learning paths. Accordingly training systems based the hypertext provide the users an almost full control over the course of educational process and thus practically overall *responsibility* for the process of studying. Nevertheless hypertext systems can promote some features of programmed training given that the system applies some sort of restrictions: *isolation* of modules i.e. using hyperlinks only inside of the given module; *programmed transition* to the following module only after successful intermediate quality check of the acquired knowledge and skills; automatic choice of the degree of complexity depending on results of preliminary and current testing of the trainee. More important is the didactic useful feature of hypertext systems allowing to create educational environments exclusively favourable for research type of training when the studying material is based on *discovery*. In case of nonlinear studying (dictated by the trainees) these systems can give new opportunities for creative search on a way inaccessible in linear models of training.

Along with the internal structure of a hypertext system the choice of the main principles of *conceptual design* is highly important. The conceptual design is related with the visualized structure showing the interrelation between separate elements of the course. This structure provides the trainee with opportunities of a choice on the basis of a table of contents, an index, a special navigation chart or text-through search. In a context of research type training, on the contrary, we can advice to hide from a trainee the full structure of the course. And then the necessary task for a trainee will be the discovery or even the creation of structure on the basis of own decisions. Such a conceptual design is more appropriate to a research training system, the purpose of which is to set up conditions for a trainee to make own decisions on further strategy for his/her research, being guided not only by the system, but also by the intuition.

One of important factors for using CAIT is *the subject domain.* It is obvious, that CAIT relating to humanitarian disciplines could be characterized by large amount of text material and comparatively less significant degree of formalization. On the contrast CAIT for science disciplines could include a plenty of illustrative materials, videos, animations and thus increase enormously the didactic effect of the instruction tool.

CAIT based on Microsoft HTML Help Workshop

In order to design and construct a CAIT the educator should be more or less familiar with a programming language and possess some programming skills. Moreover for different components of these instructional tools usually a mixture of different programming languages is used (say HTML for general design, Java or Flash for animations, etc.). That is why creation of own CAIT is highly problematic for an inexperienced (in the field of ICT) instructor. The main objective of current paper is to introduce a simple and at the same time an effective methodology allowing instructors to design professional electronic computer-aided instructional resources applicable for virtually all teaching disciplines with multimedia exposure and structured navigation and search options. The methodology of creating CAIT is based on HTML mark-up techniques, but really neither expertise nor even simple familiarity with this language is required. The main idea is to take advantage of Microsoft HTML Help Workshop programme package for *educational* purposes. This package is freely available for downloading from Microsoft's official website and using for educational purposes. Originally this programme is predefined for creating built in Help systems in Microsoft's applications. However HTML is gradually obtaining features and status of a universal language of information processing and MS HTML Help Workshop could be used not only for design of a help system of a software product, but also for creation of various electronic educational resources with standard system of navigation and search.

The technology of MS HTML HELP. The technology of HTML solely is not enough to construct educational tools with sufficiently wide and at the same time standardized opportunities. At the same time in MS HTML HELP technology the standard mark-up language is enhanced by several important instruments that could be applied without any special knowledge of programming:

- Standard elements of navigation management, i.e. a multilevel table of contents, keywords index and search system based on keywords and inquiries;
- Flexible user-friendly interface, including panels of instruments;
- Compiled file format providing compression and association of several HTML-files in a standardized compressed file.

Figure 1 demonstrates the general scheme of the MS HTML HELP technology. Project file combines standard HTML and special *navigation* files. After processing of these files by system's compiler a standardized CHM-type file is generated. This file is manageable by standard HTML-browsers (such as Internet Explorer).

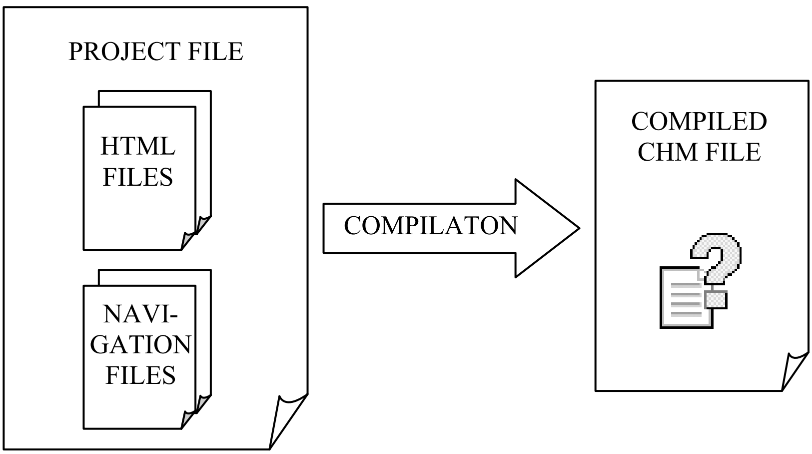

Figure 1. The logical structure of MS HTML HELP technology

Creation of CAIT by means of MS HTML Help technology. Following to some extent to Zakharova (2003) the following steps for CAIT design could be proposed.

- *Download installation.* The MS HTML HELP WORKSHOP package could be freely downloaded from Microsoft's official website and installed on user's computer. The installation is rather straightforward;
- *HTML files*. These files could be prepared by means of any computer application dealing with HTML format. Popular MS Word text processor also can be used with final saving of files as web-page;
- *Multimedia*. Pictures, photos, audio and video files are better to store in separate files providing access to them by means of hyperlinks in HTML files. It makes sense also to create such hyperlinks for bulky schemes and tables instead of storing them in main content files;
- *Project file.* The file of the Project is a simple text file containing names and addresses of the files used in the project. Project file is generated with the help of rather simple *wizard* application providing a user with step-by-step guidance leading to association of HTML files within a single Project file. Figure 2 shows the window with a MS HTML Help Project

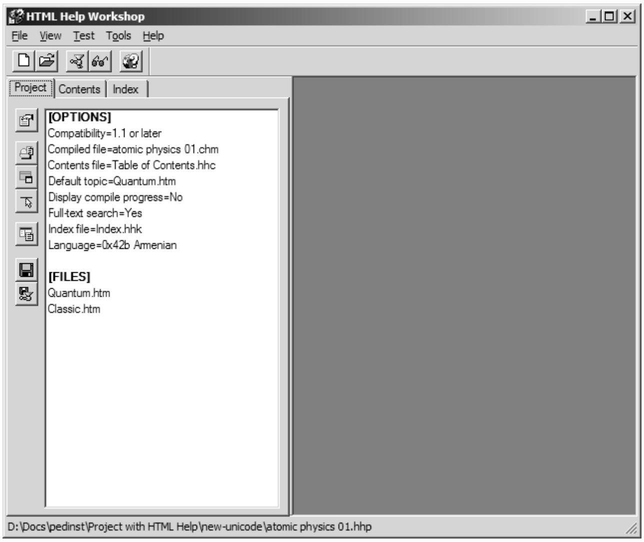

Figure 2. HTML HELP Project window

- *Navigation.* Microsoft HTML Help provides three basic ways of navigation: a multilevel table of contents, the keywords index and full-text search. Before actually developing the navigation it is necessary to establish a single-valued correspondence between the elements of table of contents and HTML files so that each element corresponds to a single specific file. At the same time any single element of the keywords index may match few files. The application provides simple approach to create navigation without any programming;
- *Compilation*. When all the components (HTML, multimedia, navigation) are included in the MS HTML Help Project, it is necessary to compile the Project generating a standardized compressed CHM-file that will store all the files included in the Project. Compilation is a single-click process. Means of HTML Help Workshop carry out rather effective compression with a factor sometimes achieving to 10:1value. As a result the volume of the final file will be much rather less than total volume of the components.

Experience

We carried out an informal survey through our educators from secondary schools and universities in order to examine the level of satisfaction on student's science comprehension after implementing small CAITs in their teaching practice. Teachers voluntarily put together computer-aided teaching tools according to proposed methodology covering some relatively small portions of their courses. Both secondary school teachers (18 respondents) and university instructors (12 respondents from physics and engineering departments) were inquired. The results of survey are introduced in Table 1.

As it is could be seen from the tables most of teachers are completely or somewhat satisfied with the suggested methodology of creating CAIT. This ratio is greater for university instructors (75% vs. 67% for secondary school teachers). This can be explained by the fact that the digital competences of educators from universities are generally higher compared with school teachers and accordingly the formers are more enthusiastic on teaching innovations.

Table 1. Satisfaction level (in percents).

	Secondary school teachers	University instructors
Completely satisfied	5	6
Somewhat satisfied	7	3
Completely unsatisfied	6	3

Conclusion

The suggested methodology of design and use of CAIT have following characteristics:

- The methodology is based on a freely available and comparatively small (nearly 7 MB) computer-aided tool;
- The methodology is not based on knowledge or experience of programming. This should ensure a better adoption and acceptance of ICT by teachers lacking digital competences, and may have a spill-over effect to the educational community. However the higher the digital competences of the educators, the better will be the results;
- The teaching tool has user-friendly and standard interface that makes it possible for wide application;
- There are no restrictions on subject domain, i.e. methodology is applicable to virtually all disciplines from both science and humanities;
- There is no restriction also on the level of education. Both secondary and higher education teacher can take advantage from the methodology.

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Web-based enrichment of science learning environments and higher order thinking

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Abstract

This paper explores the benefits of web-based environments to enhance science learning for gifted students in order to meet their special capabilities through a variety of enrichment activities. Web-based science learning environment is presented. This environment bases on enrichment activities which encourage students to construct their understanding of science problem, hypothesis testing and promote thinking skills are needed to analyze and synthesize information. Therefore this interactive web-based environment includes differentiated activities in science for seventh-grade students to meet abilities of gifted. These activities consist of concept maps, venn diagrams, semantic webs. Further activities are problem solving learning and decision making in scientific problems in light of cost-benifit analysis. This environment also allows gifted to create different learning situations supported with feedback. The strategy focuses on given experiences as an appropriate acceleration-based options. Impact of the Web-based enrichment science learning environment (WESLE) on science concepts learning with emphasis on higher order thinking for gifted is discussed.

Introduction

Use of information and communication technology (ICT) in the classroom for learning science and technology has increased significantly in recent years and has proved to be a very effective tool in a variety of learning situations (Rogers, 1997; Sassi, 2000; Kocijancic & Jamsek, 2004), As well using the computer technology in schools over the last years has transformed from electronic worksheets to interactive multimedia formats for prompting higher order thinking (Jonassen, 2000; Siegle, 2004).

Web based learning

Internet as an advancement of technology has emerged as a viable educational reference because of its ability to allow access information, either synchronously or asynchronously, in addition to integration of graphics, audio, video and animation into existing Web-based courses which leads to a better quality of learning (Daied, 2001; Pagani, 2005).

In science education, the web is increasingly used both as a learning tool to support curriculum and as a means of delivering online learning modules (Klemm et al., 2003), according to previous students were required to analyze, synthesize, and communicate information characteristics of critical thinking. At the current time, technology becomes everywhere in the classroom, web is being incorporated in a more dynamic mode. The available technology enables students to utilize a variety of skills and formats toward a purpose (Porter, 2006).

In summary, Instructional web sites are considered as one of the most important approaches of self-learning which may fulfil the needs of gifted students in order to explore their special capabilities through many various enrichment activities.

Higher order thinking

This term is used to describe complex thinking skills, such as critical thinking and problem solving (Lewis & Smith, 1993). The construct of higher order thinking and its subordinate constructs of critical thinking and problem solving are settled within the context of an individual's prior knowledge. What could be classified as critical thinking or problem solving for one individual, for whom the knowledge is new, could be prior knowledge for others (Newmann, 1990).

Higher order thinking essentially falls within the constructivist theoretical framework. Constructivist theory is based on the idea that knowledge and understanding are individually derived as opposed to universally defined (Land & Hannafin, 2000). With each of the tasks included within higher order thinking (e.g., problem solving, critical thinking, value analysis, and hypothesis testing), it is depended on the learner to construct his own understanding of the problem or information and to make decisions suitably.

Some of psychologists use the term "problem solving" to refer to a number of higher level cognitive process which include decision making, value analysis, and hypothesis testing (VanSickle & Hoge, 1991), These skills are essential for gifted to master their learning.

The enrichment activities

The enrichment has various types like dealing with mental higher order thinking, there are deferent learning styles, at the same time which require from students to deal with facts, it requires from gifted to use analysis, synthesis and generalize for the same topic (Winebrenner, 2001).

When we use enrichment strategies, it is important to follow guidelines like: Gifted students should be given experiences involving a variety of appropriate acceleration-based options which may be offered to gifted students as a group or on an individual basis, students should be given experiences which involve various forms of enrichment that extend the regular school curriculum, leading to the more complete development of concepts, principles, and generalizations. (Berger, 2001; Wienbrenner, 2001)

According to previous, some of various activities which could be involved in web-based learning environments for gifted students are discussed.

Concept maps. Concept maps are diagrams in which various forms or lists of information are classified and their links are shown. It is derived from the constructivist theory.   A concept map is divided into nodes and links. Nodes represent various concepts and links represent the relationships between concepts, words are used to label the links in order to describe relationships more easily (Anderson-Inman & Zeitz 1994).

In science education, concept mapping has been widely recommended and used in a variety of ways. It has been used to help students build an organized knowledge base in a given discipline or on a given topic (Freeman, 2004; Novak 1990).

Using of concept mapping as a strategy to promote meaningful learning has been conducted for more than a decade. For example, Novak & Gowin (1984) empasised on importance of using concept mapping for students which demonstrated superior problem-solving performance. Coffey et al. (2002) mentioned that "this method supports construction of an informal but semantically rich representation of expert knowledge and the simultaneous creation and identification of critical supplementary resources that materially augment the representation".

Pankratius (1990) found that mapping concepts prior to, during, and subsequent to instruction led to greater achievement for high school physics students.

Semantic Webs. A semantic web is a procedure which actively involves students in their learning and help to motivate their thinking processes. Semantic webs allow students to approach an activity in an individualized way and require them to relate new ideas to their own background knowledge, the advantages of semantic webs are detemined through recognizing relationship between concepts, organizing ideas and concepts between learners and increasing the knowledge for the learning via incoraporate new knowledge with previous information which are taught previously (Mohamed, 1997).

Venn Diagrams. Venn diagrams are graphic organizers which are considered as powerful ways to help students understand complex ideas, by adapting and building on basic Venn diagrams, students can move beyond comparison and diagram classification systems that encourage students to recognize complex relationships (David Walbert, 2008). Jan Moore (2003) presented some of activities to teach science including a set of Venn diagrams which help students in primary school to create and complete these diagrams.

Problem Statement

There is a few number of enrichment science web sites (in Arabic) required to fulfill the needs of gifted students in the first year of preparatory schools also the importance of meeting gifted challenges, as well as, it should be noted that the presence of dynamic technology in a classroom is insufficient to encourage higher order thinking. In order to solve this problem, the researcher formulated the following two questions:

1- What is the structure of a suggested science enrichment web site to fulfill the needs of gifted students in the first year preparatory schools?
2- What is the impact of the suggested enrichment web site on increasing gifted students' achievement (high order thinking) of science concepts?

Objectives of the current paper

1- Design an enrichment web site including some science activities related to science course taught to the first year of preparatory school students.
2- Study the effectiveness of the designed enrichment website on higher order thinking for the gifted.
3- Create enrichment instructional opportunities for the gifted students to meet their abilities.
4- Design accelerated, enriched, differentiated web-site.

Research Procedures

1- Selection sample of research.

The researcher used a restricted experimental sample chosen from the first year gifted students taken from preparatory schools in Dakahlia governorate, Egypt 2007/2008, The sample of research consisted of sixty students, The experimental design depended on one experimental group. For identifying the gifted students, the sample had been chosen according to academic achievement levels, students who had gained at least 90% in the achievement exam held at the end of the primary stage and those who gained at least 85% in the achievement science monthly tests.

2- Preparation the enrichment activities

I prepared the activities which had been presented related to unit "Environment and its resources" according to gifted needs and interests. Scientific experiments supported with graphic, audio, viedo and simulation are prepared in order to help students dealing with problem through observation skill, testing hypothesis then achieving to inferring, in addition I prepared a set of concept maps, semantic webs and venn diagrams which are not completed, as students are required to complete them to measure their abilities on correlation, Inferring the relationship between concepts and sub concepts. Scientific problems have social and ethics aspects are also prepared, students can make a decision in light of cost-benift analysis to develop their abilities to analysis the situations, I prepared as well a set of scientific quizess and diagrams to provide students to find relationships, additionally, the opportunity for students to ensure their responses through immediate feedback.

3. Setting up the enrichment instructional web site

I prepared and designed the web site according to the following steps:

- Web Site Planning: Analyzing the content of the chosen unit under study, extracting the major and subsidiary concepts, specifying the characteristics of the learners, and formulating instructional objectives.
- Web Site Design (Web Site Structure): Arranging enrichment activities, preparing the formative evaluation for each lesson, specifying relations and correlation among the elements of the web site in a way that make it easy to use and move through, and finally submitting the web site to a group of reviewers.

- Web Site Production (Carrying out): Interning suitable required images, video shots and animations, as well as effective elements that can be used in the site, then uniting and programming these elements in the mode of the web site, and finally uploading the Web Site on the Internet.
- Web Site Evaluation: The validity of using the web site (the potential of usage) was tested to see to what extent a gifted student can react actively to the web site, and then the web site was presented to a group of reviewers.

4 - Preparing Instruments

- A questionnaire was designed by the researcher concerning science teachers and supervisors' point of view about the use of enrichment web sites in teaching science in preparatory stage.
- Achievement test designed by the researcher and reviewed by specialists; as well pilot study was conducted to calculate the appropriate time of answering the test. The easiness and difficulty factor of the items as well as the validity of the test were estimated.

5- The Application:

For implementing the Web Site, the following steps had been carried out:

- Selecting the study sample as indicated above.
- Applying the pre-test on the experimental group.
- Carrying out the experimental study by presenting enrichment Web Site environment to the experimental group.
- Applying the post-test on the experimental group.
- Registering students' grades.

6- Statistical methods

The results had been analyzed statistically using t-test, the pre and post results of test was compared to determine the effect of the enrichment Web-Site on students' higher order thinking levels. The results display in Table 1.

Table 1. Paired Samples t-test results for experimental group of the pre-and post results of test

Achievement Levels	Group	Mean	Standard Deviation	F.	Value of (T)
Comprehension	Before	10.9167	2.4445	59	13.99*
	After	14.9000	0.7962		
Application	Before	6.4667	2.0039	59	11.135*
	After	9.9333	0.6342		
Analysis	Before	4.0333	1.2751	59	17.35*
	After	7.3167	0.5365		
Synthesis	Before	2.000	0.8234	59	22.841*
	After	4.6500	0.4809		
The total Grade	Before	23.4167	2.6572	59	61.039*
	After	36.8000	1.8848		

(*) It means that there are significant differences at the level of 0.01.

The result indicated that there is a significant difference at the level of (0.01) between the mean score of gifted students of the experimental group in the pre/post- achievement test, in favor of the post test.

Measuring the effectiveness of the designed enrichment Web Site on the gifted students of the experimental group for the attainment of knowledge using McGugian equation (Packhman et al., 1971). The results indicated the effectiveness of the designed web site which was 80.7% for the cognitive domain.

Discussion and Conclusions

The current paper takes into account the possibility of using the Web based environment to enrich science education through creation a learning environment allows active interactions and enriching experience of the learner, Haury& Milbourne (1999) emphasised on effectiveness of using educational Web Site on the Internet in enriching academic achievement for secondary students.

Results of the current paper indicate that there is significant difference between the mean score of gifted students of the experimental group in the pre/post-test, in favor of the post test. Concerning the effect of Web-based enrichment of science learning environments on students' higher order thinking in science and the relationship between this environment and gifted students' performance, it had determined that the mentioned activities increased students' Higher order thinking levels positively, additionally diverse of evaluation styles and immediate feedback which are considered as an integrated part of learning process Daid (2001). As well as supporting the web site via involving graphics, simulation and video into user interface learner-content.

Interactivity in Web Site is identified through various activities which are supported with feedback through active interaction between student and the program, findings of Barry (2001) ensured on that interactive mode and availability of discovery options are important for setting educational web sites.

Simulations could be considered as effective an instructional technique for activating science process skills of students which are the basic skills for scientific inquiry, Schmidt (2003) assured on essential of simulation which fulfill learning objectives and concepts of lessons.

Concerning enrichment activities used in the online environment, activities which had been used as an enrichment gave opportunities for gifted to analysis and synthesis, this is in harmony with findings of (Starke & Mares, 2001) whom investigated and discovered impact of two enrichment programs in science containing enrichment activities on gifted performance.

The results of this paper confirmed the importance of the various activities which based on issues, problems, semantic webs, Venn diagrams, concept maps. Using concept maps increased understanding of the relationships between the concepts, it was required from student to complete them via a set of concepts presented to him to link the concepts together, results of Brown (2002) emphasised on importance of finding the nature of the relationships between scientific concepts through concept mapping.

Web Site included activities to develop the capacity of gifted to make decisions dealing with social issues, moral and ethical issues associated with scientific investigation of the principle of linking science and contemporary social issues so as to increase the effectiveness of the programme, the students in the study learnt how to make a decision concerning social issues, these finding relate to results of Malekpour (2003) who emphasized on including the educational process of social and ethical issues are given the opportunity for students to practice scientific thinking based on analysis of the relations of elements of the case and concepts given.

Conclusions, the researcher aimed to develop higher order thinking for gifted students through a set of various enrichment activities which involved simulation, concept maps, semantic webs, Venn diagrams, and scientific problems have social and ethics aspects as well set of scientific quizzes. As well, providing the opportunity for students to ensure their responses through immediate feedback. The enrichment programs and styles are vital to develop the education process as general and science education specially, as they can contribute acquiring gifted students higher order thinking. The importance of involving enrichment science program for problems and social issues which can provide the opportunity for practising scientific thinking based on analyzing elements of the problem and its concepts to enable students to make a decision, so attention should be directed for using instructional technology especially the Web in the instructional process through out enrichment activities with emphasize on gifted needs.

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C. B. E. and progress alternative against high costed material for mechatronic education

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Abstract

The rapid developments in technology make it costly to educate the work force for the sectors. In modern technology and in today's world in which the education system is more modern and the need for modern stuff is increasingly high, Computer-Based Education (CBE) techniques and software are no more a luxury but a necessity. Because these softwares become the basic component and means of easy and comprehensible manner of telling in modern education system due to the visuality that they concern. This study presents the examples of material to make the content and the subject of electromechanics more effective and comprehensible.

Introduction

Mechatronics and education. Mechatronics, the popular science of our century, is an interdisciplinary perception which grows out of the combination of machine, electric-electronic and software technology in the process of planning to production. Mechatronics which is in fact shortly expressed as 'interdisciplinary' is a synergism which is formed by technical and physical sciences. Mechatronics: It is the field of implementation which is realized in an interdisciplinary and equal-aimed structure of computer technology. Mechatronics products aim to produce smart machines, devices and systems that make human life easier. (Toprakkiran and Ersoy, 2006)

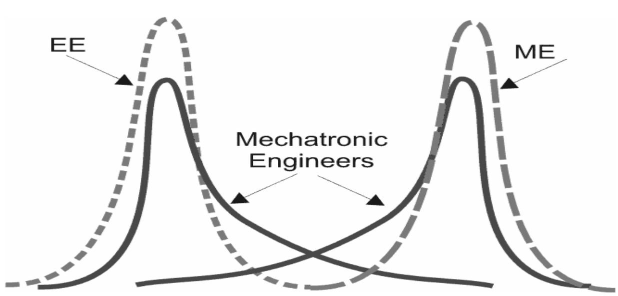

Figure 1. Mechatronic engineers versus conventional mono-disciplinary EE's and ME's (Van Amerongen,2006)

The human profile that the society of our present-day needs is different from the human profile that the society of the past-times needs. The globalization occurred due to the improvements in science and technology and the basic components that identify the human force profile which is required by info-based society. The discussions about the quality and quantity of education began to take place and the re-construction in education is put on the agenda. In the period of 2000s, the students' and the teachers' being able to gain new skills depends highly on their being able to use the technology. Because technology is a means of reaching, using, producing and sharing data. The most important means to enable us to reach the data is computers. The use of computers is becoming increasingly important in today's societies.

By considering these things, the educational institutions began work and implementation in order to make the students gain computer skills.

Web-based education. Within the developments in communication technology, the demand for the informal education has increased. As the instruments which are used in e-learning vary and get stronger, the interest in that type of learning has increased more. According to International Data Corporation (IDC), WBT is growing at a rate of over 100% per year.

Education and teaching aimed data's transference to the required place electronically by means of communication instruments such as radio, television, computer, internet and similar items is called 'e-learning'. Even the instructor and the student are in different places, the transference of information and teaching function is fulfilled by means of communication technology. Shortly, e-learning eliminates the difficulties of distance and participation.(University of Cukurova, 2007)

The Internet and web offer a number of advantages over other computer-based approaches to distance learning that do not use wide area networks. Here are some of them: (Locatis, 2001)

1. Resource management
2. Student/user management
3. Time/place flexibility
4. Currency
5. Ease of use.
6. Cross platform compatibility
7. Accessibility
8. Customization
9. Resource leveraging/enrichment
10. Resource integration
11. Collaboration
12. Dual use
13. Duplication and other distribution costs
14. Productivity

E-learning and the improvement of e-learning materials. For the teachers' being able to gain the skills to prepare effective teaching materials, they need to know very well the functions of these materials in teaching environment, the principles that they need to consider at the stage of preparation, the benefits and limits of commonly used materials and the features that needs to be considered when they choose and use these materials. When they know these things not in only information level but also in implementation and evaluation level, it will be helpful for these teachers to develop materials in their future lives.

It's shown below the way followed in combining technology and lessons for the education of teacher candidates. (Gunduz And Odabasi, 2004)

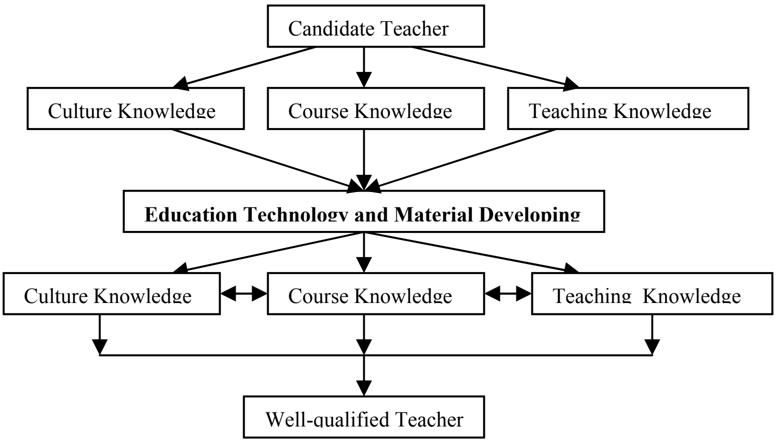

Figure 2. Process of "education technology and material developing" course in Education Faculty

In order to increase the quality of education and teaching, the effective use of modern teaching technology in teaching of concepts is becoming more important day by day. In that case, one of the most important advantages of the use of computers in teaching environments is its increasing the degree of learning by appealing to a lot of sense organs at the same time and make what's learnt more permanent. Because of that reason, it is pointed out that the use of animations, pictures and sound at the same time eliminates the conventionalism of teaching environment and increases the degree of learning. (Saka and Yilmaz, 2005; Clark and Craik,1992) On the other hand, technology-based teaching materials are extremely needed in order to construct teaching environment for the students who come from different social environments and who are physically, biologically and cognitively different from each other .However, the students' having different cognitive, perceptional qualities and physcomotor skills makes it more difficult for teaching technologies to improve by considering individual differences. Because of that, it is emphasized that there is no technology to make it possible that a topic is learnt by all the students at the same degree and at the same speed. (Saka and Yilmaz, 2005; Akpinar, 1999)

The Stages of Development of Teaching Material

In order to be used in the software design of research content, "Macromedia Flash5" software is preferred due to its well-known file structure, rapid running, its files' taking little space, its interaction functions and its being user-friendly. In material's development process, the stages below have been fulfilled:

1. Available researches and developed teaching materials were examined by leading the research of computer-based education, experiment notes and related literature.
2. Some examinations were done about the experiments and the qualities of Electro Mechanic Laboratory.
3. The topics that the students have difficulty in the lessons that are done by traditional methods were considered.
4. The identified topics were examined by using the various lesson books which suits to the teaching program. As the result of interviews that are made with instructors, it's decided to develop a study sheet for teaching of these three concepts below.
5. Some experiments about the identified subjects and concepts were done in laboratories and were recorded.
6. A literature scan about visual design was done and the qualifications of an effective and a suitable interface were decided.
7. The necessary animations, texts and shapes were designed for to be prepared packet program by identifying the most suitable animations and design programs for the goal of the research.
8. In Macromedia Flash5 program, an interface is prepared and all animations and texts were inserted into that preface.
9. The suggestions about the visual design of the education expert were considered.
10. Some visual buttons were inserted in order to enable the interacting use of activity's implementation process.
11. The pilot implementation process will be implemented at the spring term of 2008-2009 education term.

There are 30 students in the class. These students will be divided into 2 groups as the experiment group and the control group. The control group will have education with traditional methods and the experiment group will take the courses by E-learning Method. The length of time of the implementation of the Experiment group will be as much as the length of time of the implementation of Traditional group which will be exactly one day.

Lesson ELK232 Electromec. Sys. Theoric – 3 / The implementation will be implemented as 2 hours long, totally as 4 credits within 12weeks of academic term. The total implementation time will last for 3 days which will be totally 24 hours.

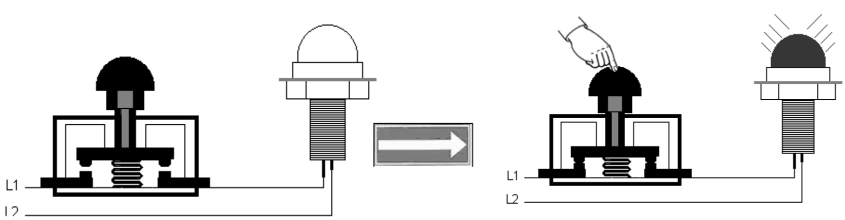

Figure 3. Schematic shown of open switch in circuit

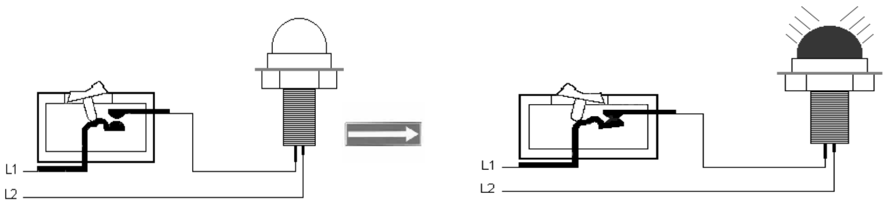

Figure 4. Schematic shown of wrench in circuit

There needs to be an implementation at the laboratory workshop for the comprehension of topics of this lesson. The connection schemas of controlling unit circuits needs to be drawn at technical lessons in accordance with Turkish standards and the way how it Works needs to be told. During the implementation, some little voltage (lower that 50 V.) needs to be used at the weak rheo controlling unit circuits for the security of life.

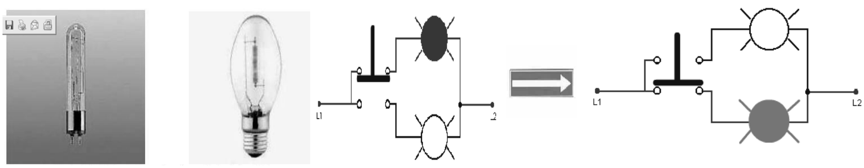

Figure 5. Lamps and shown in circuit

The Creation of The Materials

We can explain simulation in different ways:

The simulation of a system is the procedure of forming a model which can represent that system. Simulation is a process of the designation of the model of the real system, the implementation of experiments in order to understand the conduct of the system and evaluate the different strategies for the goal of running the system with that model.

Simulation is the experimental study which is done for fulfilling the process procedures of the duration which is improved or reorganized, executing experimental studies and estimating the time of the error of these procedures. We can understand the possible reactions that the new process gives against the changes. It is the observation of a qualification or a conduct about an event, a process or a system on the model.

The Cost

The rapid developments in information technology have affected the societies and it became possible for everyone to use the computers. Due to the rapidly changing world, it became a necessity to use the computers in teaching-learning process at schools in order to prepare our children who are face to face with a rapidly changing world to the information societies of 21 century.

As the relationship of the human being with information and society changed in our present day, the qualification of it changed too. The case of information explosion changed the function of information in the life of human being and society and the method of being produced and being gained. The modern society became different in the aspects of structure and function. All of these cases affect the basic model of the education and causes fundamental changes in education. (Dogu and Eroglu, 2004)

The matter of education has been considered with common sense rather than a scientific approach for a long time. The education concerns the establishment and the assimilation of the ideas rather than the change of ideas. However, this era that we have been in possesses an imbalanced and an inconstant characteristic and it is characterized by the rapid change. In that atmosphere, the skills in mechanization are replaced by skills in information technology. (Ozer, 1989)

In that case, the education needs a change to prepare itself and a new conceptional frame in which the decisions about the innovation can be taken easily. (Dogu and Eroglu, 2004)

The change for output and effectiveness in the process of teaching and learning becomes more and more important. Because the education services constitute one of the biggest costs in the life of the nations. Today none of the societies can endure an education with a high cost and low output. (Dogu and Eroglu, 2004)

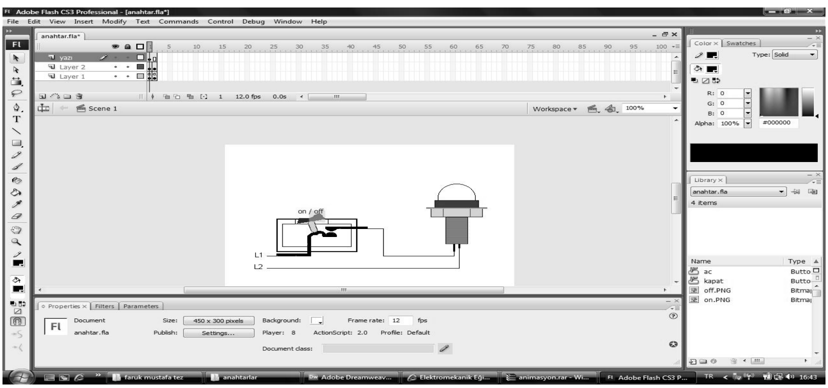

Figure 6. Generated to materials animations

Figure 7. Web page of using in Electro – mechanics course

Conclusion

The education which is put into practice during the process of educating workforce in developing disciplines like Mechathronics is costly and difficult. In addition the distribution and the spread of information is highly important at the process of globalization. The implementation and the pursuit of information during its stages of rise and development are possible with e-learning. Digital and online materials can dramatically reduce the cost of education materials, particularly for university students and researchers. (Oxfam Briefing Paper, 2008)

The electro-mechanic lesson materials that we submitted during our study take little part in Mechathronic Education. The institutions need to focus on the studies about the e-learning model, spread it everywhere and form a basis for the updates.

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Development of spatial abilities using computers

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Abstract

The lack of spatial imagination among pupils and students is a more and more frequently observed phenomenon. However, students of engineering are expected to have just as good spatial imagination as they used to have and this lack is rather troublesome. Opportunities for the improvement of these abilities missed at the age of 10–12 years are difficult to substitute later, but it is never too late. Unfortunately, this process requires a lot of effort and it is extremely time consuming for teachers.
The aim of this paper is to show didactic programs for students and aids for teachers. Each of them offers a background for solving problems and a set of tasks (for students) and special functions for teachers. Programs are freeware. They can be used in the same way for 12-year-old pupils as for 20-year-old students.

Introduction

The lack of spatial imagination of students has led us to the idea to design some didactic applications and materials focused on the development of spatial imagination of 12 to 20-year-old pupils and students. Although the manual manipulation and tactile experience (especially in pupils' early childhood) are impossible to substitute, such applications are necessary. The possibilities for incorporating of natural manual manipulation into the classroom have their limitations and the lack of spontaneous stimulation of spatial abilities requires new additional didactic methods. Improvement of these abilities is a long-lasting process. Incorporation of new didactic methods that needn't bee focused on particular mathematic topic but that require using spatial imagination helps it a lot. Using computer applications and preparation of such a lesson is in many cases time-consuming for teachers. The user friendliness, low time-demand and possibility to easily follow students' progress are crucial for the use of a particular application in a lesson.

We want to present three didactic programs. The first and the second one includes an application that consists of background for solving problems (for students) and of background for creating tests or tasks and for evaluating of students' progress (for teachers). It provides a set of tasks for children or students, too. Programs are freeware and require only a web-browser with VRML plug-in (it is free, too). These programs can be used in the same way for 12-year-old pupils as for 20-year-old students. If presented in the form of a game, the problems can be more attractive and catchy. Some young children are even able to promptly solve the same problems that require a lot of thinking and make troubles to older students and even to some teachers. The less gifted students can train their abilities individually and they can follow their own pace. The third presented application is an online web game. It provides usual functions of such a game – successive levels of tasks and a chart of players. The goal of this game is to train a position imagination in a space.

The Game

Characterization. The goal of the first program – "GAME" – is to develop student's shape and position imagination, to guess hidden parts of shapes, and to combine shapes. Students choose basic pieces from given sets and set their position to piece together the given shape exactly. Their solution can be observed and finally evaluated. We have created a set of tasks and didactic materials for this game. The demands of tasks increase from very simple ones to the brain-teasers that train technical imagination. They can be used at school training or for homework as well. Besides that, this program allows teachers to create their own tasks. Teacher receives a tool for testing student's ability. The record of student's answers is written into a text file.

A student sees a picture of given final shape from different (three or less) views and he gets a text list of pieces of basic shapes (cube, box, cylinder, cone, sphere, pyramid), given sizes and colours. He doesn't see them in 3D scene. His task is to select the right pieces and to set their positions so to "glue" together the given final shape completely and without collision of partial pieces. In the case of the more difficult tasks, the full information about the shape and size of the final object can't be observed from the given pictures and it must be decided from the given pieces.

Table 1. List of the given pieces for the Task 44.

	Size			Position			YES/NO
Shape	rx	ry	rz	x	y	z	Use
box	3	3	1	0	0	0	NO
box	2	2	1	0	0	0	NO
box	2	1	1	0	0	0	NO
box	2	1	1	0	0	0	NO
box	1	1	2	0	0	0	NO
box	1	1	2	0	0	0	NO
box	3	1	1	0	0	0	NO
box	1	2	1	0	0	0	NO
box	1	2	1	0	0	0	NO

A student can ask for help whenever he wants. Then the 3D model of his partial scene is generated and he can preview it, move and rotate it in a virtual scene. The same happens if he finishes the task. All the requests for help and the time needed for the completion of the task are written into a text file. This record can help a teacher to evaluate students' progress or to follow their troubles so he could help them individually.

Table 2. List of one possible correct answer for the Task 44.

	Size			Position			YES/NO
Shape	rx	ry	rz	x	y	z	Use
box	3	3	1	0	0	0	NO
box	2	2	1	0	0	0	NO
box	2	1	1	1	0	0	YES
box	2	1	1	0	0	0	NO
box	1	1	2	0	0	0	YES
box	1	1	2	1	1	1	YES
box	3	1	1	0	0	2	YES
box	1	2	1	2	1	2	YES
box	1	2	1	2	0	1	YES

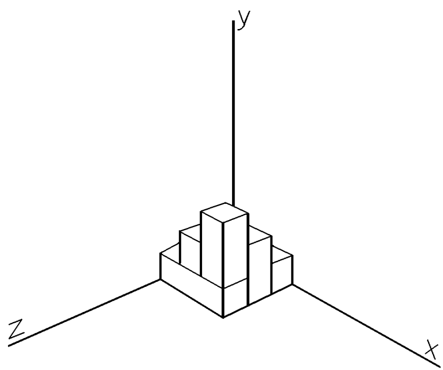

Figure 1. A figure of final shape

A set of tasks. Tasks are numbered according to their difficulty, but they can be loaded in any order. The teacher can plan his lesson according to the capability of his students or select individual homework for them. We have created a plan for training this imagination in the warming periods (each about 10 minutes except for the first one) of four consecutive lessons for 12-year-old pupils.

In the first lesson the time reserved for this game should be longer so the teacher could demonstrate the background of the program to the pupils. For this demonstration we recommend to show some of the tasks 01–03. Then the pupils themselves solve tasks 11–15. As a motivation, the task 20 can be chosen for the homework. The next lesson after checking the homework it is possible to solve one or two from the tasks 21–25 and then one of the more complicated tasks 25–28. These tasks have some redundant pieces in their piece-list.

If pupils are gifted or interested enough, the third and fourth lesson can follow with tasks – problems. In the third lesson some of the tasks 31–34 could be solved as an easier variety and later (or with talented pupils) some of the tasks 35–37. The given shape looks monolithic like the block of concrete and it has to be "glued" from pieces. It needs a lot of imagination to decide which of given pieces can shape together the final object and they must be chosen carefully. The last tasks 41–44 are real brain-teasers. If a teacher decides not to solve them in a lesson he can use them anytime later, when the more gifted pupils in the class have finished their tasks or tend to be bored.

These tasks (30–44) are difficult to solve even for the adult students and, possibly, even for the teacher. However, luckily, he can have the record of the proper solution.

The program also gives a teacher a possibility to create new tasks himself.

The Cube

Characterization. The second presented program – "UNFOLDING CUBE" – is a kind of a well-known quiz: "guess how an unfolded net of a given cube looks like". It allows to generate a cube with chosen textures on its sides interactively and to select the rotation of these textures. Then students can examine given cube on a virtual 3D scene. They can rotate it and unfold it. While unfolding, the textures can be visible or hidden. Finally, student should hide the textures on the sides of the cube and fill in the blank positions in the picture on the list of the paper correctly. Virtual 3D scene helps to solve the problem and explains the mistakes.

We have added a possibility to create a model of a textured regular octahedron and unfold it in the virtual 3D scene, too.

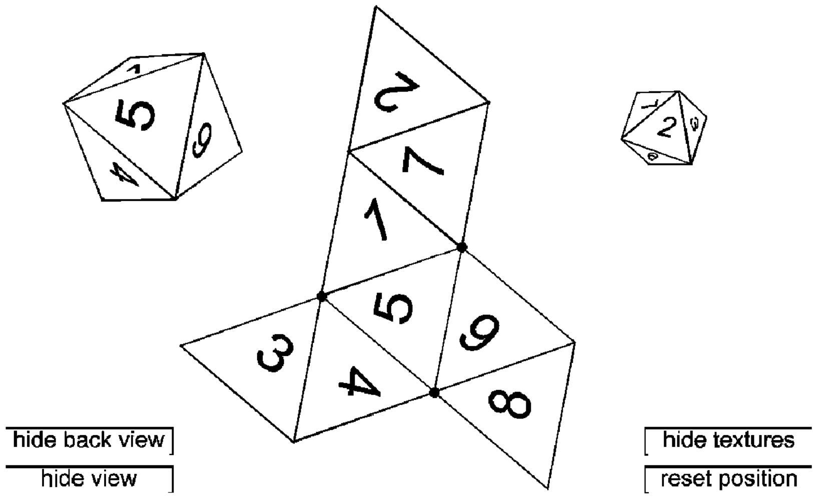

Figure 2. Net of the given octahedron in virtual 3D scene.

A Printed Quizzes. The application also contains a tool that allows teachers to create easily a set of different printed tests and quizzes: The original net of the cube can be modified, its particular textures can be rotated or hidden. Pupils then can fill up missing figures on the sides of the cube's unfolded net, they can be asked to guess the way the cube moves, decide if the given nets are the nets of the same cube, they can sort different nets according to the original cube the net corresponds to etc. This kind of task trains spatial imagination effectively and can be tackled on student's own, but hand-making of such a test is time consuming and it is always difficult to explain to the students the mistakes if you don't have the solid cube in real. The program can stand without it.

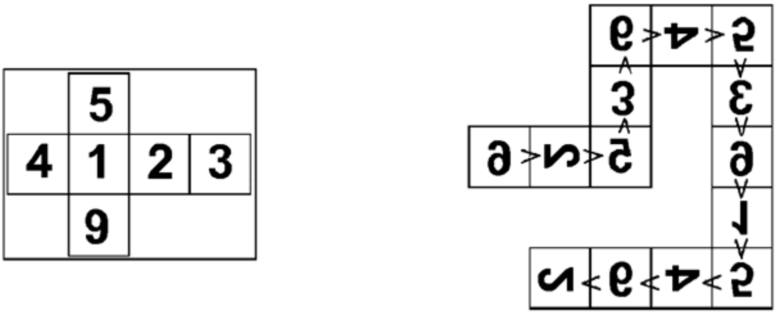

Figure 3. Net of the given cube and one of its paths

Another kind of quiz is to guess the shape that cube "prints into the sand" while rolling away. This track differs from the net mentioned above. It can have (almost) any length and shape and the textures are drawn "inside out" – exactly like the real track is. You can see it in the Figure 3. This track can be easily designed and then arbitrarily modified (its fields can be rotated or hidden) and printed. The teacher can easily create his own quiz, print it and keep and print the correct original track. It is also possible to save the model of the cube and then demonstrate the solution as well as it is written above. Examples of two possible quizzes can be seen in the Figure 4 below.

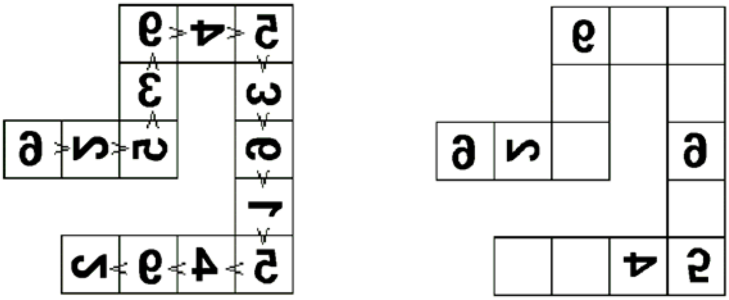

Figure 4. Two quizzes, one with the textures wrongly rotated,
the later with some of the textures hidden.

The Labyrinth

Have you ever experienced the feeling that after having taken a few corners in a foreign city you have got totally lost? Not having even a slight idea of your direction and/or position? So, probably, you should try our last presented application – The Labyrinth.

Characterization. The goal of this game is to train one of many spatial abilities – ability to follow one's position and orientation in 3D space while travelling in space. It is a free web application that requires only the Flash-player. As a player, you are placed into the box somewhere in the "orthogonal" space. You can see only the walls in the room-box you are in and the room-box that is immediately in front of you. You can step forward or rotate along any axis (you can bend up–down, rotate right–left as well as tilt to the left or to the right). No other bench-marks except for the moving edges of (empty) rooms can be seen.

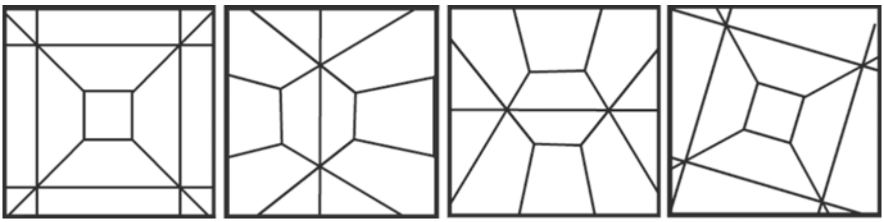

Figure 5. The walls of the room-box as seen by user.

At the beginning of each level you are moved somewhere. While moving you can see the edges of the boxes you are in so you could follow the motion. The motion stops and you have to return back to the starting box (however, your orientation doesn't have to be the starting one). You don't have to follow the path you were moved along exactly. You can take your own path. There are no obstacles.

After the successful finishing of one level, you are allowed to continue into another one. You can also try again any level you have already reached –you may want to try another way back or just to practice again. In case you fail, you are informed about the distance (number of steps) of your final position from the desired (starting) one. No new level is accessible in this case. The number of attempts for a level is not limited.

Tasks escalate from simple ones which take the player only a few steps away and need him to be able only to turn to the left or to the right (and backwards via two moves). In further levels the path elongates so it is more difficult to remember the path itself. The ability to be aware of your current position and orientation while being moved away is important. The second group of ten of tasks needs bending up or down (and upside-down via two moves) and combinations of steps, bending and rotations. Beyond that, the moves in the tasks of the third group of ten tilt the player to the left or to the right. Finally, tasks 31–40 train all kinds of the motions, their paths are long and the direction or tilt of the player is often changed.

The chart shown on the Labyrinth web page keeps the player motivated. The player sees his name (or nick) there and he can (but he needn't to) compete with other players.

The data collection. Data from the web database allow us to analyze the ability of a player to remember or imagine his position in a space. We can find the most difficult combinations of steps, find out which kinds of moves are more natural (which are preferred by players if they can choose) and to see the average number of attempts needed for solving particular levels as well as the time needed for correct answering the individual levels. It is also interesting to see whether successful players follow the path they were moved along or if they are aware of their gauge to the starting point and follow their own path.

An experiment. About 60 volunteers took part in one week test. Some of them were at the age of 15 but they were mostly university students. Nine of them were 20-years-old students of the Technical University, Faculty of Mechanical Engineering. They were not forced to keep the game if they did not want to. About one fourth of them gave up the game. In the Table 3 below you can see some results of this experiment. More than 3000 attempts to the game were made in this one week. Some of the players became really caught and a lot of them returned to the previous levels to train more if they were not able to break through some difficult level.

Table 3. Average number of attempts for successful solving of levels.

Level No.	Avg of attempts per level	Level No.	Avg of attempts per level	Level No	Avg of attempts per level	Level No.	Avg of attempts per level
1	1,8	11	2,0	21	3,5	31	5,0
2	1,1	12	2,6	22	2,0	32	3,7
3	1,9	13	5,9	23	2,6	33	5,2
4	3,1	14	2,3	24	6,9	34	2,1
5	1,5	15	7,4	25	3,5	35	3,4
6	1,5	16	10,3	26	18,4	36	7,5
7	1,3	17	31,1	27	1,8	37	13,6
8	2,9	18	5,9	28	7,5	38	4,7
9	1,7	19	8,0	29	9,7	39	9,3
10	4,0	20	14,3	20	7,7	40	9,0

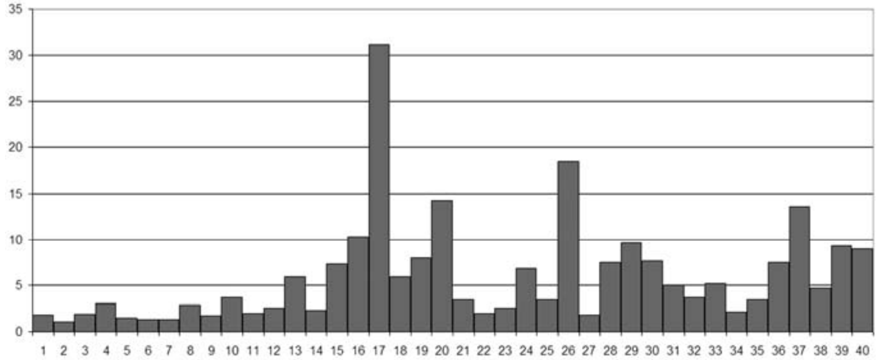

Figure 6. The graph of the Table 3.

We can see that among the players willing enough to continue the game about one third were not able to get through the level 10. That means that it was difficult for them to get over the levels with a long motion, which they probably were not able to follow or remember. The second "crucial" level seems to be the level 17, which was another level of long path combining rotation and bending up and down. Only seven players were able to overcome the level 20, but five of them finished (or nearly finished) the game of 40 levels. The Figure 7 below illustrates the number of attempts to particular levels. Successful attempts are drawn in white.

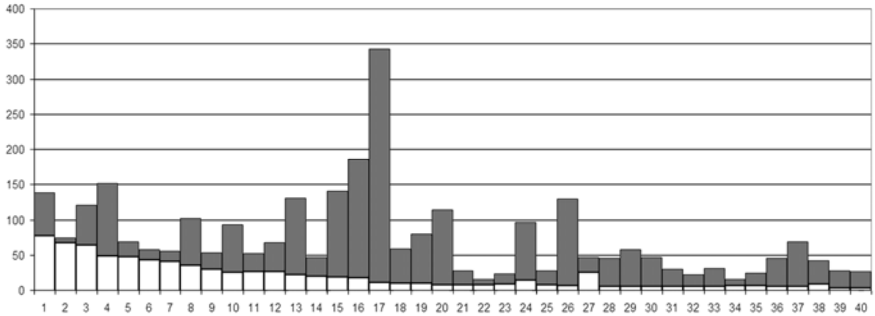

Figure 7. Number of attempts per level.

Table 4. The top level achieved by players.

Number of players	Levels	Mode (level)
15	1–5	3
20	6–10	7
14	11–16	16
5	17–20	19
6	21–40	40

From the record of attempts it can be seen that having reached higher levels (15 or more), the player is later able to go through all the previous levels fluently and quickly, almost without unsuccessful attempts. Because it is almost impossible to remember the previous tasks, it seems to show that particular abilities of players are really improving.

Planned experiments. We would like to design another experiment with different sets of tasks and to observe carefully the troublesome moves or combinations of moves, relations between the age of a player and reached levels, the most successful strategies in particular levels etc.

Conclusions and sources

Using computer applications and especially didactic "games" is more interesting and more attractive for many students then traditional methods. Besides, even university students that are not willing to develop their spatial imagination by classical means are willing to take part in such a game as well as their much younger mates.

All the applications presented can be found or free downloaded from the address: http://3dhricky.wz.cz/

These applications were originally designed in Czech, but there are English versions of these applications there, too.

Acknowledgements

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The use of motion sensor in the teaching of mathematics

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Abstract

It is a common paradigm that first, you must learn mathematics and afterwards you can apply it in physics. However, the development of cheap and efficient sensors makes a different approach possible. Fundamentals of calculus can be already introduced earlier during physics lessons. By using a motion sensor device it is easy to obtain plots of position vs. time and velocity vs. time (x(t) and v(t) graphs) of a student walking in front of the sensor or a falling ball movement etc. Further analysis of the graphs shows the relationship between x(t) and v(t). At the age of 16 the students are already capable of analyzing the slope of the tangent on the x(t) graphs and comparing its coefficient to the values on v(t) graphs. This activity is a part of physics lessons (kinematics). Two years later the same measurements are repeated during mathematics lessons. Using these experiments the teaching of calculus becomes more realistic and connected to historical invention of this mathematical tool.

Introduction

The development of various measurement techniques makes physics lessons more realistic and attractive. Can the same be said for lessons of mathematics? The following contribution shows a proposition for implementing real time (physics) experiments in the teaching of mathematics.

An example *par excellence* of novel measurement techniques that can be used for this purpose is the so-called motion sensor, a device which uses ultrasonic pulse technology to measure the object's position. An ultrasonic transducer generates a 40 kHz sound pulse and the device measures the time it takes for the pulse to travel out, bounce off a target and travel back to the sensor. The travel time of the ultrasound pulse is proportional to the distance. By connecting the sensor to a PC, it enables us to measure the position of a moving body; such as a student walking back and forth in a straight line in front of the sensor, or a ball falling under the sensor. The computer plots real-time graphs of such linear motion.

The emitter can emit ultrasonic pulses up to 100 times per second, which is sufficient for a fast moving object. Some additional features like using two devices simultaneously to plot the path of a an object moving in a plane or following two objects during collision events increase the teaching value of this equipment. The necessary software was developed independently all over the world by firms and individuals. In the case of Slovenia [1, 2] its development was supported by the state and therefore it is available at no charge for all schools. The apparatus itself is in the price range of 120 EUR.

Graphs and functions

Plotting a graph is a very basic task. Certainly it must be done many times without the use of computers. The students need to be able to plot calculated points into Cartesian system. Taking into account everyday use of computer, they expect that the computer can do some boring work instead of them. But how to connect the computer and the real world? Very popular option is to use a temperature sensor. Therefore computer (with the help of an interface and sensor of course) measures temperature of a cooling glass of water.

It is my opinion that "Homo sedens" should as often as possible stand up and walk – also during learning. As a student is walking in front of the motion sensor he is active in creating changes and these changes (x(t)) are simultaneously displayed and seen on the screen. If he stops for several moments he/she can observe that the independent variable (time in this case) run actually independently – the position just doesn't change (Fig. 1).

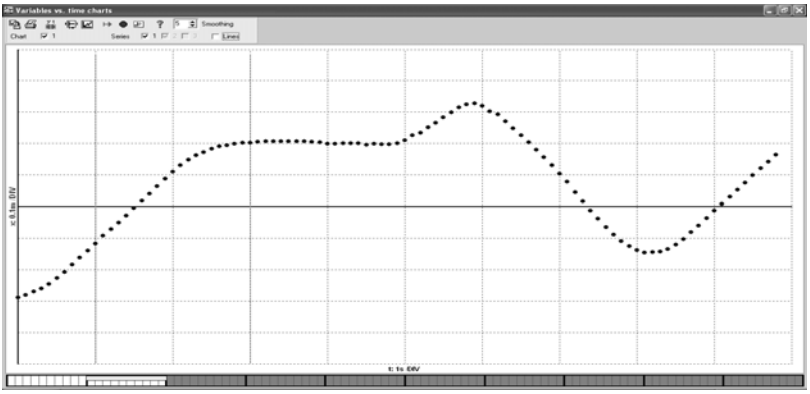

Figure 1. Linear motion of a walking student; graph x(t) obtained by motion sensor connected to a PC.

Linear function can be obtained with the help of an inexpensive toy-cart with a self roll mechanism. (Fig. 2.a). The graph is practically a straight line (Fig. 2.b). However, it should not be too difficult for a walking student to move in a straight line with constant speed to produce the same result.

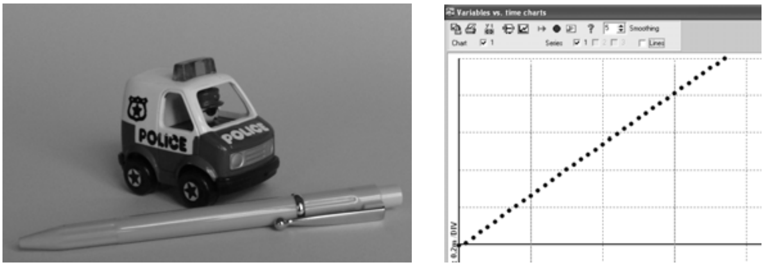

Figure. 2 a, b. Inexpensive toy-cart (a) and linear graph (x(t)) produced by its roll mechanism movement (b).

From physics toward calculus

The basic procedures of the measurement system are simple enough to be explained to the students. They must understand what kind of data the computer collects and how it processes them in order to plot graphs *x(t)*, *v(t)* and *a(t)*. To make this point, I begin with a very simple measurement without the computer. We collect all the data and perform calculations by ourselves. I push a toy-car with non constant velocity in a straight line and simultaneously I plot dots at the pace of a musical metronome at the rate of 1.25 beats per second in order to obtain the data: positions of the toy-car vs. time. Then we measure the positions of the dots and fill in the table: time, position (t, x). After drawing the graph, position vs. time (*x(t)*), we add the third column - : displacement during the time interval. We then calculate the average velocities during each time interval. Finally, we plot both graphs, *x(t)* and *v(t)*, drawing a soft line connecting the points corresponding to the values from the table.

Table 1. A few top rows of the table containing measured (t, x) and calculated values (Δx, v) for a toy-car pushed with non-constant velocity. The time interval is 0.80 s.

t [s]	x [m]	Δx [m]	v [m/s]
0	0		
		0.09	0.11
0.80	0.09		
		0.12	0.15
1.60	0.21		
		0.13	0.16
2.40	0.34		
…			

Once the procedure is understood, additional experiments can be done with the aid of computer. First, it is necessary to introduce our computer measurement system to the students. We repeat a similar experiment, this time using the motion sensor. Its principle is similar, the only difference is that it uses ultrasonic pulse technology to measure the object's position to obtain the set of data *x(t)*. The advantages of using a sensor are clear. First, it measures the position several times per second with an accuracy that exceedingly surpasses man's ability to plot the position of a moving body. Furthermore, it plots graphs *x(t)* and *v(t)* almost in real-time. The final outcome of the two methods is basically the same: set of raw data, position vs. time (*x(t)*), from which the other kinematics quantities are calculated as well as their graphs plotted.

Graph analyses – precursor of calculus

At the age of 15 or 16, which corresponds to the second year of high school in Slovenia, students are able to analyze a graph; therefore, they observe and examine the two graphs (*x* vs. time and *v* vs. time) for an object with variable velocity. They soon determine that the slope of the curve *x(t)* is exactly the velocity at that instant. Looking at the position graph, *x(t)*, they are able to sketch the velocity graph, *v(t)*. It should be noted that this is a qualitative task (Fig. 3)

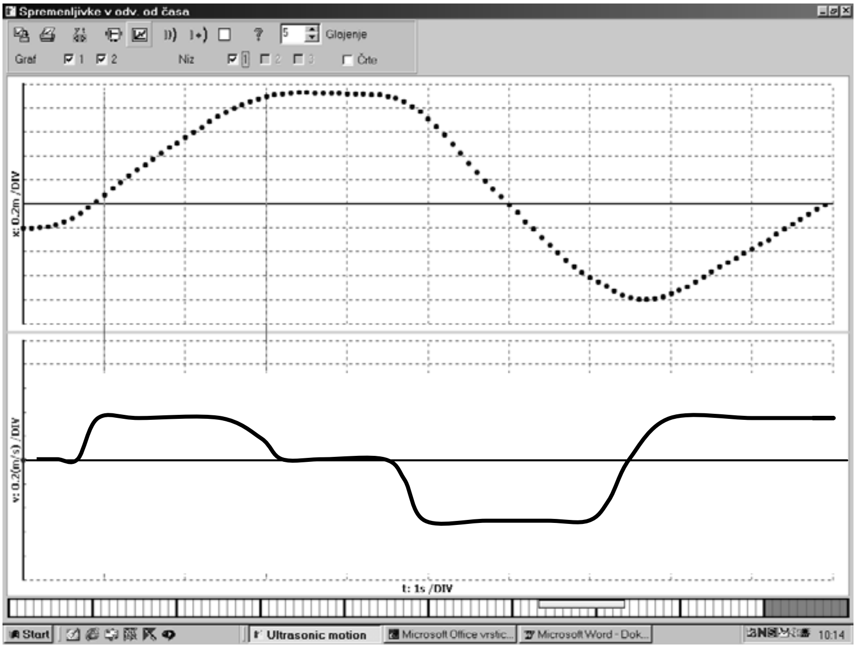

Figure 3. A student has sketched v(t) graph by analyzing x(t) graph. The latter displayed v(t) graph computed by the measurement system confirmed the student's prediction of v(t) graph.

Their quantitative task is to draw a tangent and calculate its slope in order to determine the instantaneous velocity. The result is checked by the graph *v(t)*, plotted by computer. I am convinced such students' activities are the right moment to tell them that this process will be called differentiation and explained in details two years later during their mathematical lessons (Fig. 4).

As the reverse process is also possible, we will use the opportunity to deal with it, too. Let us now focus on the velocity vs. time graph. We choose a time interval and observe the area under *v(t)* graph during the chosen time interval, Δt. Let us first consider the case of non-uniform motion, Fig. 4. The graph is not a straight line. We estimate the average velocity during the time interval and plot a horizontal line; therefore, we obtain a rectangle which has approximately the same area as the area under *v* vs. *t* graph during that time interval. The area of the rectangle is calculated and is equal to the displacement (during the same time interval). We can check our result using *x(t)* graph: $\Delta x = x_2 - x_1$. If the curve *v(t)* is under the time axis (negative velocity), the "area" is negative; it corresponds to a backwards displacement. Again, a physics teacher has a perfect opportunity to explain to his students the importance of such a procedure, and one day they will call it integration.

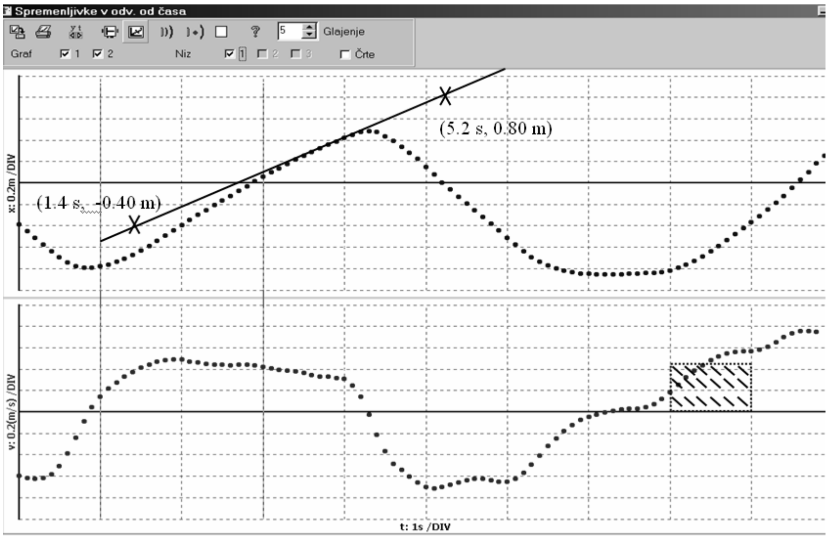

Figure 4. The slope of the curve *x(t)* is defined as the slope of the tangent at that point. The calculated slope at t = 4,0 s equals the instantaneous velocity at that instant (Δx/Δt = 0.32 m/s). Graph *v(t)* confirms the result. The reverse process is shown on *v(t)* graph. The displacement during the time interval is determined by calculating the area (in our case Δx = 1,0 s·0,45 m/s = 0,45 m)

Now it is time to complete Table 1. We define acceleration as the rate of change in velocity. We add two columns to the table: *Δv* and *a*. As we plot the graph *a(t)*, it can be obviously seen that the instantaneous acceleration is given by the slope of the tangent to the *v(t)* graph.

To further convince the students that this is in fact so, let us examine a freely falling object. In the case of free falling object, there's no need to use special equipment. The measurement system enables us to simply drop an ordinary volleyball or basketball from rest under the motion sensor, Fig. 5. It is right to assume the air resistance is negligible. The system displays both graphs (*x(t)* and *v(t)*). As the ball rebounds several times from the floor, a part of this motion is like an object thrown straight up. During one bounce it continues to move upwards for a certain time t and then drops back to the floor. Graph *x(t)* clearly shows the two time intervals, upwards and downwards, are the same. At the same height the instantaneous speed is the same. The velocities are opposite, as we can see from graph *v(t)*. And finally, it is possible to measure the acceleration – by calculating the slope of the graph *v(t)*. It is the same all the time, regardless of the ball moving upwards or downwards … with the exception of a short time interval when the ball hits the floor.

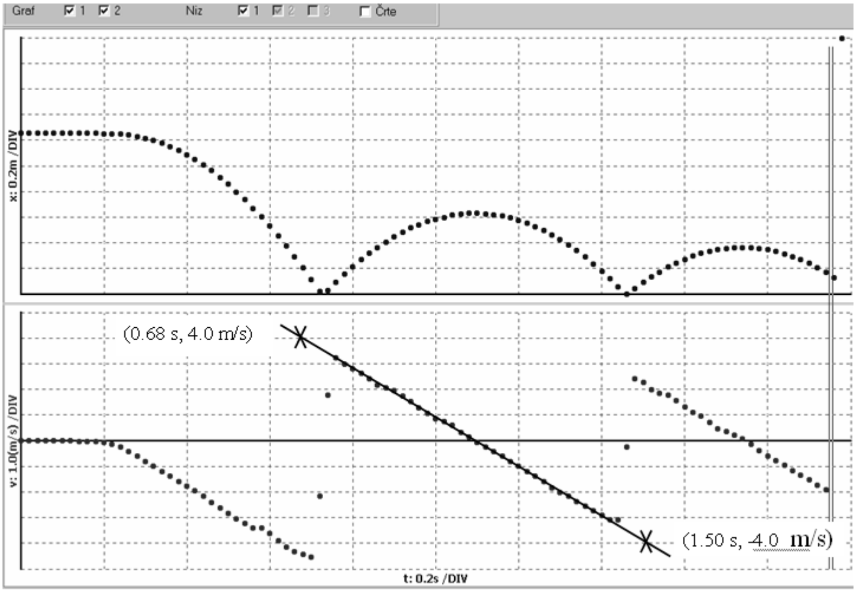

Figure 5. An ordinary ball was held under the motion sensor and dropped from rest. It bounced twice from the floor during the measurement. Graphs show that the instantaneous speed (= the magnitude of the instantaneous velocity) at points of equal elevation in the path is the same regardless of the ball moving upwards or downwards during the bounce (e. g., compare t = 0.80 s and t = 1.40 s). In addition, during one bounce the ball slows from the initial upward velocity to zero velocity. At the highest point it changes its direction of motion. Certainly, it experiences the same acceleration the way downwards. The acceleration, which is the rate of change of velocity, is constant. Therefore this part of the v(t) graph is linear. The slope of the line equals the acceleration. As calculated for this case:

$$a = \frac{\Delta v}{\Delta t} = \frac{-4.0\,ms^{-1} - 4.0\,ms^{-1}}{1.50\,s - 0.68\,s} = -9.76\,ms^{-2} \approx -9.8\,ms^{-2}$$

What about graph *a(t)* for this experiment? The brightest students can draw it, so I expect the readers of this expose will find this task as a minor challenge.

The software can also plot a tangent to the curves *x(t)* and *v(t)* and display its coefficient (slope). However, we use this option only after the students have mastered the same procedure themselves.

Once these basic experiments have been performed, it is possible to play with other options. The program allows us to select the place of each graph. In addition, it is possible to hide the legend. Therefore, students can check their understanding by "hidden graphs". For example, we measured a pendulum motion. The three graphs are displayed but without legends and not in the usual order (*x(t)*, *v(t)*, *a(t)*). One can assume the first graph is *x(t)* and then examine its slope looking for the *v(t)* graph. If one of the two graphs could be *v(t)*, the task is not finished yet. Now it is time to prove that the last graph corresponds to the slope of the second one. If not, one would simply assume the graph in the middle could be *x(t)* and repeat a similar procedure until the two consecutive graphs are "in slope relationship with the previous".

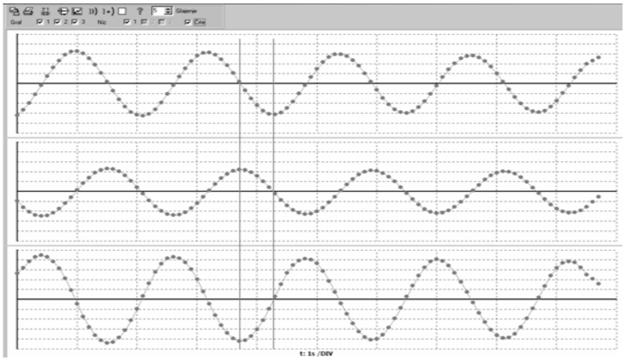

Figure 6. Motion sesor analyzed pendulum motion. The graphs *x(t)*, *v(t)* and *a(t)* are not displayed in this order. Students must find out the legend of each graph by investigating their slope and interrelationship between the graphs.

From calculus and its procedures to physics

So far, I have shared some ideas which mathematics teachers could discuss with their colleagues, physics teachers. Because calculus is not used in most high school physics courses, my next suggestion is designed for mathematics teachers. I am sure almost all mathematics textbooks show the use of calculus to derive equations for constant acceleration, and to find out the work required to compress a spring. So there is no need to repeat these common examples but to make a step forward; that is, to offer new examples of the interrelationship between mathematics and physics in the teaching of calculus.

Let us take a balloon and drop it from rest under the motion sensor (Fig. 7). The air resistance is not negligible in this case; therefore, we cannot use the equations for constant acceleration.

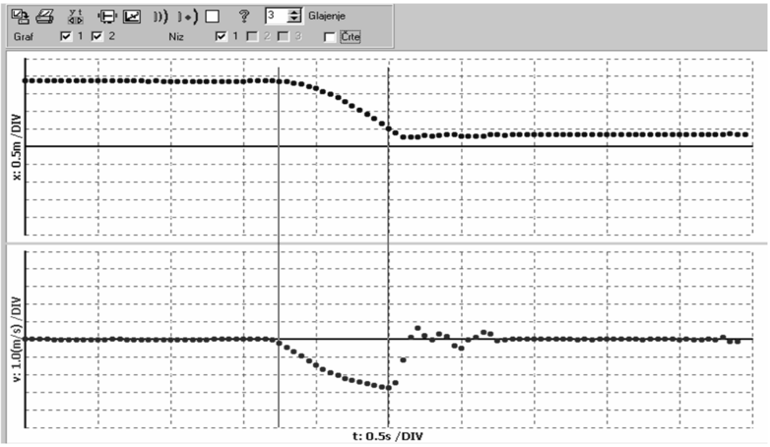

Figure 7. A balloon was held under the motion sensor and dropped from rest. Besides the three graphs, the computer programme can also display the table of values for *x(t)*, *v(t)* and *a(t)*.

After measuring this non-constant velocity motion (and even not uniformly accelerated motion), the selected data are imported into Excel® or a similar program, Fig.8. We copy only the values that correspond to the dots within vertical cursors. Time $t = 0$ is set for the first pair of values. Then we select option "insert trend line, polynomial approximation" and the program returns the equation of the approximated polynomial. We choose to approximate this movement with a polynomial of 6^{th} order.

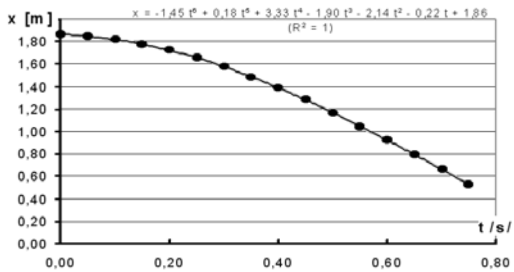

Figure 8. The data, x(t), are imported to Excel and the graph is plotted. In addition, the polynomial approximation is calculated and the equation is displayed.

The derivative of the polynomial is calculated and the calculated values, *v(t)*, can be compared by values, and displayed by the measurement system by computer. The similarity of both sets of data proves the applicability of the differentiation technique.

The polynomial, calculated and displayed by Excel (Fig.8), is derived by students, and they obtain the equation that describes fairly well approximation of velocity vs. time dependence.

$$v(t) = -1.45 \cdot 6\, t^5 + 0.18 \cdot 5\, t^4 + 3.33 \cdot 4\, t^3 - 1.90 \cdot 3\, t^2 - 2.14 \cdot 2t - 0.22$$

Let us compare *v(t)* calculated by computer ($v = \Delta x/\Delta t$) and *v(t)*, calculated by the derivative of polynomial approximation of *x(t)*. Except one pair, the differences are less that 1 %.

Table 2. The first three columns contain the measured and calculated values displayed in a table by motion sensor software. The values in the last column have been calculated using the derivative of the polynomial approximation.

t[s]	x [m]	v [m/s]	dx/dt [m/s]
0.00	1.86	-0.20	-0.23
0.05	1.85	-0.45	-0.45
0.10	1.82	-0.71	-0.70
0.15	1.78	-0.95	-0.95
0.20	1.72	-1.20	-1.21
0.25	1.66	-1.44	-1.45
0.30	1.58	-1.70	-1.68
…	…	…	…
0.70	0.66	-2.70	-2.70
0.75	0.52	-2.77	-2.81

To show the usefulness of integration, we must execute the reverse process. Therefore, we take the *v(t)* values as our input data, displayed by our measurement system. After importing the selected data into Excel, the program calculates the polynomial trend line and displays the equation:

$$v(t) = 82t^6 - 188t^5 + 150t^4 + 46t^3 + 5.9t^2 - 5.26t - 0.20$$

We integrate the polynomial as a definite integral, $s(0)=0$:

$$s = (82/7)\, t^7 - (188/6)\, t^6 + (150/5)\, t^5 - (46/4)\, t^4 + (5.9/3)\, t^3 - (5.26/2)\, t^2 - 0.20\, t$$

The x-values are the distances above the ground, therefore the values of x decrease with time. The negative values of the definite integral, which are equal to the displacements during the time interval, mean downward motion.

Beside columns t, $x(t)$ and $v(t)$, there are two additional sets of calculated values, as shown in Table 3. The fourth column, s, contains the calculated values (using the approximation and definite integral), which correspond to the displacement during the time interval. The last column contains the values, calculated from the $x(t)$ graph, displayed by the measurement system. The initial coordinate x_0 is taken from the current value of coordinate x, which corresponds to the current position. The shaded row shows (as all others do) the agreement of both approaches. After the balloon has been falling for 0.40 seconds, its velocity has become –2.053 m/s, while the displacement has been 0.474 m in the negative direction. This result is calculated using the definite integral. On the other hand, the displacement at t = 0.40 s is equal to 0.473 m in the negative direction, computing this value as the difference between the displayed coordinate and initial position.

Table 3. The first three columns contain the measured and calculated values displayed in a table by motion sensor software. The values in the fourth column have been calculated using the integration of the polynomial approximation. The last column contains the displacements calculated from the values in the second column and initial position.

t[s]	**x [m]**	**v [m/s]**	**s [m]**	**x – x_0 [m]**
0	1.863	-0.203	0.000	0.000
0.05	1.847	-0.454	-0.017	-0.016
0.10	1.817	-0.705	-0.045	-0.046
…	…	…	…	…
0.40	1.390	-2.053	-0.474	-0.473
…	…	…	…	…
0.7	0.661	-2.703	-1.201	-1.202
0.75	0.524	-2.772	-1.338	-1.339

Conclusion

Physics teachers could and should introduce calculus on a visual level using tangents and areas, while mathematics teachers should use some measurement techniques in order to persuade their students that calculus is a very useful tool. The two teachers (or only one in some countries) should be aware of the teaching methods of both subjects. That is the best way to take advantage of the interrelationship of the two subjects. In summary, I strongly believe that the cooperation of physics and mathematics teachers can enhance the understanding and utility of calculus, this indispensable mathematical tool in science; the tool which was independently invented by two geniuses: physicist Newton and mathematician Leibniz.

Acknowledgements

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Teaching science and mathematics subjects using the Excel spreadsheet package

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Abstract

The teaching of scientific subjects usually require laboratories where students can put the theory they have learned into practice. Traditionally, electronic programmable calculators, dedicated software, or expensive software simulation packages, such as *MATLAB* have been used to simulate scientific experiments. Recently, spreadsheet programs have replaced the electronic calculators and are now widely used by science, engineering and mathematics education in modelling and solving complex problems. One of the advantages of a spreadsheet application in science education is that a given problem can easily be modelled and then simulated with varying parameters. The change of the output can then easily be displayed in graphical format as the simulation progresses. This paper describes how spreadsheet programs such as the *Microsoft Excel* can be used in simulation. Examples are given in the paper for mathematics and physics teaching.

Introduction

Effective science and mathematics teaching is very important in all undergraduate engineering and science classes. In UK, students are accepted to Universities based on the results of their *A-Level* examinations. There is strong evidence that most students are opting for easier *A-Level* subjects over the sciences and mathematics (see Figure 1 and Figure 2). Students usually find the science and mathematics subjects harder and their results from these subjects are generally poorer compared to social science subjects. As a result of the lack of interest in science subjects, there is a serious shortage of specialist physics, chemistry, and mathematics teachers, which has become a barrier to better teaching of these subjects.

There are many reasons for the lack of interest in science subjects. One of the reasons is that these subjects require *creativity*, *positive thinking*, and *problem solving logic*, whereas most of the social science subjects can be learned by memorizing the topics. Perhaps another reason for the lack of interest in science subjects is that these subjects are usually laboratory based and many students have difficulties to carry out real experiments on their own and then present their results in a scientific manner.

Software simulation techniques are currently used by many educational institutions in the teaching of engineering, science, and mathematics subjects. Simulation is usually in the form of a computer program with user-friendly graphical interface, developed to mimic the operation of a real physical system.

For example, the behaviour of an electric motor can be modelled on a computer using a simulation package and students can learn the operation of such a motor on a computer, away from the actual physical laboratory.

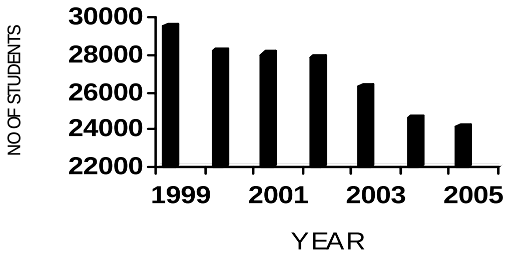

Figure 1. Students taking Physics subjects

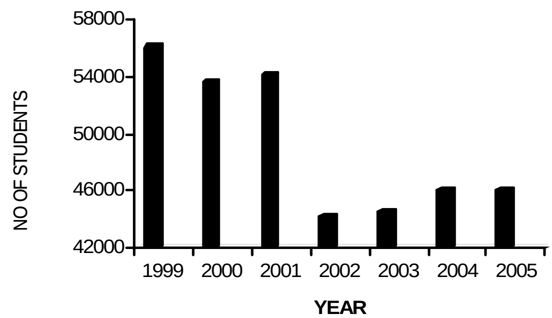

Figure 2. Students taking Mathematics subjects

Although simulation can not replace a real physical experiment carried out in a laboratory environment, nevertheless it has several advantages as outlined below:

- Physical experimental laboratory kits are usually too expensive and many institutions can not afford to purchase such kits. Especially, in a laboratory environment usually more than one kit of the same type may be required and this increases the cost considerably. Simulation on the other hand is simply a computer program and is much cheaper to purchase and use. In addition, more than one copy of the simulation program can be obtained at reduced cost under special educational licenses and discounts offered by many organisations.
- Physical kits require maintenance and in many cases it can be too expensive to replace faulty components, or to maintain a large number of kits. Simulation on the other hand does not become faulty, and does not require any maintenance, except for occasional software updates, which are usually either free of charge or are supplied at low cost to existing users with maintenance contracts.
- Physical kits may become obsolete in very short time as the technology is advancing very rapidly. It then becomes rather expensive to upgrade or replace these kits. As mentioned earlier, it is very easy and usually a low cost process to apply updates to a simulation program.

- Physical kits can be damaged very easily if they are not used properly. For example, a power supply kit can be damaged beyond repair if the output pins are shorted together. On the other hand, it is not generally possible to damage a simulation program by making wrong selections. The only problem may be the accidental deletion of the simulation program or some of its components. Accidental deletion does not normally happen since most software is protected for deletion. If the simulation software happens to be deleted by mistake, it can be re-installed easily at no cost.
- Software simulation provides access to many variants of a physical entity with no cost. For example, many different models of transistors can be chosen and used in electronic simulation packages. On the other hand, it would be too expensive to purchase many different types of physical transistors.
- The purchase of a physical kit or a physical component may take long time as it may have to be approved by the finance departments. With software simulation however, any type of component can be modelled and simulated with no purchasing or waiting time.
- One important disadvantage of simulation compared to real physical experiments is that the simulation can sometimes hide the reality from the users. For example, it is very easy in a simulation program to pass a 100A current through a small resistor. But in practise, in a laboratory environment this is very unlikely to happen as the resistor would probably be damaged as a result of excessive heat dissipation.

There are many commercially available simulation packages in the market, developed for engineering, science, and mathematics teaching. Perhaps the most popular one and the most comprehensive one is the *MATLAB (2008)*. Although extremely powerful, MATLAB is a rather expensive simulation package, formed of a base system with many additional *toolboxes* for modelling and simulating various engineering, scientific, and mathematical applications. For example, using MATLAB students can model a complex control system and then easily investigate various controller algorithms to find the optimum one for the system. Similarly, for example, students can perform matrix multiplication or inversion manually and then check their answers using MATLAB. *ANSYS (2008)* is another commercially available simulation package similar to MATLAB and developed for engineering, scientific, and mathematics applications.

Some of the simulation packages are developed for specific applications. For example, *SPICE (2008)*, *Multisim (2003)*, *EasySim (2007)*, *B2Logic (2008)* are developed to simulate electronic analog and digital circuits. Users can model complex electronic circuits using electronic devices, and then the operation of the circuit can be simulated under various input conditions, with the outputs either observed on *virtual instruments* (e.g. a virtual oscilloscope or a virtual multimeter), or plotted as graphics.

This paper describes how the Excel spreadsheet can be used for the simulation of mathematical equations, and also in teaching physics.

Using Excel in science, mathematics, and engineering education

The use of spreadsheet programs in science, mathematics, and engineering education is not new.

Aliane (2007) reports the development of a control system teaching package using the Excel spreadsheet program. With the help of this simulation package students can construct computer models of both continuous-time systems and digital control systems. The described package is low-cost and it provides graphical output of the system response where the plant parameters, controller parameters, and the simulation time can easily be modified while the output response is observed dynamically

Evans (2000) describes simulation techniques using the Excel spreadsheet program. The simulation of a financial system is given as an example where students can modify the price, cost, discount rate, and profit of an item and then observe the expected profit as a dynamic graphical output. Evans reports that spreadsheets offer the following pedagogical advantages in learning:

- *Rapid start-up*, where the simulation can be carried out easily after a short course in the general use of spreadsheets.
- *Integrated graphics*, where the extensive graphics facilities provided by the spreadsheet programs can be used in simulation outputs.
- *Dynamic updating*, where new simulation results can be immediately obtained as input data are changed.
- *Statistics integration*, where a full complement of statistical tools and functions provided by the spreadsheet programs can be utilised in simulations.

Pecherska and Merkuryev (2005) describe a spreadsheet-based approach to teaching simulation, where the objective is to introduce spreadsheets as a powerful simulation tool for educational purposes. The paper deals with basic types of simulation models suitable for spreadsheets. The static stochastic or Monte Carlo simulation models are introduced in the paper through a sample model for lead-time demand distribution evaluation. The authors conclude that the spreadsheets provide broad possibilities for creating simulation models for educational purposes in business games, case studies, engineering etc.

Cooper (2002) reports how data analysis and simulation can be carried out using the Excel spreadsheet program. The paper describes how a computer can be used to collect experimental data and then how this data can be analysed using the Excel. The paper also describes how simulation can be carried out with the Excel and how formal worksheets and charts can be developed to present information in scientific manner.

El-Hajj, Karaki & Kabalan (2002) present a spreadsheet based method for the graphical simulation of analog computers used in control systems. Analog computers are very expensive hardware devices used to simulate the behaviour of dynamic control systems. The paper describes a simple low-cost method of simulating analog computers using basic building blocks such as adders, integrators, potentiometers, inverters, and non-linear devices. The authors conclude by saying that the proposed method is very convenient for a quick simulation when one does not have the time or means to write a sophisticated program or to access advanced commercially available simulation packages. It is also concluded that the method is sufficiently accurate for a large number of practical applications since Excel stores numbers and performs calculations using 15 digits of precision.

Another interesting paper is by El-Hajj, Kabalan & Mahmoud (2001) where a spreadsheet toolbox is described for simulating digital networks. The paper presents a simulation method using advanced spreadsheet features such as toolbars, menus, controls, graphics, and online help. The authors report that instead of writing lengthy formulas that are spread all around the worksheet, the user can draw a complete logical network by mere mouse clicks. Many examples are given in the paper to illustrate the method presented.

Chemical process simulation using the Excel program is described by Henao and Velasquez (2000). The authors report that using a low-cost tool such as Excel, it is possible to build and solve simulation models that duplicate the results obtained using commercial simulators. It is reported by the authors that a chemical process simulation involves the integration of three basic elements:

- Mathematical models of unit operations
- Thermodynamic properties calculation methods
- Numerical methods for the solution of non-linear equations

Examples are given in the paper on the mathematical modelling and simulation of a chemical plant.

Lundkvist (1997) presents an interactive Excel based method for biology teaching. The aim of the paper is to develop an interactive Excel-application as a pedagogic tool in biology teaching in order to enhance the learning and understanding of dynamic biological systems and complex theoretical sections of genetics. Two simulation tools are presented in genetics, each consisting of a series of modules, intended for demonstration of dynamic biological processes or used as laboratory exercises.

Example application of Excel in mathematics

In this section of the paper a simple mathematical application of the Excel spreadsheet program is given to illustrate the simplicity and power of performing dynamic simulation of a mathematical problem. In this example, as shown in Figure 3, the graph of the simple quadratic equation:

$$y = ax^2 + bx + c$$

is simulated dynamically. Students can use a “spin” form control (shown on the left-hand side of the graph) to change the three coefficients a, b, and c of the equation, and the graph is re-drawn dynamically. Thus, students can have an excellent visual understanding of how the shape of the graph varies as the coefficients are changed. Graphs of higher order equations can also simulated very easily and students learn easily the significance of the coefficients of an equation.

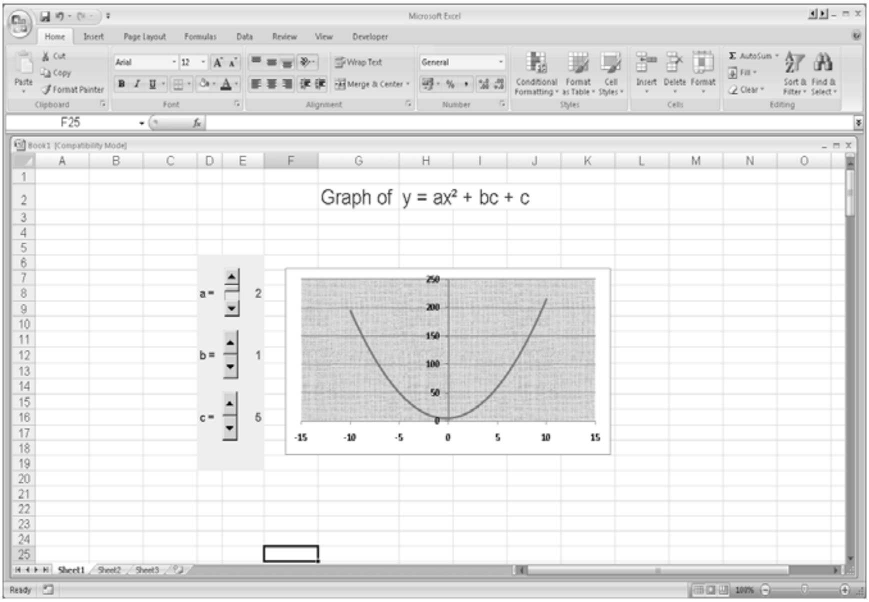

Figure 3. Example application of Excel in mathematics

Example application of Excel in physics

This section shows how the Excel spreadsheet program can be used to simulate a physical problem. Here, the equations of motion of a projectile are used to simulate the behaviour of a projectile. If a projectile is fired with an initial velocity of V_o, at an angle of θ with the horizontal, it is well known that the three basic equations describing the range, height, and the flight time of the projectile are given by:

$$\text{Range} = \frac{V_o^{\,2} \sin 2\theta}{g} \qquad \text{Height} = \frac{V_o^{\,2} \sin^2\theta}{2g} \qquad \text{Time} = \frac{2V_o \sin\theta}{g}$$

Figure 4 shows the Excel simulation setup. Here, the picture of a typical projectile path is given with the basic equations of motion under the picture. Students can enter the initial velocity V_o, and angle θ using a "spin" form control. As these parameters are entered, the range, height, time of flight, maximum range, and the maximum height attained by the projectile are all calculated and displayed automatically. In addition, these outputs are also shown in graphical form so that students can see the changes visually and easily.

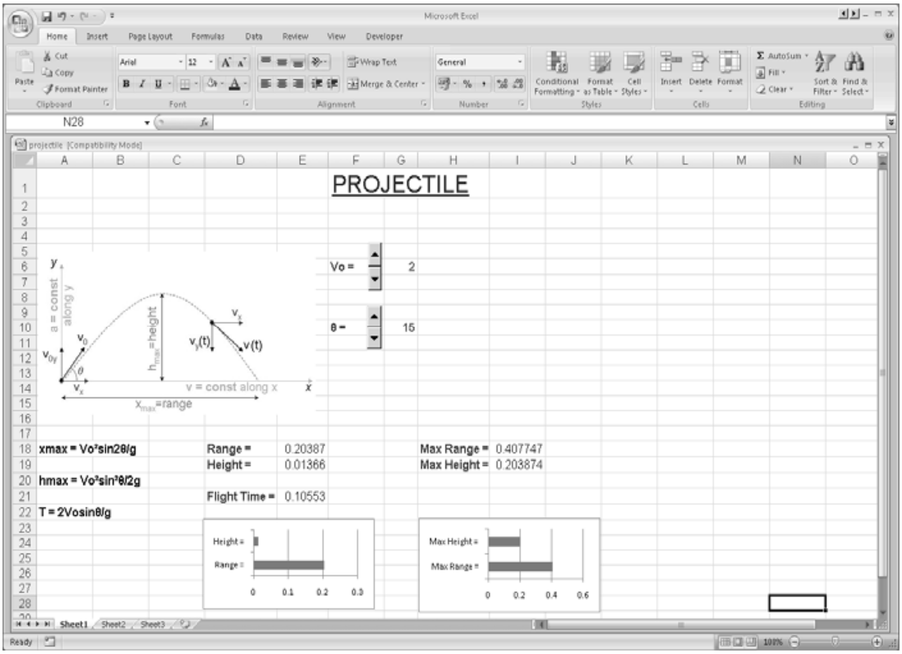

Figure 4. Example application of Excel in physics

Conclusions

The paper has described how the Excel spreadsheet program can be used as a useful tool in science, mathematics, and engineering education.

Science and engineering education are more expensive than the social sciences education because of the laboratory requirements. The experimental parts of most science subjects are nowadays carried out using computer based simulation packages. Commercially available simulation packages are very powerful, but at the same time their cost is considerably high. Most of the science and mathematics experiments can easily be carried out by developing spreadsheet (e.g. Excel) based simulation programs. References to some of the existing spreadsheet based simulators are given in the paper. In addition, examples are given on using the Excel spreadsheet as a tool in simple mathematics and physics teaching.

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From mathematics to technology and backwards by intuition

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Abstract

We present simple intuitive ideas which have profound meaning and applicability in technology and which can be described by basic mathematical concepts. The ideas are useful in mathematical teaching as only elementary knowledge is a prerequisite. Ideas can be described and motivated intuitively and backed by modern technology use. The ideas offer easy progression into challenges which can go beyond regular high school mathematics and reach even advanced mathematical analysis for its full comprehension, while its intuitive understanding remains accessible to any curious mind. Presentation of ideas has been enriched by the use of advanced computer simulations to visualize the concepts. We present the ideas of *the arithmetic mean* in relation to the modern *car technology, the ancient properties of a parabola* in relation to *car lights* and the ideas of *discrete functions* in relation to the modern *digital sound technology*.

Introduction

We present three very simple mathematical ideas which have an incredibly intuitive and useful meaning in modern technology. The first one is the idea of *arithmetic mean*, which is the essence of the powering of modern cars. *Car differential* is nothing but a mechanical realisation of the mathematical idea of arithmetic mean. Driving a car, we are not even aware of this marvellous device, which allows easy steering of a car and solves the question of how it is possible to smoothly steer a car… which is powered by one (which one, left or right?) or by two wheels (would make a car to go only straight!). The idea can be connected with very interesting and also deep questions of practical definitions of *straightness* which give rise to intuitive understanding of *geodesics*. The second idea is an ancient idea of a parabola, which explains the functioning of car lights and satellite dishes. And finally, simple understanding of (discrete) functions can be used to comprehend the 'miracle' of a modern digital sound technology.

The arithmetic mean and differential gear

We all know, that a car is powered by a motor. But how? How is the power (the rotation) of the motor transferred to the wheels that make the car to move. On a bicycle, we use a chain that transfers the rotation of the pedal to the back wheel. Is it not done very similarly for a car, just that the source of power is a motor and not our muscles? Well, the very first cars were truly done that way. By the use of a chain the rotation was transferred from the motor to the (back) axle. So both, right and left wheel rotated simultaneously and made the vehicle to move.

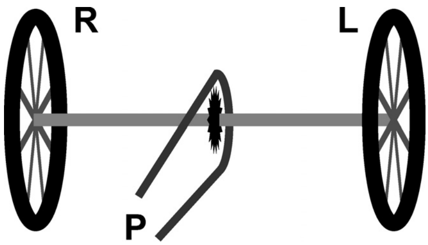

Figure 1. Right and left wheels are attached to the same axes of rotation

With a look on the picture, disregarding possible transmission ratio and denoting 'power' (engine rotation) by P, right wheel rotation by R and left wheel rotation by L, we get a very simple equation:

$$P = R = L$$

But does a car work like that? Well, the very first cars did function like that and as a consequence, the steering was very hard. In a left turn the left wheel slows down and the right speeds up a bit. Their average speed remains unchanged. If P is their average speed, R is the speed of the right and L is the speed of the left wheel, then their moving is described by a simple equation:

$$P = \frac{R+L}{2}$$

Could this simple formula be mechanically realized for powering right and left wheels of a car? But how? It might be surprising, but a positive answer to this question has been known for over 2000 years. In fact, a mechanical realisation of the formula for arithmetic mean is surprisingly simple.

Imagine first, that equal powering of the right and left wheels is achieved by a 'rotating handle on a disc', which is attached to the right and left disc, that are welded at the end of the right and left wheel axes, as shown on the bellow picture.

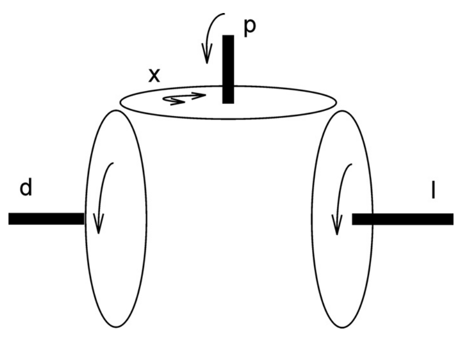

Figure 2. Right, left and freely rotatable powering discs

Instead of discs we can imagine cogs. It is obvious, that with a help of such a mechanism, a rotation of 'the handle P' would imply an equal rotation of the left and right wheel, thus *P*=*R*=*L*. This seems like still far away from the desired arithmetic mean equation. But it is not.

Denoting $$\frac{L-R}{2}=X,$$

we have $R=P-X$ and $L=P+X$

The value of *X* can be understood as a free parameter in the relation of three variables within the arithmetic mean equation. Namely, if we allow that our 'power disc' in the above picture, is freely rotatable (free variable *X*) around the 'handle', as shown in the picture, we already have a model of a differential gear.

It is a nice exercise to think about the different values of the variable *X* in different situations, like when we drive straight, when turning left or right, when one of the wheels is blocked.

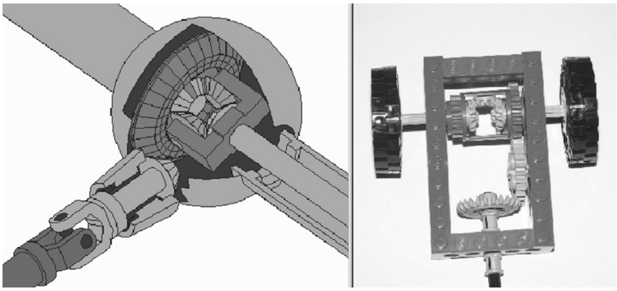

Figure 3. Drawing of a differential gear and *Lego* model of a differential

Today, one can easily experiment with the idea, as even *Lego* (*Technic*) provides sophisticated but yet simple models of devices like differential gear. And with such a model one can ask many interesting questions related to practical 'car driving' issues (like snow driving) and relate them to the abstract mathematical meanings of the arithmetic mean formula. A creative teacher can further find many interesting historical findings which are related to the invention and development of these ideas in car technology.

Ancient concept of a parabola an car lights

Simple geometric properties of the parabola, which were known already to the ancient Greeks explain the use of parabola in car lights and satellite dishes.

It is a nice intuitive approach in teaching the geometric parabola concept if we start with a computer simulation, where students can interactively 'play billiard' by shooting at a 'parabola shaped table' and trying to hit the (focus) point.

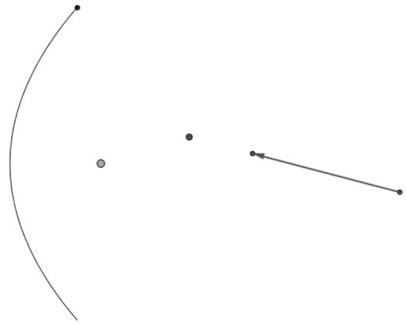

Figure 4. Billiard on the parabola shaped table

Sooner rather than later students realize that horizontal launch results in the desired hit (interactive computer simulation can be reached at http://uc.fmf.uni-lj.si/com/Parabola/parabola.html). It is well known that such a statement can be easily proved by elementary geometry. Turning the direction of 'ball travel' and exchanging it with a beam of light, we can explore and easily explain car lights. It is interesting to first explore how a single beam of light reflects from a parabola. Again, a computer simulation (also found at the above web address) is perfect to experiment.

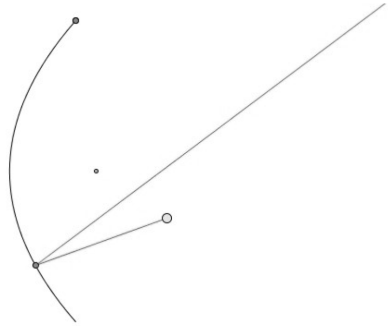

Figure 5. Reflection of a beam from a parabola

Putting the source of light in the focus of a parabola, the beams reflected from the parabola travel a straight parallel path. This explains car's long (head) lights.

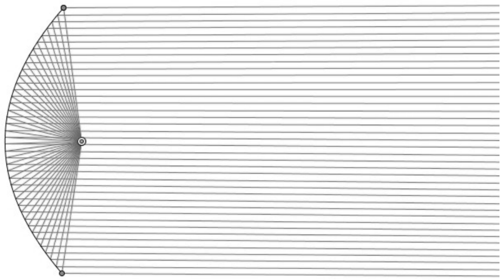

Figure 6. Long car head lights – the source of light is in the focus

What about the short car head lights? Exploring the interactive computer simulation (at http://uc.fmf.uni-lj.si/com/Parabola/parabola.html), we see that putting the source of light in front of the focus of a parabola gives a 'special reflection' which explains the short lights.

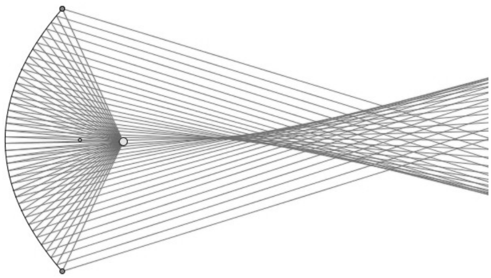

Figure 7. The source of light is in front of the focus

Shading of the bottom part of beams creates the functionality of short car head lights.

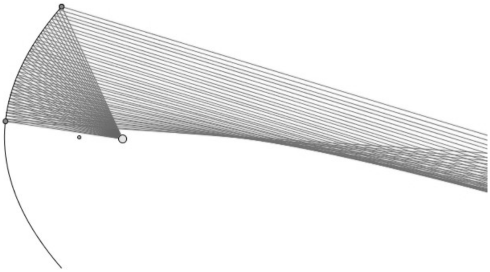

Figure 8. The source of light is in front of the focus

And that is exactly how the car lights function. Just a couple of millimetres deference and a 'bellow-cap' under the 'short light wire' in a car light bulb makes all the difference between the long and short car lights.

Figure 9. Long and short lights wires in a car light bulb

It is also easy to explain, why the car light bulb has 'front metal cap'. The very similar ideas can be used to explain the functioning of a (parabola) satellite dish.

The concept of a discrete function and communication technology

It is pretty obvious that any sound, conversation, recording, ... can be presented as a function. We will not get into details of how a common sound is presented as a function. For example musicians know, that a perfectly sounding *A* can be described by a function *Sin[Pi 440 t]*, or one octave above is a function *Sin[2 Pi 440 t]*.

As further examples one can present sounds expressed by functions like the following:

$$\sin(2\pi\ 440\ t)$$
$$\sin(34+\sqrt{2}\ \sin(950t))$$
$$\sin(700t+35t\cdot\sin(123t))$$
$$\sin(700t+\cos(150t)+45t\cdot\sin(350t))$$

All of the above sounds can be played for example by program *Mathematica,* where one has a command *Play*, which is very similar to a command *Draw*. These sound-functions can be played-reproduced interactively at http://uc.fmf.uni-lj.si/com/Digimusic/digimusic.html.

Functions that describe 'artificial sounds' or pure tones (of a single frequency) are of 'orderly shapes' like this pure tone described by a sin function.

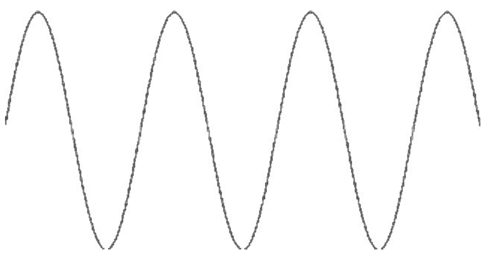

Figure 10. Pure tone presented by a *sin* function

A simple human voice 'hello' is a much more complicated function like the one seen in the bellow graph.

Figure 11. Recording of a human voice *"HELLO"* reveals much more complicated function

But whatever the sound, imagine now, that it is presented by a function. A true shape of a sound function is not essential for our ideas. Thus, let us say that we could basically take any function to present a sound. Different functions would present different sounds. Let us start with a simple *sin* function.

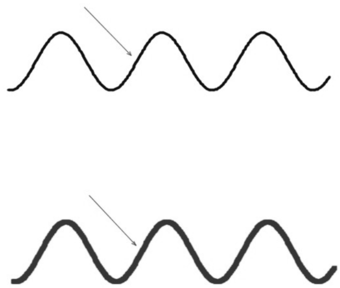

Figure 12. Two sound presenting *sin* functions look very much the same

We drew two functions, which look very much the same. Imagine that the ‘slim’ function is a sound that is recorded on one side of the phone line and the ‘thick’ function is a reproduced sound on the other side of the phone line. Functions look exactly the same and it seems just to say, that phone line service provider is doing a good job, transmitting a perfect copy of the sound from one side to the other. But let us take literally a closer look and let us focus on both graphs at the point indicated by the arrow.

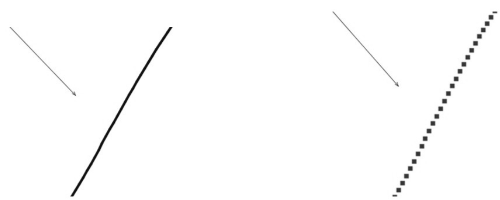

Figure 13. A closer look at the two functions

Phone provider can 'cheat' and only transmit a discrete function, which consists of points at a certain distance. Of course, points have to be dense enough for customers, talking on the phone, not to notice any 'empty spaces'. Certainly, if the provider would only 'transmit' a point every five minutes, we would hear nothing. But if one imagines a point every millionth of a second, what we get is 'very smooth' looking function. Our above graphs present the same *sin* function. The ‘thin’ is an 'analogue' continuous function, while the ‘thick’ one only has about 150 points for one period of a sin. What would the phone provider gain with such a cheating? Well, whenever we draw a point, we draw it of a certain thickness, but point's true thickness is 0. Imagine, we take further focus to the above point of the graph. What we get looks like this:

Figure 14. An even closer look at our ‘transmitted’ function.

It is now pretty obvious, why the phone line provider would 'cheat' like this. As the technology has long time ago won the race with human sensitivity and it can 'split the time' to far tinier bits than a human ear could notice, we see, that technology offers the provider 'lots of free time'. The necessary density of points is determined by human ear sensitivity, and if the technology offers the 'split of time' to tenth of interval that human ear can notice, the machine can be programmed to 'listen' only one tenth of a time and is free nine tenths of a time. Basically, we see, that if we imagine the above 'dots' as discrete values of a function, we can squeeze ten other points in-between.

Let us look at the graph of four different functions. We made the functions to intersect (at a point indicated by arrow) just to make it easier to explain our idea. It seems we have four different and 'precisely described functions'. It is clear that if we think of functions as sounds, this picture could easily be transformed (imagine colour filter) into four different (clearly heard) sounds. And this is basically the trick of digital technology. People talking on a phone and real life users and customers of audio technology have very limited ear sensitivity and can be fooled to truly hear four different sounds from the bellow picture. In fact we can say, that our eyes were fooled to see four different functions bellow, while mathematically (that is precisely) speaking, we even do not have one function defined at the whole visible interval.

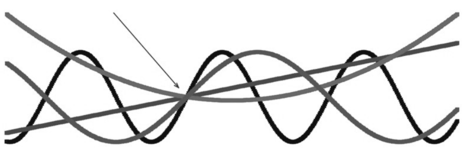

Figure 15. We see four different functions.

To see and comprehend what we are talking about, let us again focus to the intersection point indicated by the arrow.

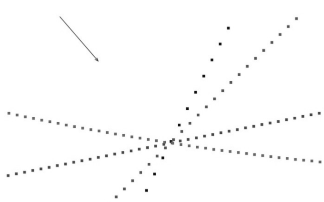

Figure 16. A closer look at the intersection of the four functions.

And an even closer focus reveals a truly different picture:

Figure 17. A close-up the intersection of the four functions.

We see, that 'much less than one digital' function can be made to carry enough information to reproduce 'four different functions', that are still precise enough to carry all the information necessary for human ear to 'hear a continuous sound'.

Understanding the essence of functions and discretely defined functions, it is pretty obvious that this process looks unlimited. How many functions like that can be 'squeezed' into one discrete function? How many phone conversation can be squeezed into a single phone line? Of course it depends on the quality of the sound required (density of discrete points, which represent particular functions) and on the ability of technology to 'listen' and 'record' ever shorter bits of time.

In reality, the machine would not only record bits of conversation on evenly spread out intervals, namely, that could result in recording noise (sound pollution), but the machine would record ‘all the conversation’ and transmit only (noise filtered) average in those tiny bits of time.

With modern computer technology this wonderful and simple idea can easily be simulated by dynamic presentation of functions, when 'zoom in' and zoom out' can nicely and intuitively visualize how relative to human eye and ear a discrete or continuous looking functions can be. A nice interactive computer simulation of ‘squeezing several functions into one’ can be found at http://uc.fmf.uni-lj.si/com/Digimusic/digimusic.html.

Finally, not as a complete joke, the idea can be given a funny but meaningful parallel. Imagine a class of students taking a test and a teacher attending the students not to cheat. If a teacher leaves the classroom unattended, students might be tempted to start communicating and cheating. So it is hard to imagine, how the same teacher could take care of two different classes of students in two different classrooms at the same time. But that is because a teacher would be forced to leave at least one class unattended. But for how long? Imagine the teacher's strict eye is searching around the classroom every second... Theoretically, imagine the teacher who could shift its full presence and attention from one class to the other in tenth of a second. Is it not obvious that in such circumstances one such a speedy teacher could attend not only two but ten classes simultaneously?

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Use of 3D virtual environments in teaching astronomy and physics

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Abstract

We have developed several 3D graphics applications to support our teaching. Some of these applications create virtual environments. In particular a telescope simulator has been used to introduce students to the controls of a particular telescope that they will then subsequently use at an observatory. Most students have never used a telescope before and find controlling one rather challenging. This results in significant wasted observing time at the observatory. The developed application simulates the sky, the telescope, and the handcontroller. They sky is rendered in a familiar planetarium style. The telescope is a 3-D, fully-animated and textured graphical entity that gives the user the look and feel of the real telescope. The handcontroller works identically to the actual one except within the application it is clicked on with a mouse. This enables the students to gain a familiarity with aligning the telescope before commencing the course. It also allows them to gain a working knowledge of using celestial coordinates and the night sky. This paper describes the simulator and how it has benefitted students.

Introduction

The Open University runs a one-week residential course in Observational Astronomy and Planetary Science (SXR208 2008) at Observatori Astronomic de Mallorca (OAM 2008). Groups of five or six students share a telescope dome. The domes house a 30cm Meade Schmitt-Cassegrain telescope on an equatorial mount equipped with an SBIG 1001 CCD camera. The telescope is computer controlled via a handset connected to Right Ascension and Declination drive motors. Sidereal tracking of the stars is automatically performed by virtue of the equatorial mount being aligned with the celestial north-pole. The students must complete preparatory tasks before their week at the OAM and write up the results of one of their evenings' observations as a report (Norton 2004). There are several courses that run in the spring and several in the autumn. At the beginning of each observing session the students must align the telescope with a known star in order to allow the coordinates indicated on the telescope's computer handset to coincide with the actual coordinates that the telescope is physically pointing at. Without this alignment (commonly known as synchronisation) it would be difficult if not impossible to find faint targets. Most course students have never used a telescope before and find this task rather challenging. As a result, the synchronisation procedure often takes up too much of the precious dark time needed for data acquisition. The students feel rather intimidated by the telescope hardware, they may not be familiar with the constellations, the finder-scope inverts its image, and of course they are required to work in the dark. After performing a synchronisation most students will assume that this has worked perfectly and guide the telescope to the first star field that they need, which will often be quite faint and hard to identify by eye. If they do not find what they are looking for immediately, they waste time trying to identify the field, and then perhaps declare that the telescope doesn't work! An experienced observer will on the other hand always check that the synchronisation has worked by guiding the telescope to a bright, easily identified star and checking the coordinates on the handset agree with those in the catalogue. What is needed here is a little confidence in using the kit as these operations seem elaborate and intimidating to the first-time user. In order to give the students this experience before their arrival at the OAM a simulator was written. This is a 3-D immersive program showing the night sky as they will see it during the observing times when they are at the OAM. The telescope is rendered in 3-D and can be moved in the same way as the actual telescope using a modelled hand-controller which mimics the real one in every way but in its control interface (it must be interacted with via the mouse). The user can move forward and away from the telescope and can rotate around it in order to obtain the view needed. In particular, when aligning on a star, a rough alignment along the tube of the telescope can be performed before using the finder-scope feature (this shows the finder-scope view with cross-wires centred on the screen). The students are set a number of tasks to complete using the simulator and must submit a trace produced by the simulator as part of their assessment.

Implementation

The simulator is a C++ program using the OpenGL library (Shreiner et al, 2006) and the GLUT API (GLUT 2008). A finite state automata (Hopcroft and Ullman 1979) models the handset whose transitions were carefully plotted by interaction with the actual controller. This gives a near perfect recreation of the interface. The only differences being: (1) only a limited set of features are implemented, i.e. those deemed useful for this exercise, (2) the user clicks with a mouse rather than actually presses buttons. An example of the graph of the finite state automata is given in figure 1 as a directed graph. The key presses are shown in ellipses, the display is shown in rectangles, and the state numbers are shown in triangles. Once this diagram has been obtained it can easily be implemented as a transition matrix.

The limited number of buttons on the handset leads to some controls being achieved by pressing and holding a button down for a certain interval. Synchronizing on a star is achieved by pressing and holding the Enter button for a few seconds. These peculiar interface issues are re-created in the simulator where, in this instance the user would click on the Enter button with the mouse and hold the mouse button down as though it were the button on the handset.

The object-orientated features of C++ were extremely beneficial to the implementation with objects being created for each of the main entities, in particular: the telescope, the controller and the sky. The complexity of the various coordinate systems needed was tamed by the object-oriented approach. A screen-shot, is shown in figure 2.

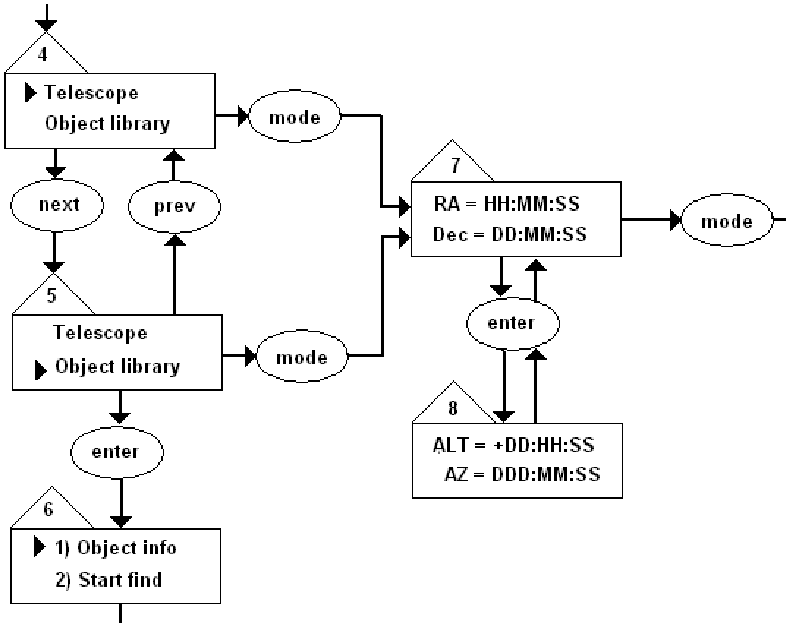

Figure 1. A sample of the graph of the controller's finite state automata. The key presses are shown in ellipses, the display is shown in rectangles, and the state numbers are shown in triangles

Figure 2. The simulator on start-up

The stars are modelled using a single 2-D star texture mapped to the relevant size depending on apparent magnitude. They are coloured according to their spectral type and bill-boarded so that they always point towards the camera. The night sky as it will appear when the students are actually at the observatory is plotted. The program automatically selects the spring or autumn sky corresponding to the date of the next course depending on the computer's current date. This allows the students to become familiar with the bright stars that they will commonly use for alignment. The celestial sphere rotates as per real time. The star data is from the HYG database (Astronomy Nexus. 2008). The constellation outlines can be plotted, making star identification that much easier. The line segments can also be seen in the finder-scope view. In the simulation, the celestial sphere is relatively close to the telescope to keep the zenith reasonably low (the monitor is a flat surface in-front of our eyes, it does not have a ceiling we can look up at). This does cause some parallax difficulties. In the real world stars are effectively at infinity, no parallax being identifiable. In the simulation this is not the case. However, slightly altering the telescope position has resolved any parallax problem that we might have had.

The telescope is built in an hierarchical fashion literally from the ground up, pushing and popping the transformation matrices to negotiate the hierarchy of components in the drawing. Depth checking is used to remove hidden surfaces and several low-level lights are used to make the telescope visible against the dark sky. The lights can be switched off, leaving the telescope as a dark shadow faintly visible against the stars of the night sky. The finder-scope view is rendered as a 2-D image centred on the screen.

A trace facility that writes to disk all the interactions that the student makes was implemented in order that we could assess the competence of the students in controlling the program. In particular we use this facility to grade the students' performance in the assessment that we set. This is a sample of such a trace. The screen of the handheld controller is shown between the parallel lines with the state number in square brackets:

```
============================[102]
STAR226    STAR
MAG 0.770000
================================
============================[107]
Coordinates
matched:STAR226
================================
Coordinates matched for OurStarNo = 12
CurrentMeadeStarNo = 226 at RA = 297.69 deg Dec =   8.87 deg

StarName = Altair


Actual RA = 297.65 Actual Dec =   8.81

============================[  4]
->TELESCOPE
 OBJECT LIBRARY
================================
============================[  7]
RA   = 19:50:46
Dec  =+08:52:02
================================
Setting Slew Speed to:   0.13
```

A number of buttons are available on-screen for changing the position of the observer within the scene. The observer can also change his position by using the mouse. The mouse gives a very immediate and intuitive way of moving around.

It is possible for the students to drive the telescope into the mount as with the real telescope setup (the camera does not fit through the forks), in which case a warning is given and the telescope resets its position and the simulated computer is rebooted.

Student use

The students are given a tutorial guide to the software that requires them to run the simulator and perform a series of tasks indicated by the text. The tasks include: switching on the telescope's computer, slewing the telescope, changing the speed of slewing, using the finder-scope, use of the mode key to show sidereal time, Right Ascension (RA) and Declination (Dec). They are then taken through the process of synchronizing on a star with the constellations and RA/Dec coordinate lines visible. Finally, they are asked to manually slew to a particular star using its RA and Dec coordinates. Although both the actual telescope and the simulator can 'goto' any of a large number of stars, either by name or coordinates, we discourage this as the camera may hit the telescope forks during an automatic slew causing considerable damage to a very expensive piece of kit!

For the test, the students are asked to align on a different star depending on the season in which they are doing the course. They are asked to do this without the constellations nor the RA and Dec grid being visible. For example:

For those doing the course in the autumn

(1) Manually drive the telescope to Arcturus and then synchronize on it.
(2) Then drive the star to the RA and Dec of Rasalhague.
(3) When you have reached Rasalhague repeat the synchronization process on Rasalhague.

Student survey results

The first survey was voluntary and few students took part. Therefore it was difficult to make definite conclusions. Although the little feedback we had was encouraging and enabled us to make some small improvements. For the second survey the students were given an incentive of earning extra marks.

These are the results of the second survey. All the students were given a questionnaire to fill in before and after they had completed their week at the observatory. For the pre-week survey we analysed 48 responses. Most of the questions dealt with issues of installation, time taken, crashing, support given and ease of use. The responses have been very useful in developing the application further. In particular stars near the horizon were showing in the main view but not consistently in the finder-scope. We were also able to improve the user interface which some users had found rather slow to react in this version.

For the post-week survey we analysed 52 student responses, all but seven of the students tried the simulator. The ones that didn't reported various reasons, including lack of time (4), failure to install (1), wouldn't run on a Mac (1). Questions were posed as five point Likert items. The results on the familiarity they gained using the simulator are given in table 1:

Table 1. Familiarity gained from using Meade simulator

For obervational projects the MeadeSim activity helped as I was already familiar with…	**Agree (5)**	**(4)**	**Neut (3)**	**(2)**	**Disag (1)**	**No resp (0)**
[7.1] the concept of RA and declination	17	11	8	3	5	1
[7.2] the general set-up of telescope, camera, controls	16	14	9	3	2	1
[7.3] the telescope mount	15	13	8	4	4	1
[7.4] slewing the telescope	22	10	7	3	1	1
[7.5] using the controller to find a star	22	10	8	4	0	1
[7.6] using the controller to match the coordinates of a star	20	14	7	1	2	1
[7.7] slewing to a star using RA and Dec	15	8	8	2	1	1

Other, more general points are given in table 2.

Table 2. General points

	Agree (5)	**(4)**	**Neut (3)**	**(2)**	**Disag (1)**	**No resp (0)**
[8.1] I had forgotten details of MeadeSim when I used the real telescope for the first time	2	9	9	8	16	1
[8.2] I was confused by the two different handsets	7	12	9	8	8	1
[8.3] I found the simulator activity useful	27	10	5	1	2	1

Among other issues that surfaced included how slowly the program would run under Vista. This is a significant problem as some reported the performance under Vista made the simulator unusable. Fortunately it appears that disabling the Windows Desktop Manager resolves this issue which can be achieved by selecting Windows Classic or Basic interface style. There are two versions of the Meade hand-controller in use at the OAM and the slight differences in their functionality caused some confusion (the simulator only uses the earlier type of handset).

Discussion

The data clearly indicates that the student perception is that the simulator benefitted them. There are 37 positive responses (i.e. agree strongly or agree) to the question 'I found the simulator activity useful' and only 4 negative and 5 neutral. This is supported by the more detailed responses in the first table where around 30 of the students have responded positively to each question.

In addition to this questionnaire data we also have some responses from the tutors. In all cases these have been positive. Typically the tutors are noticing a significant improvement in first night performance with students showing a marked familiarity with the telescope operation and handset. This is one of the tutor's comments:

"*Since it has been introduced tutors have had to spend significantly less time teaching students how to operate a telescope and could focus on the more essential bits of the tutoring.*"

Although simulators are not uncommon in Astronomy, these are usually either text based or 2-D. Telescope simulators are available but these often are just a means of obtaining data for the students to analyse rather than being focused on the control of such a device, such as the Indoor Telescope (Dukes 1990). This is also true of the Virtual Telescope (Norton 1998) and even more so for the ASCOM (ASCOM 2008) simulated telescope driver that has no visual component at all! It is the 3-D animated visualisation of the telescope embedded in a planetarium style program that makes this application unique. The level or realism given by the 3-D program is seen as a huge advantage. Students find it very attractive and commonly describe it as 'cool', but more importantly, it actually gives them a feel for the real thing.

Further development

A current requirement is that the students' performance, as indicated in the trace file, is to be marked automatically. A specific format for this is to be decided on and implemented. The current comprehensive trace will be kept for diagnostic purposes and for resolving any issues that may arise from the automation.

We have currently implemented an indexed database of some two million stars. We intend to simulate the behaviour of the camera and allow the students to practise imaging and calibration. We envisage the Maxim DL photometry package (Maxim DL 2008) being used alongside the simulator with the simulator's camera implemented as an ASCOM device.

Conclusions

The data clearly indicates that the student perception is that the simulator benefitted them and this is reinforced by the comments of the tutors. The simulator particularly benefits from an accurate representation of the hand-controller, the night sky and the telescope. The accurate modelling of the hand-controller is due to its painstaking mapping and implementation as a finite state automata. The accurate rendering of the night sky and the telescope is due to the sophisticated 3-D modelling functionality of the OpenGL graphics library as well as the benefits inherent in an Object Oriented programming language.

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Development of personal desiderata while learning GIS

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Abstract

This article investigates students' process of creating a professional profile through their studies. It presents an analysis of the choices and processes of creating a professional profile among 8 students attending an undergraduate course in "GIS in planning and management" at the University of Copenhagen. The analysis is based on a generalization of Thomas Kuhn's idea of an "essential tension" in paradigmatic knowledge, and his theory of learning by ostension. In terms of acquiring the intended knowledge, most students solved the planning problem in the course adequately and all did well on the exam. However, interviews show that the heuristics of the learned content was extremely different for the 8 students – different students conceived of the planning problem of the course as either a revelation, a means to an end, or a decided turn-off. The article concludes that the analysis provide evidence of the utility of the suggested theoretical distinctions.

Introduction

When a student completes a master degree in a subject he/she has developed a professional profile based on the choices made in the course of the study. This profile characterises the student and her professional competences.

Many of the ideas and values held by the student when she entered the programme have been abandoned; others have been reinforced by the learning experiences. Few students follow a straight trajectory based on ideas and values held when they enrolled, and even fewer just adopt a new set of ideas provided by the study programme.

When a student engages in a science education programme he/she has personal reasons for doing that. In the courses that the student follows, these personal reasons are gradually moulded and transformed in interplay with the work practices and the content knowledge encountered in the meeting with study. In this article we shall investigate this moulding process in relation to a course in GIS in planning and management.

To analyse this process of acquiring a professional profile we adapt Kuhn's work (1959, 1974, 1977), that is his description of the essential tension, learning by ostension, and his theory of values and choice of theory. This will be elaborated in the following.

Kuhn (1959) argues that in order for science to develop the ability for both convergent and divergent thought must be present simultaneously in the successful scientist: 'Very often the successful scientist must simultaneously display the characteristics of the traditionalist and the iconoclast' (Kuhn, 1959).

This ability is what Kuhn named the essential tension and which he developed in his subsequent writings (Kuhn 1974, 1977). The basic idea is, that in science education the problem-solving activities are related to accepted and paradigmatic problem solutions, and provide the student with an arsenal of exemplars on the basis of which he or she may proceed to new (but similar) problems. Such reasoning by exemplars is not a rule-governed activity, but based on fundamental perceptions of similarity or dissimilarity with previously encountered problems.

The absence of rules mean that even though students learn to solve problems and ostend (i.e. judge that Y is an instance of X) in fairly much the same way, they do not do so because of a mutual agreement on the necessary and sufficient conditions for X. Instead, Kuhn argues that, scientific concepts should be understood rather as family-resemblance concepts, and acquires their meaning in application rather than in virtue of necessary and sufficient conditions (for a thorough exposition of this see Andersen (2000)). In this way, Kuhn provides an answer to the question of how scientist who for long periods of time have agreed in their professional judgments, may suddenly come to disagree in judgments as the exploration of the paradigm extends into new anomalous domains.

Even though normal science is generally described by consensus in judgment, it also contains a seed of possible conflict, and future exploration of the paradigm may lead to situations where ostensions are suddenly no longer the same. The essential tension has been there all along, and this tension is crucial for the development of science. If normal scientific activity was just a matter of following rules equivocally, then conflicts would not arise in face of anomalies.

When such disagreement occur and develop, scientists may have to choose between two rivalling theories. In these cases reliance on the theories themselves will obviously not suffice. Kuhn argues that instead of using their normal scientific methods and techniques, the scientists have to rely on more general values such as accuracy, consistency, simplicity and fruitfulness. Kuhn regards these values as relatively stable over time, and part of the cultural heritage of the natural sciences as such. Thus, these values are shared by all scientists. Hempel (1988) has used the term desiderata to denote these values.

The desiderata are quite imprecise, and two individuals who both subscribe to the same value (e.g. accuracy) may still come to disagree about whether one theory is more accurate than another. In addition, there is no fixed way in which to determine how the different desiderata should be weighed with respect to each other in specific evaluations of theory. In addition, the scientist's personal experiences, preferences and values will determine how the scientist will end up weighing the desiderata with respect to each other. Thus, in order to employ the desiderata to concrete cases of theory choice, the desiderata relies on personal values and convictions which are not shared in the scientific community more generally. Hereafter we will distinguish between the generally *shared desiderata*, and the individual *personal desiderata*. The personal desiderata may be related to the individual's scientific background, but may also be found in other personal convictions.

Like the scientist choosing between theories, the students are in situations of choice when they are establishing and developing their professional profile:

Should they specialize in Geographical Information Systems (GIS) or not? Should they concentrate on fieldwork or theoretical work? Such questions often lead to the more mundane question: Should I elect this course, or that one? In making such decisions the personal desiderata are significant. However, once the choice has been made and the course begins, the personal desiderata must be set aside. Instead it is the convergent reasoning by exemplars that becomes important – the learning activities. The student must also agree to "play the learning game", and for instance parttake in computer exercises, group work etc. Thus, a "local" set of shared desiderata are established in the course setting; a set of norms and values that the students must agree on. They must, in other words subscribe to a didactical contract (Brousseau, 1978). After the course, when students face the next choice, the personal desiderata become significant again – but then they may have changed because of the learning and the learning experiences in the course just followed.

Based on this framework the paper analyses how students' personal desiderata interact and are transformed during a course in GIS in respect to their choices concerning including GIS in their future professional profile.

To address these issues the remainder of the paper is organised as follows: first the methodology is outlined and the actual GIS-course is described. In the third and main part of the paper we analyse the students' personal desiderata and their meeting with the course. In the discussion we reflect upon how the analysis can inform the educational system and finally we give a short conclusion.

Methodology

In this project we followed 8 students and their meeting with an undergraduate course named "GIS in planning and management", in spring 2008, at the University of Copenhagen. Observations were made (twice) of students learning strategies during classes in the beginning of the course and contact with the students were established. The 8 students were selected with the purpose of securing a diverse group of students in order to optimize the opportunity to learn the most from the case as discussed in Stake (2005). The group of interviewed students consisted of 5 girls and 3 boys. 6 are geography students of which 3 are either taking quite a number of courses or a whole master in other disciplines (political sciences, economics, and development studies). 1 student is from biology and 1 is from geography at one of the other universities in the Copenhagen area.

Individual qualitative interviews were made with the 8 students before the students started working on the central problem of the course (pre-conception interviews), and follow-up interviews were made after the exam (post-conception interviews). In the pre-conception interview the point of departure was taken in the students' interest in and expectations to the GIS-course. Further, they were asked how they related to the case they were working on in the course (planning in Tårnby Commune) and they were told to describe GIS in various situations. In the topics addressed focus was on the relation between GIS/the course and their life situations both as a student and in general. In the post-conception interviews focus was on the students' reflections on the now finished course as well as finding out if and how the students saw GIS as part of their future professional life. In addition, the students were asked to elaborate on the project they had been writing especially the different choices the students had made during the project. This was done with the written project in front of us. Based on the pre-conception interview the students were asked to go into detail about topics that we had found interesting in order to understand the students perception and choices in relation to GIS (for example a job, a bachelor project).

The teacher was interviewed after the course and exam. He was asked to explain the intentions, history and outline of the course. Further, focus was on the case of Tårnby Commune that is used as an authentic planning problem in the course; what is the idea behind using this problem and how is it integrated in the course.

All 17 interviews were taped and subsequently transcribed in accordance with the interviewees.

The course "GIS in Planning and Management"

The course GIS in planning and management is taken by about 30 students each year. It is an elective course at the bachelor level for students in geography. However it can also be taken by students from other studies (e.g. biology, natural resource management) as either a bachelor or a master course and further, by people already having a master as a paid course (open university course).

The course introduces central GIS-tools for working with planning and management issues like network analysis, digital records, and web-based communication systems. It is organised as an actual planning process in Tårnby Commune, were the different assignments are feed into a complete project on a specific planning issue the students choose to work with (e.g. locating a new school, shopping mall etc.). The project must be finished and delivered before the oral exam where the students individually describe and argue for their use of different GIS-analyses in their work with the authentic problem.

The course runs for 7 weeks and consists of 1 three-hour weekly hands-on computer laboratory class where ArcGIS, version 9.1 is used. The laboratory classes use a 'manual' that contains practical instructions and assignments. Further, a general introduction to the Danish planning system is given. The students are divided into two classes and work either alone or in pairs at a computer. The students are given feed-back on their assignments during the course.

The students' stories

Before entering the course all the interviewed students had ideas of the course and how they could use it in their study-programme and/or life situations. Likewise, all the students did take something with them from the course. What they learned was highly influenced by how the authentic problem of the course matched their initial ideas about the course. Further, their conception on if and how GIS will be part of their future professional profile is influenced by how the course fits with their personal desiderata. However, these personal desiderata are not a fixed set of ideas; they are influenced and transformed during the course. In the following we give a short description of the eight students and their process of forming their professional profile during the course. We give special attention to the students' description of moments of change in personal desiderata.

Thomas has a master degree from another university on oil-industry in developing countries, and had no strict study programme plans when he entered university and have just taken the courses he found interesting. In the end of his master studies he then takes three GIS-courses as paid courses along with his master. He now has a girlfriend and leaving Denmark seems non-attractive. He sees GIS and his participation in the GIS-courses as a means to get a job at home. Thomas finds the authentic problem in the course interesting. When we meet him after the course he just got a job in a commune. He has used all the concepts at the course to inscribe him in a planning discourse and succeeded in the job interview. In reflection he thinks great of the course, it just fitted his needs. Thomas has in all aspects during the course been confirmed in his views of GIS and how it can fit his future professional profile.

Emilie is a student in Geography and is writing her bachelor on the protection of the Wadden Sea. She has an idea of using the course to learn more GIS and apply it in her bachelor in relation to shoreline shifts. However, during the course she becomes more reluctant to use GIS. It seems to demanding to try to use GIS in her bachelor project and she does not know where she can get help to the process including solving technical problems. When we meet Emilie after the course she as just finished her bachelor. It ended with being much more oriented towards the cultural geography aspects of the Wadden Sea and she did not use any GIS. She has now decided to take a job in the next semester, relevant for her studies and has further been shopping around at different master degrees. However, she has not decided anything yet. In retro perspective she states that she finds it frightening that in her perception many GIS-jobs focus so much on the technical aspects of GIS and in lesser degree on the geographical problems. Emilie has during the course been pushed in a direction of not including GIS in her future professional profile; both factors within the course and outside the course have been part of this process.

Charlotte has taken the GIS course because she has heard it was an easy course to pass. She is a geography student and sees GIS as a tool: 'it is good to have' but it does not in itself interest her. She does not link GIS with geographical problems. Talks enthusiastic about her job where she works with a programme named GeoGIS. She has been typing in data in a database and do not see that it has any relation to GIS – in fact she does not see the general perspective of GIS. She finds the authentic problem ok, but not something real. When we meet Charlotte after the course she has just been defending her bachelor project with good results and is very happy. She has decided to use some more time on her job. She has had some conversations about her future work tasks and in this process she has realised that there is a GIS-function attached to the database she has been working with and that GeoGIS is a GIS. This lead her to ask to do some of the GIS-related stuff at her job. She has realised that she can do GIS in her job and has become fascinated of how GIS can be used to solve geographical problems (in this case soil pollution). Charlotte has during the time of the course integrated GIS in her future professional profile due to a combination of the course and her job functions.

Carl studied one year at computer science before starting at geography. However, he found that computer science was to far from real issues and he sees GIS as a way of combining his interest in computers with real problems and has taken many of the possible GIS-courses at the Department despite he is still at the bachelor level. GIS has been an important factor for him to engage in geography. Before entering the course he has different ideas of how GIS can be used to develop e.g. running programmes. While he plans to take all the GIS courses he has no specific thoughts about the choice of this particular course. He finds that GIS is interesting in itself and works during the course with self-invented applications in the problem solving process. However, the authentic problem he finds boring and not challenging enough. After the course when we meet him his has gotten a slightly lower grade than most other students for the course. He is disappointed about this because he feels that he understood much more than many of the other students and has an experience of being able to help the teacher during the course by helping other students. However, when we discuss the project he has made, there are clear errors. He recognises them, but he does not consider them significant. In relation to his future professional profile he has come into doubts about if GIS can be used to bridge his interest between computer and real problems and the course seems to have fuelled this process.

Søren is taking a master in Agricultural Development at another faculty of the University. He has taken a number of GIS courses both at geography and at his own faculty and has also worked with GIS in a job at the University. He has a bachelor degree from geography but decided to change because he found the development studies at geography to abstract. He wanted a more tangible study and has subsequently spent several months in the field studying agricultural practice and decision-making in a developing context. His interest in taking a master has always been founded in a wish to work with developing issues and he sees the ultimate job as being living abroad combining development issues and GIS. He is fascinated by the possibilities within GIS and is often playing with it at home trying new functionalities. Finding a job abroad is, however not straightforward and due to his family obligations he sees GIS as a way to get at job as soon as he finishes his master in Denmark. He finds the authentic problem interesting and has made choices in relation to the assignments related to the problem during the course. He further finds the authentic problem highly relevant for later job opportunities. When we meet Søren after the course he has almost finished his master project. He has not yet started to look for a job, but he will look for a job in a commune or another place where he can use GIS. To go abroad is not something that is just next month – he wants to create a base in Denmark and getting a job in the development branch is not easy at the moment. However, when asked where he will be in 10 years time, he states that hopefully he will not be in Denmark but living abroad teaching at a university in agricultural development.

Maria studies biology and has previously taken other GIS courses at the Department of Geography. She wants to take all the GIS courses that she can take and therefore she has not specific expectations to this course. She original started to take GIS-courses because it was recommended by colleagues at her job at a Museum. She finds GIS very appealing, the fact that you can work creatively and get a product and all the time follow the process. It is a great challenge to work with and she finds it great fun. She has spent rather many years studying biology, but not really found what she was looking for in relation to her personal development. Taking GIS-courses has meant that she again finds it attractive to study. She has found the joy in attending class again. She is now in a process of finding out how to combine GIS with her studies in biology. In relation to the authentic problem she does not find the planning problem in itself appealing but the tools and the intentions with the course she finds highly relevant. When we meet her after the exam she is following a geography course where GIS is used and she is still trying to figure out how to combine her fascination of GIS and her master in biology. For her the most important thing of the course is that she got the inspiration to finish her studies and that she sees possibilities of a future career with some aspects of GIS. A month after the last interview she got a job as teacher at an introduction course in GIS.

Anette is in the second year of her geography studies. She plans to take a bachelor in geography and then a master in another subject (history or political science). Her interest in GIS is that it would be a good tool to know if she wants to work with planning in the future. However, during the GIS-course she realises that she wants to work with the political level and not the more practical level of analysis. This is partly due to her experience with the course – where she finds it very unsatisfying that there is so little focus on the analysis behind and so much focus on the visual aspects of GIS – partly because she follows a course in political geography that she finds very interesting. She finds the authentic problem too simplistic and sees a challenge in putting it into a realistic complex planning situation. She has applied for a job in one of the unions that she is very interested in. When we meet Anette again she tells us that she did not get the job and she is planning to study the next year and take courses in other subjects of the university and at other universities some of them related to her interest in the European Union. She is thinking of doing her bachelor in development geography with another student but if it fails she wants to work with European issues. When she looks back at the GIS-course she thinks that it is fine that she now knows how to understand different GIS-analyses but she does not expect to need to use them herself in her further studies or after graduation. She sees GIS as a tool for political decision making processes where she operates at the political level.

Ida is writing her bachelor project in Geography. She has taken almost half of her courses at the Department of Economics and she sees GIS as a way of expose her professional profile compared to ordinary economic students. By using GIS she can put her own mark on economics and she finds it important to be different. Geography was not her first educational choice but now she finds that it can give her the originality that she wants in relation to her studies in economics. She has taken this specific course in GIS and planning because it fits with the social geography she is interested in. The authentic problem within the course she finds relevant in that aspect that it is a way to practice GIS technologies. However, the concrete problem in Tårnby Kommune she does not find relevant because they are surveying a non-existing problem (establishment of a new kindergarden). She has been considering using GIS in her bachelor. When we meet Ida again she tells us that she didn't use GIS in her bachelor, because it became less planning oriented than initially intended. She is now in a process of finding a job relevant for her studies. She wants to take a year off to get experience with the job market in order to qualify herself to the later job market. She does not have a clear picture of her professional profile after graduation. However, she finds it important to be special in her educational choices in order to create an interesting professional profile.

Discussion

In terms of acquiring the intended knowledge or fulfilling the learning objectives of the course, all of the interviewed students solved the problems adequately and all did well on the exam (despite the fact that one got a lower grade than the others). However, the significance of the learning experience has nonetheless been completely different from student to student. As the above descriptions of the students' personal desiderata show, the geographical problem of the course was conceived by some as a revelation, by others as a means to an end, and still others as a decided turn-off. This means that the students leave the course with quite different perspectives on GIS and the conceived role GIS is to play in their developing professional profile. In table 1 an overview of the observed changes in relation to the students' choice of including/excluding GIS in their future professional profile is given.

Table 1. The students transition by meeting a specific GIS-course. + indicates the experienced significance of GIS in relation to the students professional profile.

Student	Personal desiderata – GIS as part of the students professional profile	
	Before course	After course
Thomas	++	++
Emilie	++	-
Charlotte	+	++
Carl	++	+
Søren	++	++
Maria	++	++
Anette	+	(+)
Ida	+	+

It is clear from table 1 that there is no obvious pattern in the influence of the course on the students' conception of GIS and its role in their future professional profile. The individual interviews show how each of the individuals relate to the course, and their stories are very different indeed. Still, some similarities between the personal stories can be seen. Thomas and Søren came to the course with the clear intention that the course would be useful in their efforts to get a GIS related job. None of them were 'regular students' in the geography programme. They had very positive attitudes towards GIS when they came, and were at least as positive when they left. They were also the students who found the authentic planning problem dealt with in the course most relevant and interesting. Ida, Anette, Emilie and Carl were all students in the bachelor programme in which the course is a part. In contrast to Søren and Thomas, this group of students finds the problem somewhat simplistic, artificial, or just plain boring. They find it difficult to really engage in the problem. Most of these students leave the course more disillusioned about GIS and its role in their professional identify. It could appear that the subjective experience of the authenticity and relevance of the planning problem is related to how close the student is to entering the labour market. Interestingly, Carl, Emilie and Ida all came to the course with interests and personal ambitions about using of GIS in their future work (e.g. bachelor project). But the course did not help them pursue these interests. Perhaps moving this course from the bachelor programme to the master programme would be an idea, because at this time students are perhaps more clear on their job ambitions. Instead, it might be an idea with a bachelor course that helps students use GIS analyses and applications in relation to their bachelor projects. Such a course would probably be more authentic to this group of students.

Charlotte is an exception that confirms the above “rule” that the course is more relevant to students who are finishing their graduate studies than to bachelor students. It is precisely in virtue of her job (doing GeoGIS) that she comes to see the relevance of the learning activities in the course. For Charlotte it is a relationship between factors that are external to the course and the work on the course’s exemplar/problem that give rise to the (positive) change in personal desiderata.

This discussion points to the significance of the relationship between the “reasoning by exemplars” in the course, and the development of the students’ personal desiderata. The actual work the students do in the course is by and large the same, and the quality of their reports were all reasonable to good. The learning outcome, from this perspective, was the same. But the outcome of working with precisely this exemplar had side effects on the students’ personal desiderata; on their motivation and self-efficacy in relation to GIS.

Maria’s story points to a different important consideration. Maria likes working with GIS, and the GIS courses at the geography department have helped her recover the enthusiasm for studying that she lost in her Biology study. However, it is not because she is fascinated with the geographical planning problem dealt with in the course – she likes the authenticity of the problem, but she does not find the problem intrinsically interesting. Maria basically like the practical way of working involved in doing GIS analysis, working with the material in front of the computer. In particular she likes the way she can use her creativity in the presentation of results. She likes the ways of working that she finds she is being asked to do in the GIS courses, but not in the biology courses. It is likely that Maria would find similar pleasure in working with e.g. Excel or Photoshop that she finds in working with ArcGIS. For Maria, then, it is the relationship between the shared and the personal desiderata that is important rather than the relationship between the content and the personal desiderata.

Conclusion

Methodically we have explored the use of a generalisation of Kuhn’s work (1959, 1974 and 1977) to analyse students’ choices and development of their professional profile. We have distinguished between the students reasoning by exemplars and their personal and shared desiderata. Shared and personal desiderata have different significance on the students' choices during a study programme. The convergent nature of science education suppresses the personal desiderata while courses are on-going – here the shared desiderata are in focus. However, during a course the personal desiderata although they are suppressed can be influenced by the used exemplars, the shared desiderata and external factors. Between courses when students are to make choices of which courses to follow and thereby shape their professional profile contend knowledge are of no use – here the personal desiderata decides.

Based on our analysis of students attending a course in GIS in planning and management we find that the students' process of creating a professional profile during their studies can be understood by using the suggested framework and that it gives valuable insights into how we can improve student learning by using knowledge of personal desiderata.

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YASS: A system simulator for operating system and computer architecture teaching and learning

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Abstract

A highly interactive, integrated and multi-level simulator has been developed specifically to support both the teachers and the learners of modern computer technologies at undergraduate level. The simulator provides a highly visual and user configurable environment with many pedagogical features aimed at facilitating deep understanding of concepts which are often difficult to grasp by the students. The rational behind the development is explained and the main features of the simulator are described. A brief account of the ways in which the simulator has been used to support undergraduate lectures and tutorials is given. The current state of the research in assessing and evaluating the value of the simulations at undergraduate levels is presented.

Introduction

The teaching of computer architecture which includes key subject areas such as production of executable code, instruction set architectures (ISAs), performance enhancing features and principles of operating systems form the core set of subjects for most computing and computer science undergraduate degree programmes. These topics have been identified both in the ACM/IEEE computing curricula (USA) (Computing Curricula, 2001) and the QAA's subject benchmark in computing (UK) (Computing 2007, 2007) reports. In most cases, the teaching of these topics involve combination of methods such as traditional lectures, individual programming assignments, modification of educational operating systems and simulations. Exactly which combination tends to depend on the educational institution delivering them and can often be influenced by the teaching expertise and the resources available within the computing departments.

At Edge Hill University the delivery of the three-year full-time modular computing degree programme is the responsibility of the Business School. In the first year, the majority of students study a module on the fundamentals of computer architecture. Some of these students go on to studying more advanced topics in the second year. The delivery of the programme includes traditional theory via lectures supported by tutorial and practical sessions as well as individual and group coursework assignments. The students studying for computing degrees are recruited from wide educational backgrounds and competencies which may not include any previous computing experience or qualifications.

The tutorial and practical sessions on computer architecture have been supported by investigating aspects of different operating systems, mainly Windows and Linux. However, there remained a requirement for studying those architectural features which are difficult or impossible to access and demonstrate on real systems. With this in mind, it was decided that a software simulator would be developed with features designed to support the computing modules in computer architecture and operating systems.

On the Motivation

The motivation for developing a new educational simulator from scratch is prompted by the need for the following main requirements

An integrated system simulator. In computer architecture, different technologies are interrelated and support each other across clearly defined interfaces. It is these interdependencies and the interplay that the integrated simulator aims to represent. The students prefer to see the "big picture" and to understand how things "hang" together.

Rich pedagogical features. As an educational tool, it is important that a simulator enhances and enriches learning experiences of students and at the same time facilitates deep understanding of the key technological concepts and issues. It should actively encourage experimentation, exploration and investigative problem solving with students working either individually or in groups.

Control and monitoring facilities. In a dynamic simulation environment it is essential to be able to suspend, stop and re-start the simulations on the occurrence of some pre-determined event or state. It may also be necessary to manually make changes to selected system components (e.g. memory, registers, instructions, etc.)

Support at different educational levels. The simulator should support students at different stages of their educational development from basic to advanced levels of competencies and should incorporate simulations of a wide range of technological aspects of computer architectures.

Integrated visual displays. Animated, real-time, colour coded, visual displays can provide immediate feedback and impact which can help reveal trends, show state transitions and facilitate comparisons.

Support for problem-based learning. Problem-based learning (PBL) is a method of encouraging independent student-lead learning. The simulator can support and facilitate PBL with ease.

Little or no programming knowledge required. One of the main features of the simulator is to facilitate the learning of computer architecture and operating systems technology without requiring prior programming experience.

Support for advanced features. The simulator is designed to support advanced architectural features such as multiple processors, instruction level pipelining, compiler optimizations and virtualization.

Easy and intuitive user interface. The users of the simulator should not be faced with a steep learning curve. As the same simulator is expected to be used across different modules and over different years of study, the students soon become familiar with its usage.

Prior Work

Over the years, many simulators of computer architectures have been developed which have been used as valuable educational resources (Yurcik et al, 2001 and Yehezkel et al, 2002) at undergraduate computing courses. These range from simple, abstract, high-level simulators to advanced simulators of commercial CPUs.

Table 1 lists some examples of software simulators developed for educational purposes. The simulators are categorised as operating system (OS) based and CPU based simulations. Most of the simulators developed appear to be CPU based. The OS simulators tend to be rather fragmented along the lines of distinct but isolated functionality. It is interesting to note that none of the listed simulators incorporate both CPU and OS simulations in one software package.

Table 1. A survey of some of the educational simulators, past and present.

Name	**Simulator**		**Comments**
	OS	**CPU**	
SchedulerSim (Chan, 2004)	Yes	No	CPU scheduling concept
Sim. + assembler (Than, 2007)	No	Yes	IO processing + interrupt handling
MKit (Nishita, 2004)	No	Yes	Inst. set + data paths + control unit
SOsim (Maia, Pacheco, 2003)	Yes	No	Process + memory management
Sim. (Robbins, Robbins, 1999)	Yes	No	Process scheduling, HTML-based, scripted
Sim. (Ivanov and Mallozi, 2004)	No	Yes	Assembler + inst. set
MarieSim (Null, Lobur, 2004))	No	Yes	Assembler + inst. set + data paths
PDP-8 simulator (Shelburne, 2003)	No	Yes	PDP-8 inst. set + assembler
Simulta (Styer, 1994)	No	Yes	Inst. set + microcode + input/output
CPU Sim (Skrien, 2001)	No	Yes	Inst. set + microcode + assembler
MARS (Vollmar, Sanderson, 2006)	No	Yes	MIPS assembly language simulator
Starving philosophers (Robbins, 2001)	Yes	No	Limited OS: Syncronization + monitors
Address translation (Robbins, 2005)	Yes	No	Limited OS: Virtual memory
MPS (Morsiani, Davoli, 1999)	No	Yes	Inst. set + input/output + MIPS CPU sim.
JASP toolkit (Burrell, 2004)	No	Yes	Inst. set + assembler + high-level lang.
PsimJ sim. (Garrido, Schlesinger, 2008)	Yes	No	Various isolated OS component simulations

There have been surveys of many other software simulators and visualization tools designed to support computer architecture education at universities and colleges (Yurcik et al, 2001 and Wolffe, et al, 2002), each using slightly different approach to satisfy local educational requirements. Some simulators have been developed to accompany text books on operating systems and computer architectures (Garrido and Schlesinger, 2008, Stallings, 2009, Burrell, 2004 and

Null and Lobur, 2006). These simulators often concentrate on some specific technological aspects of the systems and do not offer a unified approach.

Another related approach taken by various universities and colleges is to develop or use existing teaching operating systems which the students are asked to modify and/or extend (Atkin and Sirer, 2002 and Hovemeyer et al, 2004). This approach often requires good programming ability by the students and, although highly realistic, is not always suitable as a teaching and learning resource.

Simulator Design Details

The design and development of the system simulator are based on clearly defined design principles. The integrated simulator is composed of three main components: a "teaching" compiler, a CPU simulator and an operating system (OS) simulator supporting each other. For example, the compiler will generate code which can be run by the CPU simulator either in isolation or under the control of the OS simulator for multiprogramming support. Each of the three components is described below.

The compiler. A basic but complete high-level teaching language is developed to support the CPU and OS simulations. This language incorporates the standard language control structures, constructs and system calls which are used to demonstrate a modern computer system's key architectural features. A compiler is developed for this language which generates both assembly-level language and its equivalent binary byte-code as output. The compiler is also able to disassemble the binary byte-code back to its assembler code equivalent thus demonstrating reverse-engineering concept desirable in certain circumstances. Image 1 shows a snapshot of the main compiler user interface.

The compiler includes refinements such as code optimizations, support for profiling, display of compiler stages and the binary code generated as well as some statistical data. Additionally, the compiler includes an integrated tabbed source editor capable of handling multiple source code at the same time. The "teaching" compiler can support a module on compiler design.

The compiler optimizations can be used to demonstrate performance gains due to reductions in code size and enhancing CPU pipelining (see below) when jump instructions are eliminated. They are also used to demonstrate that an experienced human assembly coder is still a better producer of more efficient code than most optimizing compilers.

The compiler and its associated language naturally support the CPU and the OS simulations thus reflecting the importance of the language processors.

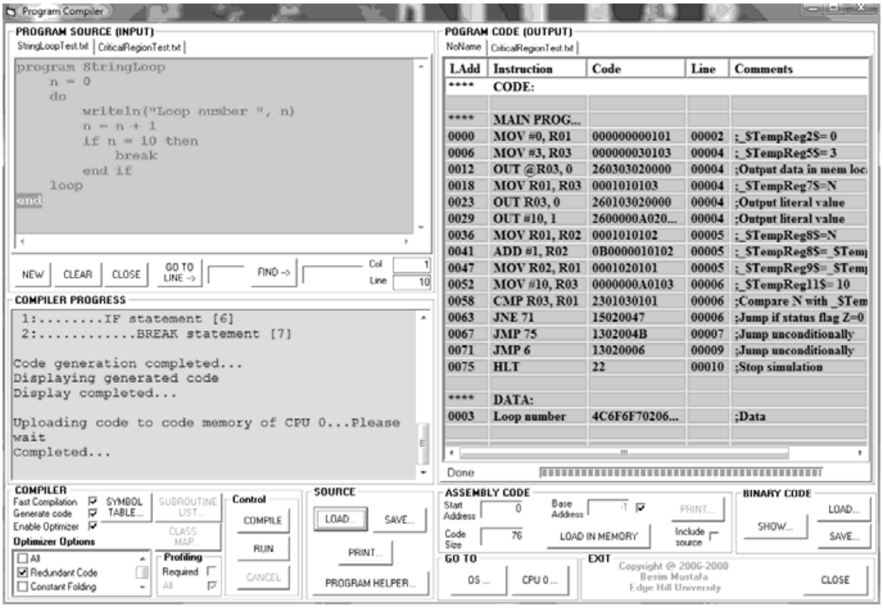

Image 1. The compiler main screen.

The CPU simulator. The CPU is loosely based on RISC architecture with a prominent register file composed of from 8 to 64 fast registers, a minimal set of variable-length instructions and a limited number of addressing modes. Except two instructions, viz. load and store, the instruction set is based on register to register addressing. Optionally the CPU instructions can be entered manually by selecting the valid instructions and any operand(s) from list of instructions and operands. In selecting operands the associated addressing modes can also be specified at the same time. The selected assembler instruction is then added to the CPU instruction memory. The stored instructions can then be individually selected and manually executed. The simulator provides runtime debugging facilities for the selected instructions, registers and memory locations. A stack is provided which demonstrates support for interrupts, system calls, subroutine parameters and return addresses.

A further refinement to CPU simulator is the inclusion of cache and pipeline simulations both of which provide highly configurable and visual operations. These advanced simulators can be used to demonstrate technology specific details and their impact on system performance. The cache placement and replacement policies can be selected; the hit/miss ratios can be plotted and compared. The pipeline stages are colour coded and animated. Different methods of eliminating pipeline hazards can be clearly demonstrated to improve performance. A history of pipeline activity is maintained which can be used to investigate pipelining. Image 2 shows the main user interface for the CPU simulator.

In order to be able to study systems with multiple processors, the simulator can optionally start multiple processors simulations. Each processor is identical and loading code in one is duplicated in others. The processors can be used to demonstrate load balancing and virtualization with multiple operating systems.

The CPU simulator defines a list of vectored interrupts. Each interrupt vector is triggered by a pre-defined event, e.g. console input or timer event. The inbuilt high-level language has constructs for the definition of interrupt routines as interrupt handlers the addresses of which are placed in the interrupt vectors at program load time.

The OS simulator. The OS simulator is designed to support two main aspects of a computer system's resource management: process management and memory management. Image 3 shows the main user interface for this simulator. Once a compiled code is loaded in CPU memory, its image is also available to the OS simulator. It is then possible to create multiple instances of the program images as separate processes. The OS simulator displays the running processes, the ready processes and the waiting processes. Each process is assigned a separate process control block (PCB) which contains information on process state. This information is displayed in a separate window. The memory display demonstrates the dynamic nature of page allocations according to the currently selected placement policy. The OS maintains a separate page table for each process which can also be observed. The simulator demonstrates how data memory is relocated and the page tables are modified as the pages are moved in and out of the main memory illustrating virtual memory activity.

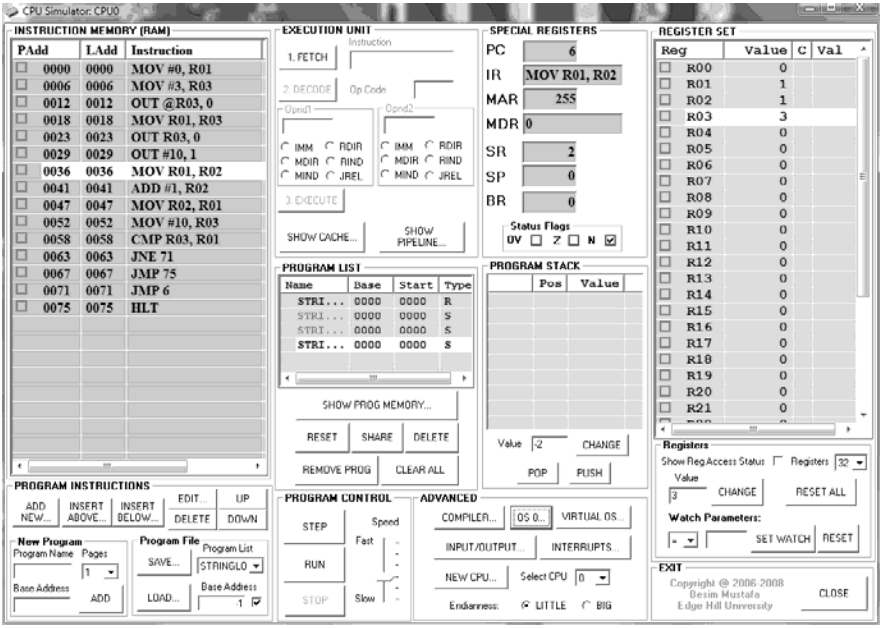

Image 2. The CPU simulator main screen.

The process scheduler includes various selectable scheduling policies which includes priority-based, pre-emptive and round-robin scheduling with variable time quanta. The OS is able to carry out context-switching which can be visually enhanced by slowing down or suspending the progress at some key stage to enable the students to study the states of CPU registers, stack, cache, pipeline and the PCB contents.

The simulator incorporates an input output console device which is used to display text and accept input data.

The OS simulator supports dynamic library simulation which is supported by the appropriate language constructs in the teaching language. The benefits of sharing code between multiple processes are visually demonstrated. There is also a facility to link static libraries demonstrating the differences between the two types of libraries and their benefits and drawbacks.

The simulator allows manual allocation and de-allocation of resources to processes. This facility is used to create and demonstrate deadlocks associated with resources and enables experimentation with deadlock prevention, detection and resolution.

Image 3. The OS simulator main screen.

Threads are fundamental aspects of modern multiprogramming/multi-tasking systems. This feature is supported by the OS simulator via special language constructs which identify parts of programs for execution as threads. The threads are scheduled like processes but they share their parent's memory address spaces. The concepts of orphan and zombie processes are also explored.

In multiprogramming systems it is sometimes necessary and desirable to prevent multiple processes accessing shared resources at the same time. So the concepts of synchronization and critical regions are facilitated by special teaching language constructs. There is also a Java style subroutine synchronization facility.

The CPU utilization can vary depending on the types of applications. The concept of CPU-bound and IO-bound applications is explored by the OS simulator by artificially varying the ratio of running to waiting processes. The simulator monitors the CPU and memory utilizations and displays the information in a graphical format at runtime.

The Virtual Machine (VM)

A separate stand-alone virtual machine has been developed which is able to interpret and execute the compiled byte-code. The VM is a native executable code and is currently implemented on Windows and Linux operating systems. This is a console based facility and runs under the control of the host operating system and supports multi-threading. This code demonstrates the concept of VM by enabling the execution of the code on different platforms.

Some Notable Features

The system simulator boasts some notable features, not available elsewhere. Below is a summary of some of these features.

Compiler. The compiler incorporates object-oriented (OO) features and can be used to demonstrate inheritance, encapsulation and polymorphism. The students can also observe the way the code is generated for object-oriented programs.

A language construct is available to demonstrate the code generated for exception handling. The programmer can specify areas of code that can be protected as in Java programming language.

The Inter Process Communications (IPC) is an important aspect of modern computer architecture. The simulator's language includes constructs which generate system calls that support IPC.

The compiler's source editor and the view displaying the corresponding code generated are context sensitive. So, as the cursor is moved or placed on a particular line of source, the corresponding code generated is highlighted and vice versa. This makes it easy for the student to observe the code generated corresponding to each line of source statement.

CPU simulator. The compiler favours registers as locations for program variables. However it can be forced to spill these over to the memory by generating the appropriate load/store instructions if the number of registers is set low.

The register file includes a "watch" facility where selected registers can be specified with a value and a condition upon which the simulation will be suspended.

In addition, the registers in the register file can be tagged with visible markers (e.g. images) which indicate the status of registers with respect to the stages of the pipeline for hazard conditions.

OS simulator. The OS simulator implements inbuilt system calls. The system calls use an instruction which causes software interrupt and passes a parameter to the OS indicating the type of the call. As system calls are frequent occurrences, the students need to understand the general mechanisms involved.

One of the interesting features of the OS simulator is its ability to create and run processes automatically for extended periods. The input/output events, resource allocations/de-allocation, deadlocking, process memory pages, page swapping, process scheduling, context switching are all randomly simulated.

Current Research

The simulator project has recently secured funding from Higher Education Academy (HEA) to carry out evaluation on the effectiveness of the simulations as a teaching and learning resource. The funding, which is for a period of six months, also aims to support the dissemination this of the results; a dedicated web site will be created for this purpose.

Both qualitative and quantitative data will be gathered and the research will concentrate on devising tutorial and lab exercises which will be attempted with and without the support of the simulations. The exercise results will be assessed and a comparison between the two sets of results will be made. There will also be a survey of student opinions on the use of the simulations in underpinning theory.

Further Work

The simulator's current state is maturing and is fairly stable. The extension of the simulator to cover areas of system architecture which are increasingly being included in our modules will undoubtedly further enhance the education of our students. Areas of development for which funding will be sought are listed below:

- Distributed OS simulation
- Superscalar CPU architectures
- Extended input/output devices

Conclusions

The creation of yet another educational simulator has been fully justified on the grounds that there is a need for a unified approach to facilitate the teaching and learning of computer architectures including in undergraduate computing courses. The research of the existing simulators revealed a fragmented presence of many simulators and none, as far as this author is aware, offers the means of facilitating deep understanding of the concepts of unification of the technology.

It is this desire of a unified approach that prompted the author to initiate a new simulator project in the first place. It is hoped that the present system simulator as described in this paper will go some way to closing this gap.

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Computational modelling with Modellus: An enhancement vector for the general university physics course

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Abstract

In this paper we present a step forward to improve general physics as an educational experience: the implementation of a new course component composed by innovative workshop activities based on computational modelling in the general physics course taken by first year biomedical engineering students at the Faculty of Sciences and Technology of the New Lisbon University. The activities were created as interactive modelling experiments with Modellus, a computer software tool designed to construct and explore mathematical models based on functions, iterations and differential equations. Special emphasis was given to cognitive conflicts in the understanding of physical concepts, to the manipulation of multiple representations of mathematical models and to the interplay between analytical and numerical solutions of physical problems. In this work we describe these computational modelling activities and their educational aims. We also discuss their effective impact on the students learning of key physical and mathematical concepts of the course.

Introduction

General physics is an extremely difficult subject for university students taking it as a compulsory part of their first year plan of studies. Due to a lack of understanding of fundamental concepts in physics and mathematics (Hestenes, 1987; McDermott, 1991), the number of students that fail on the course examinations is usually very high. For example, in the Faculty of Sciences and Technology of the New Lisbon University, on average only less than 30 per cent of the students are able to take the course on the first time. What is worse is that many of those students that do actually succeed also reveal several weaknesses in their understanding of elementary physics. There are multiple reasons for this serious problem and to discuss them is beyond our present scope.

Although not exclusively, it is clear that the solution for this problem requires changes in the way physics is taught. Results from physics education research have shown that in many occasions the process of learning is effectively enhanced when students are involved in the learning activities as scientists are involved in research (Mazur, 1997; McDermott, 1997; Beichner et al, 1999).

Indeed, scientific research in physics is a dynamical and exploratory process of creation, testing and improvement of mathematical models that describe observable physical phenomena. This process is an interactive blend of individual and group reflexions based on a continuously evolving set of analytical, computational and experimental techniques. It is from this cognitive frame of action that an inspiring understanding of the laws of the physical universe emerges. Hence, it should not be a surprise that physics may turn out to be more successfully taught in interactive and exploratory environments where students are helped by teachers to work as teams of scientists do. In this kind of class environment knowledge performance is better promoted and common sense beliefs as well as incorrect scientific notions can be more effectively fought.

Another important aspect of these interactive, research inspired learning environments is the possibility to give a central role to computer software tools and computational modelling. This sets the learning process in phase not only with modern scientific research where computation is as important as theory and experiment, but also with the rapid parallel development of technology.

Modelling physics in computer learning environments started with an emphasis on programming languages. Using, for example, professional languages such as Fortran (Bork, 1967), Pascal (Redish and Wilson, 1993) and Python (Chabay and Sherwood, 2008) as well as educational languages like Logo (Hurley, 1985), this approach requires students to develop a working knowledge of programming. The same happens when using scientific computation software such as Mathematica and Matlab. To avoid overloading students with programming notions and syntax, computer modelling systems such as Dynamic Modelling System (Ogborn, 1985), Stella (High Performance Systems, 1997), Easy Java Simulations (Christian and Esquembre, 2007) and Modellus (Teodoro, 2002) were developed to focus the learning activities on the understanding of the concepts of physics and mathematics. Of these, Modellus is specially interesting for allowing a model to be conceived almost as it is on a piece of paper, for having the possibility of creating animations with interactive objects that have mathematical properties expressed in the model and for permitting the analysis of experimental data in the form of images.

In this work we have followed recent results of science education research (e.g., Handelsman et al., 2005; Slooten et al., 2006) to create and implement a new course component based on computational modelling with Modellus, in the general physics course taken by first year biomedical engineering students at the Faculty of Sciences and Technology of the New Lisbon University. In the following sections we describe how this computational modelling course was organized, what was the pedagogical methodology implemented and the educational aims of the computational modelling activities offered to the students. We also discuss their effective impact on the students learning of key physical and mathematical concepts of the general physics course.

Course organization and methodology

The general physics course for biomedical engineering involved a total of 114 students among which 50 were taking the course for the first time. The course was divided into lectures built around a set of key experiments where the general physics topics were first introduced, standard physics laboratories and the new computational modelling classes based on interactive computer workshop activities. The students taking the course for the first time had to attend all three course components while the others, already repeating the subject, were dispensed from the computational classes.

In the computational modelling classes, the students were organized in groups of two, one group for each computer in the classroom. During each class, the student teams worked on a workshop activity conceived to be an interactive and exploratory learning experience structured around a small number of problems about challenging but easily observed physical phenomena. The teams were instructed to analyse and discuss the problems on their own using the physical, mathematical and computational modelling guidelines provided by the lectures and the workshop protocols. To ensure adequate working rhythm with appropriate conceptual, analytical and computational understanding, the students were continuously accompanied and helped during the exploration of the activities. Whenever it was felt necessary, global class discussions were conducted to keep the pace and to clarify any doubts on concepts, reasoning and calculations.

All workshop activities were created as modelling experiments based on Modellus, a computer software tool designed to introduce students and teachers to scientific computation through the construction and exploration of mathematical models based on functions, iterations and differential equations. Modellus was chosen as basis software because it is a tool that allows modelling experiments involving multiple representations (tables, graphics, and animations) almost without the need to introduce new symbols or syntax. Indeed, with Modellus it is possible to create and explore models in the computer following almost the same notation and reasoning already familiar when attempting to solve physical and mathematical problems on paper. Most importantly, Modellus allows the creation of animations with interactive objects which have their mathematical properties defined in the model and to complement them with multiple tables and graphs.

Each workshop activity consisted of a set of tasks in mechanics, presented in PDF documents, with embedded video support to help students both in class and/or at home in a collaborative online context centred on the Moodle online learning environment. The course was globally conceived to give special emphasis to cognitive conflicts in the understanding of the relevant physical concepts, to the manipulation of multiple representations of mathematical models and to the interplay between analytical and numerical approaches to the solution of physical problems.

Computational modelling activities with Modellus

The program of the general physics course offered to the biomedical engineering students was based on Young and Freedman (2004), complemented with applications of physics to biology and medicine. Following its structure the computational modelling component covered eight basic themes in mechanics (Teodoro, 2006): 1) Vectors; 2) Motion and parametric equations; 3) Motion seen in moving frames; 4) Newton's equations: analytic and numerical solutions; 5) Circular motion and oscillations; 6) From free fall, to parachute fall and bungee-jumping; 7) Systems of particles, linear momentum and collisions and 8) Rigid bodies and rotations. During all classes, the students groups would read the PDF protocols and would follow the instructions of the embedded videos as well as our personal guidance to carry out all the modelling activities. In this section we discuss a selected set of themes from the first part of the course starting with vectors, a subject covered in the lectures just after the topics on measurable quantities and units.

Vectors. A vector is an abstract mathematical object defined by a magnitude and a direction. In physics it is used to describe many important quantities, for example, the velocity or the force acting on a particle. With Modellus students were able to create vectors in the workspace and directly interact with them to visualise and reify many of its abstract properties. Indeed, when a vector is created its scalar and vector components are immediately visible on the screen. By simply using the computer mouse to drag the tip of the vector students were able to change its magnitude or its direction, and explore the effect on the scalar and vector components. Furthermore, introducing the vector coordinates as parameters and using Modellus predefined elementary functions, students were also taught to construct mathematical models to define the magnitude and the direction of any vector, the sum and subtraction of vectors as well as the multiplication of a vector by a scalar. In the end the students used Modellus to solve and animate physical problems involving the sum and subtraction of position vectors. An example requiring the definition of vector directions and the subtraction of two position vectors to find a displacement vector was that of a plane detected by radar (see figure 1): a plane is detected 2 km away in the direction 310 (using the navigation convention where the angle varies between 0 and 360 degrees clockwise starting from the North). After some time, the plane is 5 km away in the direction 350. What is the distance travelled by the plane between the two detection points? Where is the plane headed?

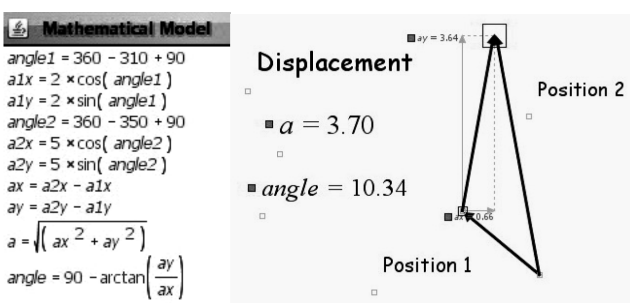

Figure 1. The plane model with the animation displaying the solution. The plane has travelled 3.7 km approximately in the direction 010.

During class, and while attempting to solve these problems involving vectors, students revealed particular difficulties in understanding how to correctly define the direction angle of a vector in the navigation convention. At first, many students were not aware that the trigonometric functions are defined with different conventions and were frequently unable to make the vectors point in the right direction. To be able to correct the models and at the same time visualise the effect of the change in the animation, was for the students an essential advantage of the modelling process with Modellus in helping them to solve this difficulty.

Motion and parametric equations. The vector modelling activities showed students that vectors are mathematical objects used to represent physical quantities that require both a magnitude and a direction to be completely defined. An example is the velocity, a fundamental vector quantity which measures the instantaneous rate of change of the position with time. In a rectilinear and uniform motion, the velocity is constant and the position vector changes linearly with time. This type of motion can be modelled with Modellus if the coordinates of the position vector are associated with the corresponding parametric functions. In this set of activities students explored interactively several rectilinear and uniform motions on the plane using mathematical models with parametric equations, graphs of the coordinates as functions of time and particle animations representing the motion trajectory. During class, some students were not completely at ease in making the distinction between the trajectory and the graphs of the coordinates as functions of time. After completing the proposed tasks these and the other students recognized that, for allowing the possibility to visualise at the same time trajectories and different coordinate graphs, modelling with Modellus was indeed more effective in helping them to manipulate, distinguish and correctly interpret these different representations of the model. After exploring these models, students also learn how to use conditions in Modellus to define branching functions and then reproduce the corresponding motion.

At the end of the classes covering this theme, students showed ability to complete activities requiring knowledge on how to characterise displacement vectors and velocities by their magnitude, direction and Cartesian coordinates as well as knowledge about the parametric equations of motion. For example, all the student groups were able to construct models to solve and animate the following problem about the motion of a car (see figure 2): a car is detected 4 km away when is moving eastwards. Seven minutes later the car is found 10 km away in the direction 035. What is the distance travelled by the car between the two detection points? Where does the displacement vector points? Assuming that the motion is uniform and rectilinear, determine the velocity of the car.

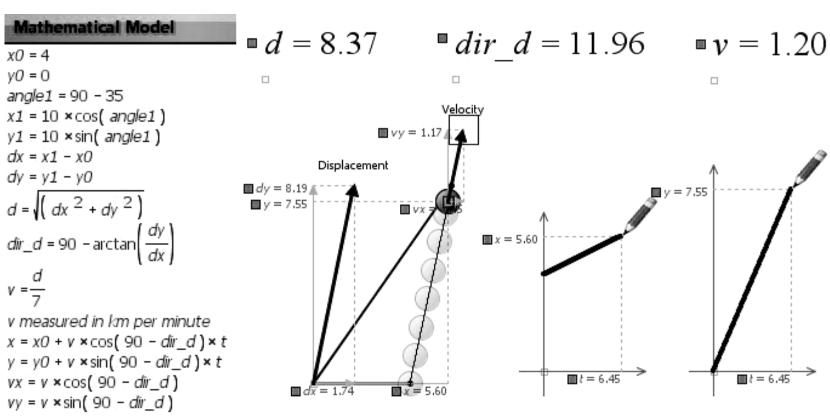

Figure 2. Modelling the motion of a car. The car travelled 8.37 km approximately in the direction 012 at a speed equal to 72 km/h.

Motion seen in moving frames. Relative motion was the subject of the third theme of the course. During these activities students had the chance to use Modellus to experience several cognitive conflicts and realise that observers in moving reference frames can have very different views of the motion. For example, students modelled and constructed the animation of the motion of a swimmer in a river with a downstream current equal to 5 m per minute (see figure 3).

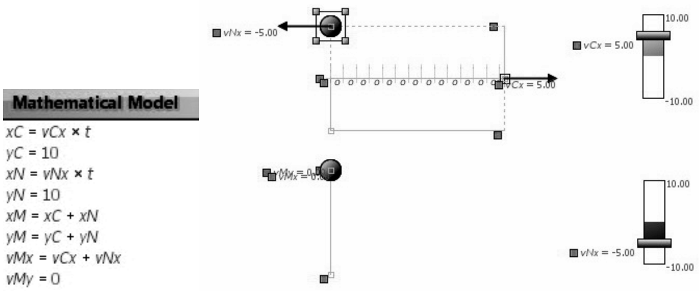

Figure 3. Modelling relative motion with Modellus.

When the swimmer tried to move up stream with the same speed as the downstream current it would not move at all relative to an observer on the river bank. However, for an observer on a boat dragged by the current, the swimmer would move up stream with a speed of 5 m per minute. When observing this animation for the first time, students were generally startled for a moment. After some thought and careful analysis of the mathematical model associated with the animation, they were all able to understand that the two points of view are related by the Galilean velocity transformation.

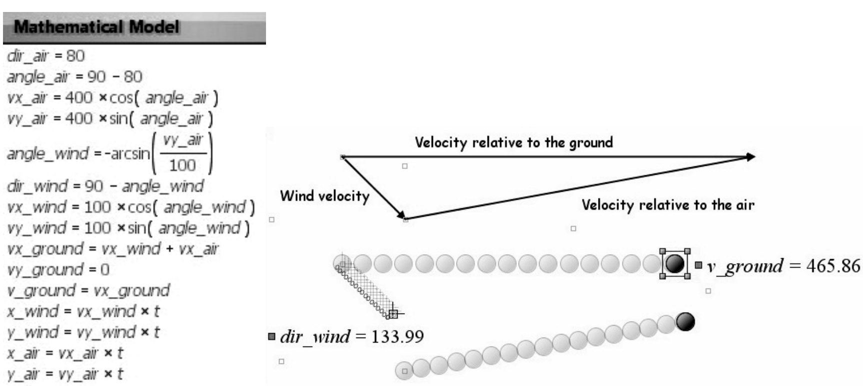

Figure 4. Modelling the motion of a plane against the wind. The wind blows approximately in the direction 134 and the plane ground velocity is 465.86 km/h.

At the end of this theme students groups were able to successfully explore with Modellus the similar problems of a boat crossing a river with current and of the motion of a plane against the wind. An example was the following: a plane flies from west to east. The pilot chooses a velocity of 400 km/h pointing in the direction 080. If the wind blows at 100 km/h, determine the wind direction and the plane ground speed (see figure 4). In this context, the interactive process of modelling with Modellus was of special relevance in helping students to realise that many different, everyday life physical situations can be explained using the same simple mathematical model.

Newton's equations: analytic and numerical solutions. What must happen for the velocity to change during motion? This was the starting question for the fourth theme of the course. If the velocity is changing during motion there must be an acceleration vector and at least one applied force. The acceleration is the vector that measures the instantaneous rate of change of the velocity with time. According to Newton's second law of motion, this vector is obtained dividing the sum of all the forces that act on the particle by the mass of the particle. If there are no net forces then there is no acceleration and the velocity is constant. This is the statement of Newton's first law of motion or law of inertia. To explore these laws, students began with an activity where the objective was to change the velocity of a particle in the perpendicular to make an Aristotle's corner (see figure 5) (diSessa, 1982).

In the Aristotle's corner model, Newton's equations of motion are written in the form of Euler-Cromer iterations. The students were thus introduced to a simple numerical method to solve the equations of motion and determine the velocity and position of the particle knowing its mass and the net applied force. The model animation is constructed with three objects: the particle, a vector representing the velocity attached to the particle and a vector representing the net force. Because the coordinates of the net force vector are independent variables and the model is iterative, students were able to manipulate this vector at will and in real time control realistically the motion of the particle. Soon it became clear that to do an "Aristotle's corner" it was first necessary to break and stop, and only then accelerate in the perpendicular. They also learn that the choice of a small time step was important for a numerical method to work. During this modelling activity with Modellus, students were helped to resolve still another cognitive conflict: to break is not that different from accelerating, it is just to accelerate in the direction opposite to the direction of the velocity. The interactive learning process of modelling this problem in Modellus, also lead students to learn that the choice of a small time step is an important one to obtain a good simulation of the motion and that this is the same as determining a good numerical solution of the equations of motion.

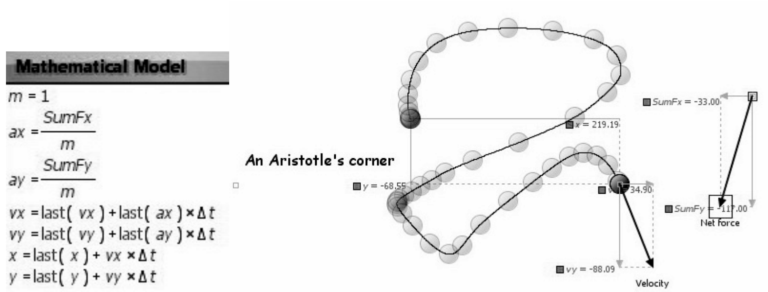

Figure 5. Interactive Euler-Cromer model to make an Aristotle's corner.

The same numerical model was then used to explore, for example, the throwing of a ball into the air (see figure 6). In this activity, students were taught to interact with the net force vector applied to the ball and to simulate the throw as well as the following motion under the earth's gravitational pull.

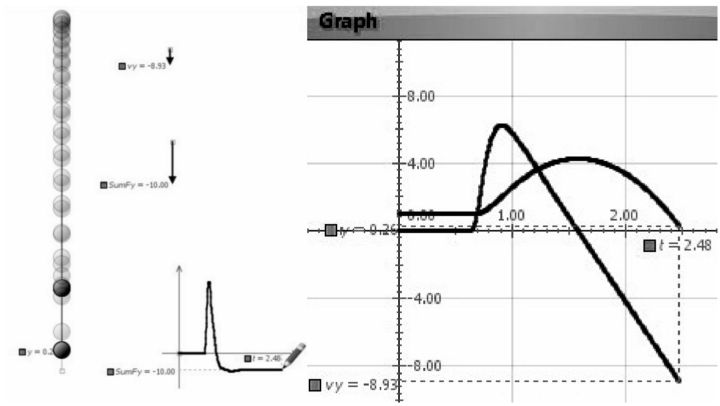

Figure 6. Throwing a ball with Modellus and iterative Newton's equations.

Again the choice of the appropriate time step was an important source of difficulties. This was resolved using the possibility of changing the mathematical model and immediately observe the effect of the correction on the animation. With the position and velocity time graphs, students were able to determine how long it takes for the ball to reach the highest point of the trajectory, what is the height of that point and when is the ball three metres up in the air. The students were also able to draw on paper the vector diagrams representing the forces acting on the ball, the velocity and the acceleration during the whole motion. This task was more easily completed when these vectors were created as animation objects. Another important learning difficulty students were helped to address during this modelling activity was the need to choose appropriate scales for the animation objects and graphs. Finally, by observing the net force graph as a function of time, they were able to estimate the duration of the throw.

The next activity in this theme was to compare the analytic solution for the motion just after the throw with the corresponding numerical solution obtained using the Euler method and the Euler-Cromer method (see figure 7). For the same sum of applied forces and the same initial conditions students were lead to find that the analytic solution is different from the numerical solutions. They were able to understand that there is always an error associated with the iterative approximations used and learn how to quantify this error for both methods. The activity showed students that the error is only present for the position and not for the velocity, since this quantity changes linearly with time. To finish, students used Modellus to model and play a basketball game. They were also incentivised to construct the analytic solution of this projectile motion and to discuss why in such a model only the time interval after the ball leaves the hand of the player is considered.

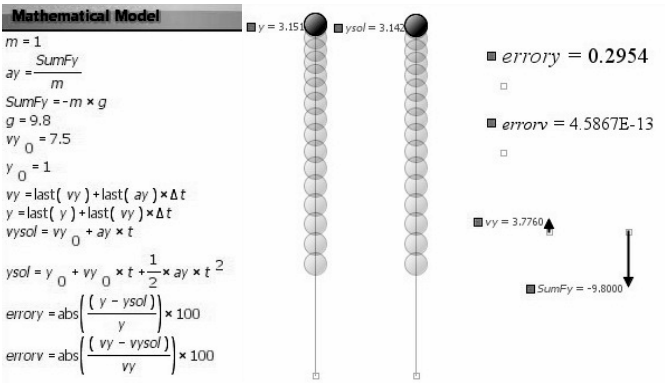

Figure 7. Comparing analytic and numerical solutions to the ball throw

Conclusions

In this paper we have presented the computational component of an introductory physics course based on innovative workshop activities with Modellus. After describing the course organization and methodology we have discussed the computational modelling activities to show how they were conceived to generate cognitive conflicts relative to important physical concepts, to promote the manipulation and correct interpretation of multiple representations and to analyse the interplay between analytic and numerical solutions of physical problems. We have concluded that during class the computational modelling activities with Modellus were successful in identifying and resolving several student difficulties in key physical and mathematical concepts of the course. Of fundamental importance to achieve this was the possibility to have a real time visible correspondence between the animations with interactive objects and the object's mathematical properties defined in the model, and also the possibility of manipulating simultaneously several different representations.

The implementation of this set of computational modelling activities with Modellus was thus successful. This was indeed reflected in the student answers to a questionnaire given at the end of the course (Neves et al, 2008). Globally, students reacted positively to the workshop activities with Modellus, considering them to be important in the context of the biomedical engineering course. Students showed a clear preference to work in teams in an interactive and exploratory learning environment, with proper guidance and support from the professors. The computational activities with Modellus presented in PDF format with embedded video guidance were also considered to be interesting and well designed. In this work Modellus was also successfully tested as a software tool that allows students to work as authors of mathematical physics models and simulations, not as simple browsers of computer simulations. Models can be presented as differential equations solved by simple numerical methods and students can appreciate the differences between numerical solutions and analytical solutions. For the students Modellus was indeed seen as helpful in the learning process of mathematical and physical models.

Acknowledgements

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Applying electromagnetism for enhancing Thai high-school students' understanding in force and motion

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Abstract

The In this study, we present the sets of demonstration that we developed and used in a physics class for Thai high-school students. The demonstration sets comprise two main parts: (1) simple motion demonstration (2) complicated motion demonstration. In the second part, tools that required knowledge in electromagnetism were used for teaching non-uniform forces. We brought a magnet and a solenoid to create and show forces between them. We carry out the demonstrations with microcomputer-based laboratory (MBL) measurements. The results could be immediately displayed on the screen in front of the class using an LCD projector. This teaching method is called the interactive lecture demonstration (ILD) and is aimed to engage students to learn as well as to help them integrate their knowledge to new situations. The demonstration sets were planned to use with high-school students who have already learned basic topics on force and motions.

Introduction

The environment of physics instruction has two main types that are a traditional instructor-centered environment and an active-engagement student-centered environment (Redish, 2003). The traditional physics instruction consists of lecture, recitation and laboratory that the students are passive while the teacher is active during the class. One of step toward improving the traditional instruction is to modify the lecture to create a more interactive environment (Knight, 2003; Steinburg, 2001). Many researchers offered methods for increasing students' engagement in lecture such as Peer Instruction, Just-in-Time Teaching, Physics by Inquiry and Interactive Lecture demonstrations (Mazur, 1997; McDermott, 1995; Novak, 1999; Thornton & Sokoloff, 1998).

In this study, we focused to engage students' learning in Newton's laws of motion by using Interactive Lecture demonstration or called ILDs approach. This approach used computer-assisted data acquisition to quickly collect and display data. One of the advantages of real-time microcomputer-based laboratory (MBL) tools is that students can compare the differences between their observations and their beliefs in real situations (Thornton, 1990).

Purpose of study

1. To enhance students' understanding in Newton's laws conceptions.

2. To develop the demonstrations sets for teaching in interactive lecture demonstrations approach.

Methodology

Participants

In 2007, 71 tenth-grade high school students who had learnt mechanics before they learned with ILDs approach.

Tools

The data acquisition and the sensors

Figure 1. (1) Motion sensor, (2) Science Workshop 500 interface, (3) Photogates

The crucial tool is an interface box (SW500) for data acquisition. It is used to connect the motion sensor and the photogates (Mosca & Ertel, 1989) to the computer connected to the SW500. The computer probes live-time plots of velocity, acceleration and force. The SW500 and the sensors from Pasco are shown in Figure 1.

The sets of demonstration involve to magnetic interactions

Our ideas for designing the demonstration sets were divided into two main parts: (1) the demonstration set for teaching about a uniform force, and (2) the demonstration set for teaching about a non-uniform force (Peters, 1982). All demonstration sets were designed for one dimensional motion. The knowledge of Electromagnetism was used to create demonstration tools. The demonstration sets are:

Set # 1: The demonstration set of Newton's first law consists of
Demonstration #1: An object moves away from motion sensor at a constant velocity.
Demonstration #2: An object moves toward from motion sensor at a constant velocity.
Demonstration #3: An object is at rest when the equal forces act on it in both sides.

Set # 2: The demonstration set of Newton's second law consists of
Demonstration #4: An object moves away from motion sensor with an increasing velocity at a steady rate.
Demonstration #5: An object moves toward from motion sensor with an increasing velocity at a constant rate.
Demonstration #6: An object move away from motion sensor with a decreasing velocity at a steady rate.
Demonstration #7: An object is attached with a magnet at one end. Push and release the object to move towards a solenoid. When the object gets closer to the solenoid there will be a repulsive force between the solenoid and the magnet. the example is given in Figure 3.

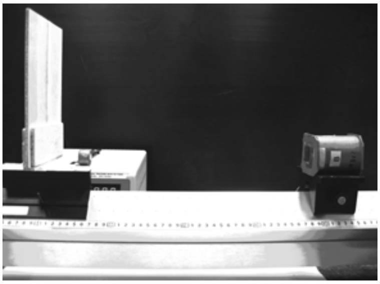

Figure 2. An example of the demonstration #7

The demonstration 7 is somewhat richer and more complex than those of the demonstrations in the set of Newton's second law, and particularly suitable for students who have learnt the basic mechanics before.

Set # 3: The demonstration set of Newton's third law consists of
Demonstration #8: A glider is heavier than the other one. Magnets of the same polar are attached on each of the glider. The gliders are then pushed with the same initial speed then they will collide without contact. The demonstration set up is shown in Figure 3.

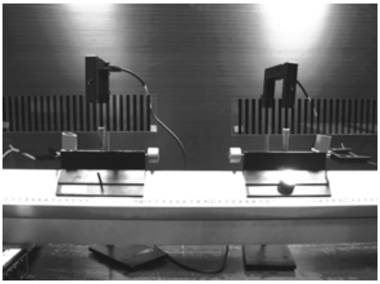

Figure 3. An example of demonstration #8

This set of demonstration is used to teach the third law of motion. The magnitude and the direction of the action-reaction forces are displayed immediately to make students belief in this law.

The conceptual test

We evaluated students' understanding in two parts; the uniform force and non-uniform force. For the first part, we chose 20 items from the Force and Motion Conceptual Evaluation (FMCE) that was translated into Thai by Emarat et al (2002).

The prediction sheets

In the teaching process, we display the results of the demonstration by using graphs. The prediction sheets are separated into 3 main parts. The first part describes the detail of the demonstration. The second part contains empty graphs consisting of velocity-time, acceleration-time and net force-time graphs. Each graph will be sketched (or predicted) by students after they observe an experiment. In the last part students will explain the graphs which they draw. Figure 4 shows an example of the prediction sheet.

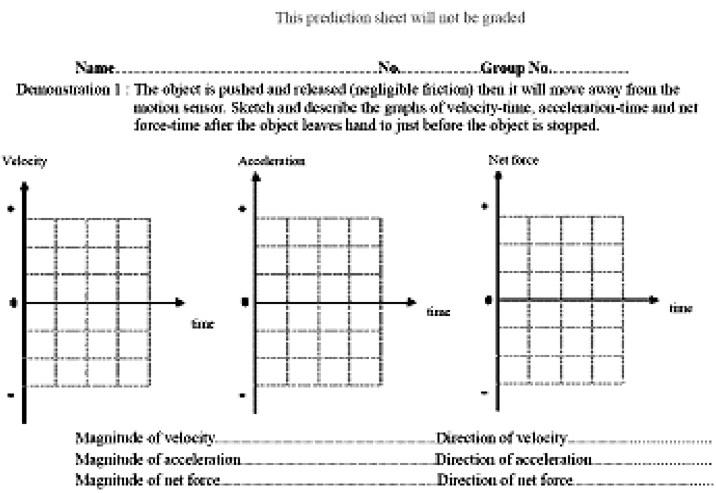

Figure 4. An example of prediction sheet

Results and discussions

The results using the FMCE as a pre- and post-test are shown in Table1 and Table2. A class average normalized gain is 0.47. The results of P-value in all items indicate that the average post-test score of students who has participated in the Interactive Lecture Demonstration is better than the average pre-test score of students who has participated in the traditional instruction at significant 0.05.

In addition, the average normalized gain in part of the graphical evaluation is greater than the natural language part. This may be due to ILDs approach that displays the results of the demonstration by graphical mode.

According to table 2, the highest gain was in the Newton's third law that was 0.91. This result suggests that the demonstration set for Newton's third law had more effective than the others. This also leads to the assertion that the real-time display of the action-reaction forces had much effect to the students' learning of Newton's third law.

Table 1. Pre- and Post-Results for Results on FMCE questions in this study.

	Full score	average pre-test score	average post-test score	P-value
Newton's laws	20	3.59	11.28	0.00
Newton 1st &2nd(Nat.Lang,)	7	0.61	2.18	0.00
Newton 1st &2nd(Graph,)	7	1.34	4.51	0.00
Newton 3rd	5	1.64	4.59	0.00

Table 2. Normalized gain [g] for Results on FMCE questions in this study.

	<g>
Newton's laws	0.47
Newton 1st &2nd(Nat.Lang,)	0.25
Newton 1st &2nd(Graph,)	0.48
Newton 3rd	0.91

Moreover, the normalized gains of different groups of students of traditional instruction and ILDs instruction are presented in figure 5.

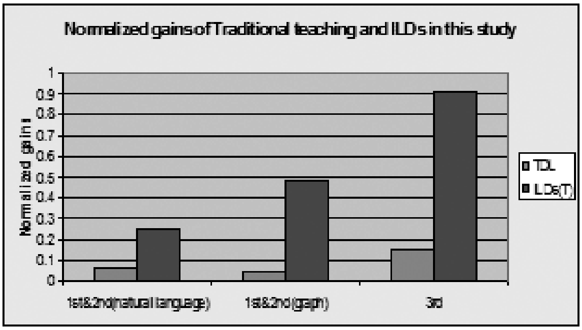

Figure 5. The normalized gains of traditional instruction and the ILDs of this study

The graphs are grouped by each conceptual area of Newton's laws according to Jairuk (2007). The average normalized gains of traditional instruction was from the research of Jairuk that he did the research about use of Interactive Lecture Demonstrations to develop Thai high-school students' understanding in force and motion. It can be seen that the normalized gains of ILDs instruction in this study are higher than the normalized gains of the traditional instruction.

Moreover, we considered the average normalized gains of our ILDs and Jairuk's ILDs for comparing the effective of demonstrations. The results shown that our demonstration sets were more effective than Jairuk's one. Jairuk used only simple demonstration sets to teach students while our demonstration sets applied the electromagnet to construct the complicated demonstrations. The advantages of our demonstrations are that they can engage students learn in basic and rich concepts and can enhance students' thinking skills.

Conclusions

The ILD is an effective instruction for improving Thai students' conception in Newton's laws of motion. The success of this work is to develop the demonstration set which consists of the basic demonstrations that solidify the students' conception and the advance demonstrations that help them integrate their knowledge to new situations. According to the complicated demonstration set, the knowledge of electromagnet is used for construction this tools. Furthermore, ILD can increase the concepts of students especially in Newton's third law. In addition to the normalized gain of Newton's first and second laws, the graphical part has higher gain than the natural language part.

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Interactive screen experiments – connecting distance learners to laboratory practice

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Abstract

Laboratory experience for students of the sciences is of great importance, but for distance learners, or those in a resource-poor environment, this experience is often not available. To address this issue, the Physics Innovations Centre for Excellence in Teaching and Learning (piCETL) at the UK Open University (OU) is developing computer-based resources, Interactive Screen Experiments (ISEs), to help bridge the distance learning/laboratory gap. In this paper, we discuss the concept of an ISE as a highly interactive movie of a real experiment, production methodology and the advantages that ISEs confer. We will examine the uses to which ISEs are being put at the OU, primarily in accessibility, training and preparation. Finally, we will summarise an evaluation study examining the effectiveness of ISEs using observations of users under controlled conditions and at residential schools.

Introduction

The implementation of virtual laboratory resources in the physical sciences relate closely to the purpose they seek to address, the experience of both students and tutors, and the suitability of an activity. In this paper, we explore these concepts in the context of the Interactive Screen Experiment (ISE), pioneered by Kirstein (Kirstein (1999, 2007)) and Schumacher (Theyßen et al (2002)), introduced to the UK as the "Reality Viewer" (Bacon (2003)) and now being developed at the UK Open University (OU) through the Physics Innovations Centre for Excellence in Teaching and Learning (piCETL) initiative (Lambourne (2007)). Additionally, we will examine how, and for what purpose, these resources have been incorporated into OU courses, and summarise evaluation in a selection of case studies.

The OU was established in 1969 to provide degree programmes by distance learning. There are no formal entrance requirements for undergraduate courses and students are usually mature adults with most in employment or with other significant responsibilities. Their study is therefore part-time and opportunities for face-to-face contact with personal tutors are limited. The situation in the sciences for practical work is very challenging. Practical work is taught at week long residential schools staffed by OU tutors, and by home experiments with some apparatus supplied by OU and students supplying common household items. However, such strategies cannot address all issues. Particular points include:

- Distance/lack of access. As an international organisation, OU students may not be UK based or may not have full access to resources;
- Commitments mean that some students cannot attend conventional practical courses;
- Students may have declared disabilities and older students may be lacking in dexterity or visual acuity;
- The OU, by definition, is 'open' - students may never have done practical work before, or lack confidence.

With these constraints on the teaching and learning of practical skills, a means of engaging students with experimental work outside the laboratory is necessary to supplement and enhance the effectiveness of the real practical work, or (where unavoidable) to act as a substitute.

Before discussing in detail the ISE concept, it is necessary to define what is meant by a virtual laboratory, understand what value it can bring and, importantly, what it cannot do. In the most general terms, a virtual laboratory is a computer-based activity where students interact with an experimental apparatus or other activity via a computer interface. Typical examples include a computer-coded simulation of an experiment and a remote-controlled experiment where a student interacts with real apparatus via a computer link, yet the student is remote from that apparatus. The latter case should be distinguished from a computer-controlled experiment, where a student will directly control an apparatus in his or her vicinity via a computer interface (figure 1). For the purpose of this paper therefore, a *virtual laboratory is one where the student interacts with an experiment or activity which is intrinsically remote from the student or which has no immediate physical reality.* The latter part of this definition may seem to imply that a virtual laboratory can have no physical reality behind it at all. For example, in a simulation of gravity we might code for behaviour different to the familiar inverse square law (if only to explore the consequences of such a universe). This disconnection with reality need not be the case. Indeed, the whole concept of the ISE is to provide as close a connection to reality as possible within a virtual laboratory environment.

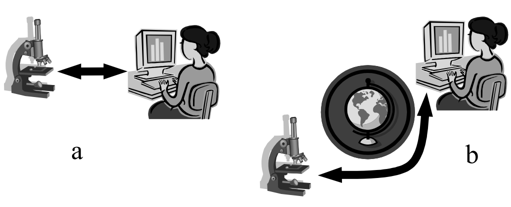

Figure 1. The distinction between (a) a computer-controlled experiment and (b) a remote controlled experiment. The latter case is an example of a virtual laboratory

It is important to understand the benefits resources such as ISEs can bring to the learning experience (Hatherly (2008)). In summary, key areas of benefit relevant to OU students include; accessibility, training and augmentation. Some specific examples in each of these areas are given in figure 2; it is of particular note that one frequently perceived benefit – that of *replacing* real is absent. Nothing can replace the experience of working hands-on with apparatus and equipment, hence, although better than no experience, the virtual laboratory should not be perceived as providing a full experience, unless such replacement is unavoidable.

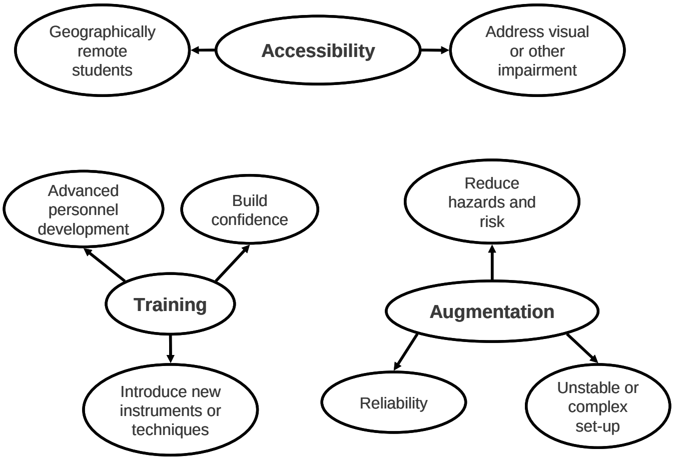

Figure 2. Some of the benefits of a virtual laboratory

The Interactive Screen Experiment concept

In its broadest sense, an ISE is a highly interactive movie of an experiment, filmed as that experiment was being performed. By highly interactive, it is not simply meant that the movie is capable of being moved forward or backward at different rates – this is trivial interactivity, and whilst valuable would limit the range of experiments possible. A specific example can be used to illustrate the point. Figure 3 shows a screen-shot of a simple ISE illustrating Hooke's Law. In this example, the user interacts with the movie (the interactive screen experiment) by clicking as normal on the dial of the force-meter, and turning it by dragging it round using the computer mouse or other control device. The dial then rotates as would the real example, with the spring extending or contracting depending on the direction of rotation. Simultaneously, the force indicated (equivalent to the tension in the spring) is shown by the pointer. Turning the dial controls the frame-to-frame motion of the movie, with each frame being a snapshot of the experiment as it was being performed. This example also serves to strengthen the distinction between ISEs and coded simulations. In the case of a coded simulation, a programmer would explicitly define the behaviour of each element. For example, in the simplest case the spring might be given the behaviour of its extension being proportional to its tension – a straight-forward Hooke’s Law case ignoring the elastic limit. In the case of the interactive screen experiment though, the images presented on the screen are taken from a *real* experiment, recorded as it was being performed. The interactivity (the turning of the dial) arises from behaviours governing how the movie switches between recorded frames as a result of user action. In consequence, the outcome of the interactive screen experiment illustrates the *real* physics of the phenomenon, rather than an idealised representation and will inherently include nonlinear effects.

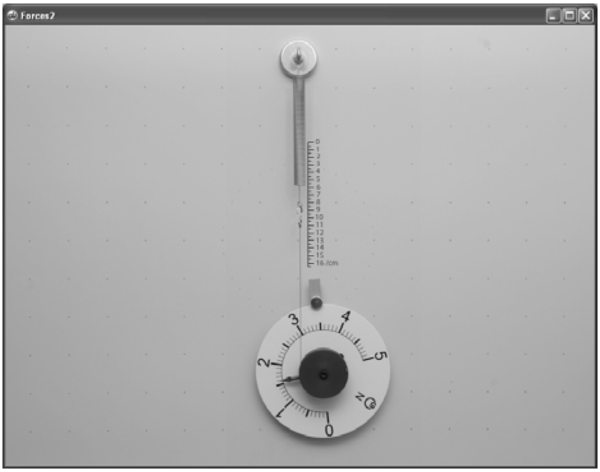

Figure 3. An example of a simple interactive screen experiment.

Producing ISEs

The production of an ISE required academic, laboratory practitioner, technical, photographic and programming skills. A typical cycle of production is shown in figure 4. The first requirement is to define the original concept. That is, the experiment or activity to be implemented, based on academic and educational need. With the concept in place, a storyboard or shooting script is produced. A detailed script at this point is essential to ensure that as complete a set of images as needed are acquired, for reasons which will become apparent.

Since ISEs are based on images of real experiments, a key requirement is high quality photography, in terms of camera equipment, lighting and studio set-up. The requirements of a sound script and high-quality equipment is essential since, as will be discussed, the final preparation of an ISE utilises images which need to have the same illumination, and with objects in those images to be in identical positions from one image to the next.

With images acquired, ISE production proper can begin. It is at this point that the need for a complete set of high image quality becomes apparent. Consider the ISE shown in figure 3. The moving elements here are the force meter and the spring; the remainder of the image does not change from image to image. Hence, these moving elements are cropped from each frame, and inserted into a fixed background. If the lighting, exposure or position of the camera varied from one shot to the next, this would be apparent as flicker or undesired movement of objects in the final result, resulting in a low quality resource. Additionally, if the storyboard were incomplete, additional images, registering precisely in position, lighting and exposure, with the original set, may be required. Acquiring such images may be problematic outside of a well-controlled environment, or impossible if the studio set-up has been dismantled. This latter case would require a time-consuming re-shoot of the entire set of images (including those originally missed).

The previous paragraph touches on the idea of image interaction, in the context of image quality. The interaction itself is achieved through proprietary software development environments designed for image and object handling, such as Flash or Macromedia Director. Such an environment uses a film or theatre analogy to define objects and interactions. Images or other graphic objects belonging to casts are placed on the workspace (or stage) either manually at the time of production, or under software control. Interactions are defined through behaviour scripts which may attach to one or more objects or be defined for the whole movie. For example, a "turn force meter" behaviour in the ISE in figure 3 would attach to the force meter dial, and sense the position, button state and movement of the computer mouse or pointing device. The displayed image would then be selected appropriately from the image cast depending on whether clockwise or anti-clockwise motion about the dial centre were sensed. The programming itself is done in either native scripting languages (such as Lingo in Director) or through standard languages such as Java. In either case, the resulting scripts are highly structured and object-oriented, ensuring ease of maintenance and reusability of code.

The final testing and release phases of development follow normal procedures ensuring the correct functionality of the resulting resources. As well as standard software testing, this phase will also contain an assessment of the resources in terms of learning outcomes defined in the original concept.

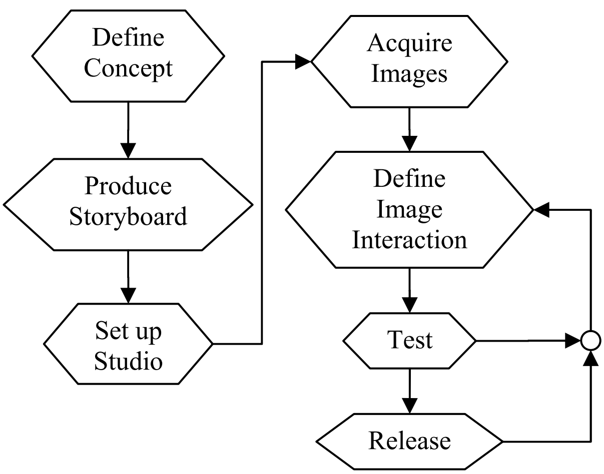

Figure 4. Outline production cycle of a typical ISE

Using and evaluating ISEs

The uses to which ISEs can be put depend on the requirements and context of the learners and of the required learning outcomes. For each ISE designed for distance learners, evaluation needs to address the following questions:

- Are students able to use the ISE effectively and efficiently?

- Are any instructions provided appropriate and easy to use, or is it appropriate that the ISE has no instructions?
- Are there any bugs in the software?
- How do students react to and perceive the ISE?
- Does the ISE achieve its intended aim, for example enabling the student to complete assessment tasks associated with the activity the ISE is supporting?

Wherever possible the evaluation is objective – recording and observing what students actually did, not what they say they did. Since it may only be possible to observe a small number of students in a controlled environment, it is frequently appropriate to make use of qualitative research methodologies

Case Study 1 - S104 Exploring Science. S104 Exploring Science is the OU's flagship level one science course, providing an introduction to the physical, life and Earth sciences. Distance learners are provided with course materials and on-line support and assessment. One aspect of the course is the inclusion of home experiments using both readily available household items and more specialist items provided by the OU.

One experiment requires students to set up a simple spectrometer for themselves, using a provided diffraction grating, a downloadable paper protractor and various household items. Most students find the experiment useful and enjoyable. However the experiment requires some skill and dexterity and moderately high visual acuity. Therefore an ISE version of the experiment has been produced for students who are unable to perform the real experiment for themselves.

Students use the ISE by themselves, without direct supervision from a tutor, so a set of brief instructions has been produced. However students are advised that in general they should just follow the instructions given to all students, in the Course Book (because they are, after all, 'doing the experiment', and keeping the experience as close to reality as possible is desirable). Tutors are given guidance on supporting students in using the ISE are also given guidance on marking assignments where the students' 'write up' is based on their use of the ISE.

Initial evaluation of the S104 ISE was via observation in the OU's Institute for Educational Technology (IET) Usability Laboratory. The IET Usability Laboratory was used to investigate the ISEs in a controlled setting. Quesenbery (2003) identifies the 5 dimensions of usability as effectiveness (the completeness and accuracy with which users achieve their goals), efficiency (the speed with which users can accurately complete their tasks), engagement (the degree to which the product is pleasant and satisfying to use), error tolerance (how well the design prevents errors or helps with recovery from those that do occur) and ease of learning (how well the product supports initial orientation and subsequent use).

Following accepted practice for usability laboratory evaluation (see for example Dumas & Reddish (1993); Stone et al (2005)), participants interacted with the ISE without assistance other than an initial briefing. They were however provided with structured notes. The participants' interaction with the ISE was observed live and recorded for subsequent analysis. A verbal think-aloud protocol was used, whereby the participants were asked to talk about what they were doing or trying to do. After the evaluation session itself, each participant was asked to comment retrospectively on the reasons for their actions and on their reaction to the ISE.

Six volunteer participants from the student and tutor body were observed, attempting the ISE. Students and tutors found the ISEs easy to use, and made comparisons with the real experiment, noting a connection between the ISE and reality. This was particularly revealing since the students had, by the time of the study, performed the real experiment, and had familiarity with the topic. On the whole, participants found the ISE and instructions clear and accessible. An issue arose due to the fact that two ‘blue lines’ were visible in the grating images, not the one described in the course text. The source of this was traced to the spectral response and sensitivity of the camera used in imaging the spectrum, which significantly differed from that of the human eye in the blue region. Hence, lines which are distinctly blue and violet to the eye both appear blue in the images. This issue is now explained and clarified in the ISE instructions to avoid confusion, but other aspects are deliberately not explained, to enable students to pursue their own investigation, as they would if doing the ‘real’ experiment.

Case Study 2 - SXR103 Practising Science. SXR103 Practising Science is the OU's level 1 residential school. The primary aims of the course are to:

- introduce the nature of practical work in the laboratory and in the field, and the skills of recording, reporting and interpreting data;
- develop confidence in working with a variety of laboratory and field equipment and techniques;
- introduce literature and web-based research;
- develop team-working, problem solving and oral communication skills.

SXR103 is the experimental counterpart to S104, in that the physical, life and Earth sciences are addressed in a way which emphasises the unity of science by taking an integrated approach. For example, one activity involves measuring low levels of radioactivity in rocks, combining skills in physics and Earth science. In another, the subject of the ISE discussed here, optical spectroscopy is used in environmental analysis.

For most students, SXR103 represents their first encounter with experimental science. A particular issue to address is the students' familiarity and confidence with equipment; it is such an issue that ISEs can be designed to address. To examine the effectiveness of ISEs in developing confidence and competence at residential school, a highly structured ISE based on the setting up and calibration of a simple grating spectrometer was created to assist students in the environmental analysis laboratory (figure 5a). The first steps are to set up the spectrometer by focusing the telescope and collimator. At this point in the ISE students can visualise what "in focus" means in the spectrometer context. To ensure this, the ISE is structured to give constructive feedback, and to require correct set-up before the student can proceed to the calibration section. As in the real activity, calibration uses an intense sodium discharge lamp. A consequence of the intensity is the presence of flares in the spectrometer view (figure 5b) which, to the inexperienced eye, may be mistaken for true lines. Since ISEs are based on images from real experiments, such imperfections are automatically present, and students can gain such intangible experience, which is often difficult to describe without examples, before encountering the real spectrometer.

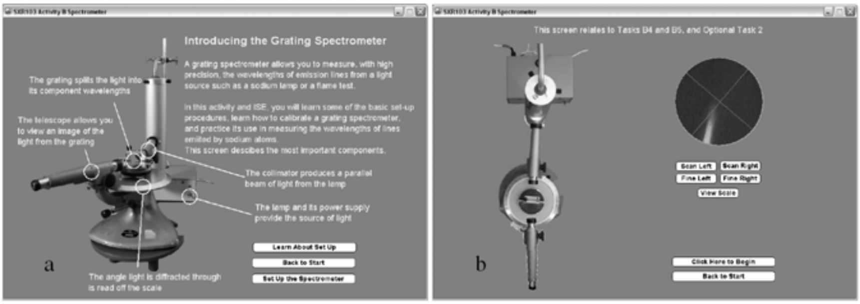

Figure 5. An ISE illustrating the setting up and use of a simple grating spectrometer. (a) An introductory screen allowing familiarisation with components. (b) Taking measurements with the spectrometer ISE, showing the presence of flares.

A typical residential school day comprises laboratory/field trip activities, with tutorials and workshops in the early evening. The spectrometer ISE was made available as an optional workshop activity over several evenings (limited to five students per session), to which students about to perform the environmental analysis laboratory were encouraged to come. In addition to observations of the students as they were working through the ISE, students were encouraged to complete a short survey concerning the usability and the benefits of the ISE.

Observations and responses from students were of value, but the ultimate test of the value of ISEs in developing confidence and competence is in the real laboratory. To this end, students who participated in the ISE workshop were followed up in the environmental analysis laboratory, and their response to the real spectrometer in the light of the ISE experience evaluated through brief interviews. As with the S104 study, numbers were insufficient for a statistically significant analysis, hence the outcomes should be viewed as qualitative.

The survey was structured as a series of objective questions in four categories; starting the spectrometer ISE, setting up the spectrometer, taking measurements and the value of the ISE. In each of the four categories, the responses were overwhelmingly positive. Students were able to access the ISE, using both on-screen and printed guidance. It was interesting to note that a number of students needed to perform the setting up more than once to get a satisfactory result - illustrating the connection to a real experiment. This ability to make a mistake illustrates the value of an ISE over a simple instructional manual. Making mistakes at the familiarisation stage means that the likelihood of students repeating the error in the real experiment is reduced. This outcome was emphasised in the final section of the survey on the value of the ISE, where students reported both an improvement in confidence for the forthcoming laboratory, and possessed a set of specimen data check against the real experiment.

Students were followed up in the laboratory, and informally interviewed as to their experiences. The value of the ISE was borne out through comments such as "I knew what I was looking for [when using the spectrometer]". Such comments addressed the use of the equipment, taking measurements and observation of spectral lines.

Conclusions

ISEs have been presented as an innovative solution to developing and enhancing laboratory practise and access for distance learners, and as a means of providing training and experience for teaching laboratories. Production methodologies have been discussed, and their close connection to the academic process of learning outcome design emphasised.

The use in the OU context of ISEs has been presented through two case studies of home-based courses and residential schools, and the use of ISEs evaluated. The evaluation has used a variety of methodologies including usability laboratory observation and surveys, and has demonstrated the effectiveness of ISEs as learning resources, and illustrated their range of effectiveness.

The overall success of the studies has been such that the reported ISEs have been formally included in courses, ensuring their benefits are felt by future cohorts of students.

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We acknowledge the inspiration of the pioneering work of Kirstein, Schumacher and Bacon in this area, and we thank Schumacher in particular for useful discussion.

We would also like to thank the relevant course production teams at the OU for their support and encouragement.

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Science experiments for communities of distance learners

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Abstract

A longstanding challenge for distance educators has been to provide a meaningful experience of science experiments. The difficulty is not only a matter of accessing equipment but also of framing the valuable social and collaborative experience that students enjoy in conventional laboratory settings. In this paper we describe the development of a module that allows individual students working at a distance to collaborate in groups, carry out simple but significant scientific experiments and acquire transferrable and professional experimental skills. Developing suitable experiments appropriate in a global distance learning environment is very different from devising a laboratory-based experiment. We report the results of a pilot with a small group of students, tested against the criteria for successful on-line collaborative experiments we have set for the new module.

Introduction

Experiments and observations are core elements of almost all science degrees. Their importance is enshrined in the values of the scientific community who see engagement with the ‘real world’ as being at the heart of the scientific method and is codified in regulatory frameworks, for example in the UK Quality Assurance Agency’s (QAA) subject benchmark statements for (i) physics, astronomy and astrophysics, and (ii) biosciences which include the following in the lists of required subject skills.

- how to plan, execute and report the results of an experiment or investigation (QAA 2008a)
- the ability to employ a variety of methods of study in investigating, recording and analysing material (QAA 2008b)

These stipulations reflect Nersassian’s comment that ‘hands-on experience is at the heart of science learning’ (Nersassian 2008). However, there are other reasons why science degrees include laboratory and field work. These arenas provide contextually rich opportunities for the acquisition and practice of a wide range of transferable skills. For example, communication, presentation and information technology skills, interpersonal and teamwork skills, and self-management and professional development skills are listed in the QAA’s subject benchmark statement for biosciences (QAA 2008b). In practising these social and collaborative skills, the students are introduced into a practice community that sustains them in their studies (Lave and Wenger 1991). Less formally, Clough (2002) comments that laboratory experiences “make science come alive’.

Universities have struggled increasingly to provide scientifically meaningful laboratory experiences, not only because of the escalation in sophistication and cost of contemporary science but also because of the demands made on student time and the consequent need to create flexible learning opportunities. Tactics to mitigate such problem have included the use of simulations and remotely controlled experiments. Ma and Nickerson (2006) have reviewed this area: they conclude "Perhaps with the proper mix of technologies we can find solutions that meet the economic constraints of laboratories by using simulations and remote labs to reinforce conceptual understanding, while at the same time providing enough open-ended interaction to teach design."

Distance educators have been forced to confront not only these problems (Scanlon et al 2004, Colwell et al 2002) but also the need to both create effective learning communities and to meet required skills outcomes of collaboration etc. without direct face-to-face contact. The difficulty is not only a matter of accessing equipment but also of framing the valuable social and collaborative experience that students enjoy in conventional laboratory settings. The experience of the distance-taught student must be broader than just designing and carrying out experiments. It should encompass the collection of data sets susceptible to statistical analysis, the combination of sets of results and the discussion of design and outcomes in a group setting.

In this paper we describe an approach that allows individual students working at a distance to collaborate in groups, carry out simple but significant scientific experiments and acquire transferrable and professional experimental skills. The aim has been to both emulate conventional approaches and add value derived from a student body that may be world-wide.

In succeeding sections we will discuss a module that has been designed to exemplify this approach and the experience gained from a small scale pilot. Finally we will consider the constraints and opportunities revealed by the initial planning and development.

The 'Science Experiments' module.

The United Kingdom Open University (UKOU) offers undergraduate degrees in both named science disciplines and a more general 'open' BSc. The curriculum is modular with courses ranging from 100 hours of study to 600 hours of study. UKOU students, who are mostly adults with a wide range of ages, study part-time at home. Anybody can enrol for any module: admission is open and there is an active focus on widening participation. The UKOU is one of a very limited number of distance teaching universities that offers experimental science degrees that meet required benchmarks. Experimental and observational learning is provided through residential and day schools, and sometimes by the use of elaborate simulations, for examople the Virtual Field Trip (The Open University 2003) and home experiment kits. Newer approaches are reported in this meeting (Hatherly et al 2008).

The 'open' admissions policy leads to students with a wide variety of backgrounds entering Level 1 study of science. A significant minority have very limited scientific skills and knowledge and may have problems of access to scheduled face to face learning. They lack opportunity to make 'science come alive' with damaging consequences for long term engagment. Furthermore, on a global educational environment where students on a course may be studying anywhere in the world, face-to-face tuition is not possible.

A new module 'Science Experiments' is being developed to support such students. It is based around the propositions that; it is possible to engage in meaningful and interesting science experiments at home without specialist equipment, computer based communicatins can enable supportive collaborative working between students and, most importantly, that a course based arond such ideas will enable the delivery of learning outcomes needed for an introductory (foundation) module on science experiments.

The module is designed for 100 hours of study over a period 12 weeks. The learning outcomes, as expressed for students are the following.

> *Knowledge and Understanding* - (1) Understand that detailed planning is necessary for successful and safe experimentation. (2) Identify the general characteristics of experiments that will yield valid scientific conclusions. (3) Understand the role of hypotheses in experiments.
>
> *Cognitive skills* - (4) Convert scientific questions into hypotheses that can be tested experimentally. (5) Select and design appropriate experiments to test hypotheses. (6) Evaluate the strengths and weaknesses of experiments and their design
>
> *Key skills* - (7) Prepare and present recorded results accurately and in an understandable form. (8) Cooperate effectively with others in a shared project. (9) Organise your course activities effectively.
>
> *Project and Planning Skills* – (9) Make and record measurements and observations accurately. (10) Reach conclusions that are supported by the experimental results.

The module includes a series of basic science activities (experiments and investigations) that cover a range of disciplines, and use equipment that students have available or could make easily. They are designed to take advantage of group working, e.g. provide sufficient spread of results to use statistical methods for analysis, thus motivating or requiring collaboration. The experiments are, as far as possible, stand-alone, without the need to teach additional science knowledge. The learning resources include a Good Experimenter's Guide that covers the key experimental and analytical skills.

Students will work in teams of ten, linked using a virtual tutorial room provided by the Elluminate (2008) web-based tools, each team staying together for the whole course. The group will share a common task following the dictum of Whitton (2004) that shared tasks are more effective in community building than overtly social activities.

Assessment includes short interactive computer marked assignments with personalised three-level feedback and submission of a portfolio that includes evidence of both personal experimental work and the use of the data by other members of the group.

In designing this module, there are several design issues or criteria that must be addressed. We have established criteria for the module, based in part on the outcomes of the pilot, reported in the next section. The four criteria are:

1. The module as a whole and the individual activities must facilitate effective learning.
2. The module must involve the student in scientific activities that are scientifically accessible and stimulating.
3. The activities must be culturally appropriate across a wide range of possible students.
4. The technologies required must be accessible and robust.

Bennett et al (2004) have discussed the difficulty of creating effective online learning in groups of students. They argue that the technological capability must be exploited effectively within an appropriate pedagogy. We may therefore expect considerable challenges in meeting these criteria.

The collaborative task centred design is intended to meet Criterion 1 by promoting the emergence of understanding through dialogue, an approach with constructivist elements within a structured context. Forum mediation and interactive computer based assessment with feedback allow the student considerable autonomy whilst providing opportunity for personal guidance.

The final list of experiments is not yet finalised, but a pilot has been carried out using suitable experiments drawn from a course on the human senses.

Pilot experiment

As part of the process of developing the module we have run a pilot experiment with students. The aim of the pilot was to develop a protocol for group participation in experiments.

Nine students were recruited from the overseas cohort of a group studying a course on the human senses as these students were already participating in on-line tutorials. The communication methods used were First Class conferencing (Open Text, 2008) for asynchronous communication and delivery of resources and SKYPE (2008) internet conference calls for synchronous communication. Experiments relating to the course that the students were studying were selected for trial. The experiments were:

(a) Perception of words – comparison of the words slit and split
(b) Measuring visual processing delays using a pendulum – the Pulfrich effect
(c) Measuring the difference between visual perception with interference and visual perception without interference – the Stroop effect

A similar structure was used for each experiment. The organisation of the experiment on the Stroop effect gives an example of the structure of an activity. Students were sent a zipped file of a video podcast that set the scene. In addition they could download and print off two Stroop test cards, one with adjectives printed in any one of six colours (21 words in all) and one with 21 words each of which was the name of a colour but printed in an incongruent colour, providing interference with the visual perception. Two sets of instructions were provided for download, an experimenter's sheet and a subject's sheet. Each student was asked to carry out the experiment on at least one subject, record the time taken for the subject to read out the words on the card and to come to a SKYPE conference prepared to discuss the hypothesis they were testing and the results obtained. A group set of data was accumulated in an Excel spreadsheet posted on their First Class conference. Each SKYPE conference was repeated once for students in a different time zone.

Discussion of the experiments in the conference session by the tutor was designed to elicit debate about the hypothesis being tested, the experimental procedures, the precision of measurements, combining of data and the conclusion from the experiment. These are all essential components of scientific experiments and, we believe, are best exemplified by group discussion. This assertion, part of Criterion 1, is one we hope to test in the future.

At the end of the course the nine students who took part were invited to complete a questionnaire. Six of the nine returned them.

Outcomes from the pilot

The number of data points required for experimental results to be meaningful is generally much greater than the manageable size of a group in a synchronous conference call, so each student needs to collect a set of data themselves rather than just one observation or measurement. As a consequence, the experiment(s) chosen for on-line group work must be sufficiently stimulating to motivate independent collection of data sets (Criterion 2).

Where experiments are offered globally there may be a need for alternative version to cope with language differences (Criterion 3). A student carrying out the Stroop experiment commented:

'(I) didn't have any English mother tongues to experiment with'

The performance of the technology used to link the student group is still not robust enough for a smooth conference every time. The maximum number of students who were successful in connecting to the conference at the same time was five (Criterion 4) and only one student had no technical problems during the pilot. Technical problems with the video podcasts were also reported by two students.

Although full instructions and a video podcast were provided for experiments, this left scope for discussion of methods, as one student commented:

'*I conducted this one with (a) friend. It was interesting to discover, how two people on the same course with the same instructions and having seen the intro-video still have differing ideas on how to set up and conduct the experiment.'*

Conclusions

Developing effective on-line collaborative experiments is challenging, even more so when a core aim is to centre them on 'hands-on' experiments that convey the experience of practical science. The pilot experiments that we carried out show that the technology of communication can get in the way of the pedagogy but they also showed that with sufficiently interesting experiments students are motivated to collect data collaboratively and take part in group discussion. There is a definite tension between the size of group that can be handled in a synchronous conference and the size of the data set needed for meaningful conclusions to be drawn from an experiment. So, in addition to being interesting and motivating, experiments must be designed to produce sufficient data from a small group of experimenters – but a small group in a global setting. These design criteria substantially constrain the choice of experiments, but delivering hands-on experiments to distance learners is fundamental to our science programmes.

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Practising computer networking problem solving using learning objects on mobile phones

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Abstract

The use of mobile technologies including mobile phones to deliver learning objects to support students taking distance learning programmes is causing much interest at the UK Open University (OU). This paper introduces and reports on the development of leaning objects to assist students on the Cisco Networking course to practise subnetting, a particular feature of the addressing used to identify all devices on the internet and the majority of today's computer networks. The ability of students to manipulate such addresses is beneficial both to their studies and their practice. A discussion of why this application was developed for mobile phones will be given. This will be followed by a description of its development, including the rationale for including the various stages of practice. The presentation concludes with a report on progress to date, feedback from current students who have had the opportunity to work with the application and plans for future work.

Introduction

Ubiquitous computing is a paradigm in which users access a variety of computational devices in the course of every day life, often without even being aware of so doing. This may be quantified by the realisation that the number of people accessing the internet from mobile phones is rapidly catching up those accessing from computers as detailed by Wright (2006). So-called smart-phones can perform the majority of tasks possible from the desk-top PC and although the current economic situation suggests a down-turn in the adoption of these devices, as suggested in Hamblin (2008), 36 million devices were still sold world-wide in the third quarter of 2008. The opportunities afforded by mobile technologies are coming under scrutiny by academics and educational developers to provide innovative materials to enhance study techniques. However, there is little evidence as to how educational materials might be best presented or how students might engage with such applications. A successful application to the Centre for Open Learning in Mathematics, Science, Computing and Technology at the UK Open University (OU) has given opportunity for research with students studying the course "Cisco Networking (CCNA)", The Open University (2008). These students were expected to be regular users of mobile technologies and to be open to trying innovative teaching methods alongside the more traditional distance teaching and learning provided by the University.

Mobile learning

There is considerable interest in the use of alternative and innovative ways of delivering learning to students studying at a distance within academic communities. At the OU delivery methods have changed as technology has evolved. Radio and television broadcasts by the BBC supplemented written texts in the early days and brought to students learning opportunities outside written text to support and enhance their experience. Audio and video cassettes replaced the need for students to 'tune-in' at specific and often difficult times. It was not unusual for OU students to study very late at night or early in the morning, outside the main programme broadcasting times. Latterly, CDs and DVDs along with online, download and web services have replaced magnetic media. The OU's VLE has become a major delivery tool, but paper based materials are still popular with students, not least because they are portable allowing study when the student chooses, not at a predetermined study location or even within range a suitable wireless data network.

Mobile learning more than fulfils the requirement to enhance learning opportunities by being spontaneous, personal, informal, contextual, portable, ubiquitous and pervasive, after Kulkuska-Hume (2005). However, students' use of digital technologies afforded by mobile technologies in education may actually impede learning according to Staudt (2005) due to having to adjust to different platforms. He suggests that the value offered by the differing platforms may not be recognized because the technology simply gets in the way.

Most mobile phones, even the older models, offer a multitude of applications although many users still use a phone simply for talking, texting and telling the time according to Burgon (2008). By choosing a mobile phone as the learning platform the familiarity of use should overcome any potential barriers. A set of menu-based learning objects, which are no more demanding operationally than simple messaging, will be provided.

Learning Objects

The success of computer internetworking is due in no small part to the simple addressing structure provided by Internet Protocol version 4 (IPv4). Correct management of network addressing ensures that computers communicate effectively and efficiently. Students can benefit both in study and practice by gaining a good understanding of IPv4 structures and to practise using them in real situations.

To understand IPv4 addresses students need to be able to undertake a number of processes which may be seen as independent learning objects covering:

- decimal to binary conversion;
- binary to decimal conversion;
- logical AND functions;
- address classification.

all of which may be practised both separately and in an integrated format according to Dye et al (2007).

The majority of mobile phones support Java ME programming language. A decision was made to exploit that opportunity by developing an application to introduce and support the leaning objects listed above along with a selection of multi-choice response questions allowing students the opportunity to rehearse for the various online tests and examinations offered by the Cisco Academy.

The layout and coding of the application was outsourced to Briggs (2008) at Luzia Research which specialises in educational tools for mobile platforms. All the content was written and tested by me. The final application, once it has been downloaded, installed and initialised, displays a menu as shown in figure 1.

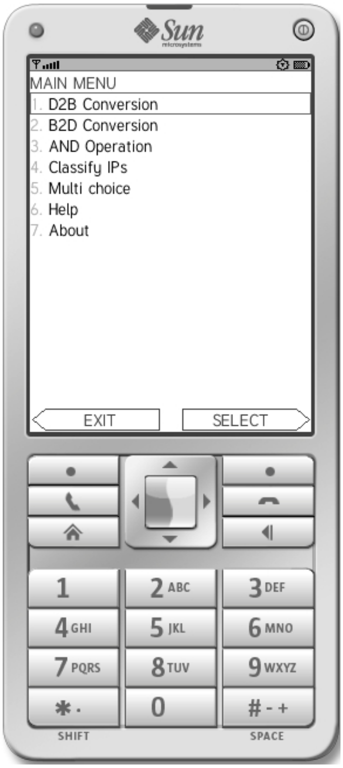

Figure 1. The Main menu of the Subnet Exerciser displayed using the Sun Java Wireless Toolkit, Sun Microsystems (2008)

The student chooses the appropriate exercise using either a keypad digit or scrolling up and down with the central cursor control keys. The two programmable buttons situated immediately below the Exit and Select bars at the bottom of the screen move the student to new screens. These buttons are used extensively within the exercises and are identified and programmed by the student during the initialisation procedure. The student may leave the application whenever the Exit bar is displayed, but due to the nature of the various exercises, the use of these two buttons changes.

The challenges in adopting a mobile platform are around the limitations of the user interface, both screen size and keypad. This has meant making some compromises in operation, and student feedback will be valuable in deciding whether the operation is feasible or just plain annoying.

Decimal to binary conversion (D2B). The IP address is always presented in a decimal notation so the first exercise is to convert decimal numbers to binary. The student is presented with a decimal value in the range 0 – 255 displayed in figure 2. Immediately below this is an 8 bit binary number, set to zero. The student sets the binary digits (bits) accordingly to obtain the conversion. To assist the student the binary weightings are shown and as the user sets bits to 1 the remainder is displayed. This assures students become familiar with the positional weighting of the bits. It is hoped they will recognise the value of the pattern so that with practice the conversion will become second nature.

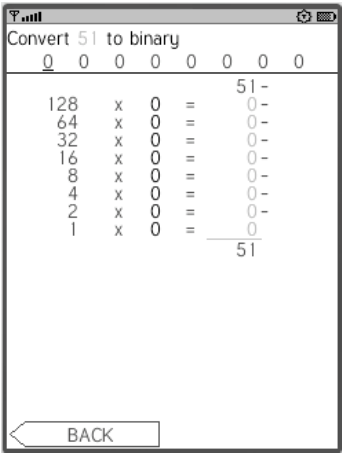

Figure 2. The D2B exercise showing the opening page

A Next bar at the bottom right, as shown in figure 3, is not displayed until the remainder is zero, i.e. the conversion is complete and correct. A new display confirms the result and prompts the student to choose either another D2B exercise or return to the Main menu. No additional support is offered at present as there is sufficient course material to cover the mechanics of D2B conversion.

Binary to decimal conversion (B2D). The practice of binary to decimal conversion is thought to be somewhat more straightforward and so a simpler display is offered as shown in figure 3. On being presented with a binary value the student inputs the weighted value for each bit separated by the plus operator (zeros are ignored), input from the star key. Pressing the hash key causes the sum value to be output. If correct the student is prompted to the next screen, if wrong to try again.

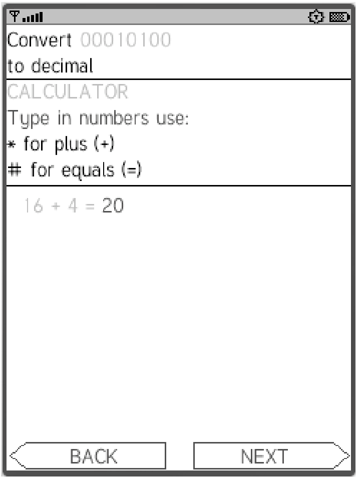

Figure 3. The B2D exercise showing a correct result

For speed and to avoid frustration the value may be input directly followed with the hash key, there is no need to perform the addition on the screen.

AND function. This is the most complex of the exercises involving several steps as the opportunity to continually practise conversions has been taken. The exercise provides two decimal values and requests the result, also in decimal. Steps 1 and 2 are to convert the two decimal numbers to binary. Step 3 bids the student perform the AND function, the final step is to convert the resulting binary number to decimal. Figure 4 demonstrates the AND function in progress.

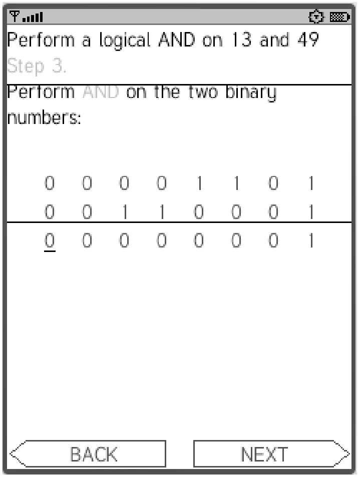

Figure 4. The correct logical AND function applied to 2 binary numbers

In all cases the conversions have less support in order to allow a higher level of practice; the object being to allow the processes learned in earlier exercises to be rehearsed.

Classify IPs. This exercise represents a departure from the numeric nature of the earlier learning objects in that it asks students to classify IP addresses by their value. There is no need to convert them to binary, rather students need to recognise from the value the address classification and whether it is categorised as public or private. This is very important when designing networks and allocating new addresses. The student is presented with an IP address in dotted decimal notation and asked to select the classification from the list using either the digit key or the cursor key, as shown in fig. 5.

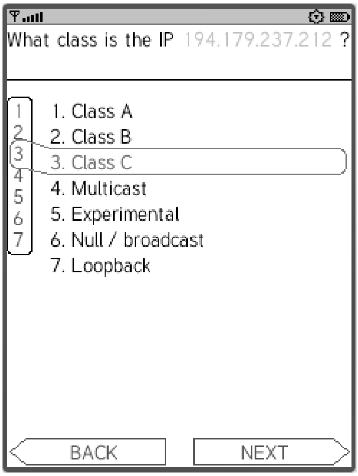

Figure 5. The classification of IP addresses

The next screen reports whether the result is correct or not, again each with an explanation, in case the student with a correct answer just guessed. The public or private category is then tested and again the result is commented upon. Throughout, the student can return to the previous page for clarification or to change the response.

Multi choice. The final exercise is a set of multiple-choice answer questions of the type used by Cisco within their Academy. All questions have been written to the specification required by Luzia Research for this type of exercise. This allows for a question page, a set of up to 6 answers to choose from, any number of which can be correct depending on the question, and a feedback page if the answer is incorrect.

Questions are grouped randomly into sets of ten which are presented to the student from a pool of fifty (which have been written). A score is given at the end of the set. Students may move back and forth through the question and answer pages before making their choice(s). Pictures may be used as well as text within the questions. As an example Fig 6 shows the choice of answers to a question asking about addresses. Note the student is prompted to choose two answers from the four offered.

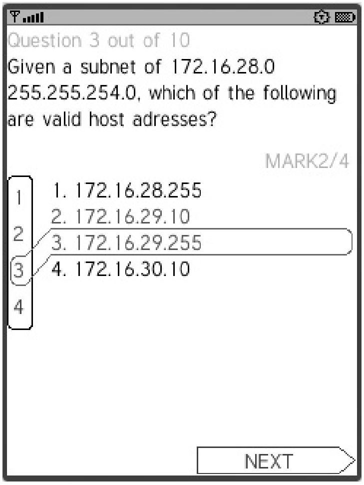

Figure 6. A question and choice of answers with 2 and 3 selected

Help. This last menu option contains support for each of the learning objects, the learning outcomes of each exercise and additional teaching support.

The Student experience

The application was released to over 600 students at the end of March, 2008. Messages were posted into the two online student forums (electronic conferences) that support the Cisco Networking courses. Each message offered students three options:

1. to load the application directly on to the phone from a designated website;
2. to download the application to a PC and upload using a method appropriate to phone;
3. to download the application to a PC and use the Sun simulator to run the application.

Loading the application. Over a third of the student cohort accessed the forums' message with more than twenty percent downloading the files for use with options 2 and 3. Unfortunately, it is not possible to separate these two options to know how many are actually taking option 3 but experience suggests this was less popular. Students were supported by two online forums which enabled them to receive support, make comments and report bugs. No official questionnaire was offered to students because the OU has strict rules regarding sending questionnaires to students and so feedback has been garnered from comments through …?

Option 1. Students who had chosen option 1 were advised to check whether their phone was suitable for running the application before attempting to install it. This was important since not all phones can support Java and/or have suitable displays. Luzia Research have a commercial website which offers a phone check service and recognises over 700 different types of phone. Once satisfied that their phone was suitable students simply directed their phone's browser to the URL supplied and followed the link found there. The application then downloaded and self-installed automatically, without the need for intervention by the student.

Option 2. This would only be used by students with reasonable knowledge, since it required familiarity with the transferring of applications between a computer and a phone. There is no way to tell how many students chose this option but no problems were reported.

Option 3. This was provided for students without suitable phones or who chose not to use their phone for this purpose. They were directed to the Sun Java Toolkit for CDLC website where could download and install a phone simulator application to enable them to run the program on their computer.

Students' comments

Students were mostly very welcoming in their appreciation of the Subnet exerciser application:

"Downloaded and easily installed on my Nokia N70. Program runs well and very easy to setup."
"I would say that this is a very worthwhile tool for anyone learning to subnet."
"Definitely an excellent idea to be able play with subnetting on the mobile. D2B & B2D exercises are 24ct gems."
"Easily installed on my phone. Program runs well and very easy to set up. I would say that this is a very worthwhile tool for anyone learning to subnet."
"The idea is great and offers a very useful way to kill 10 minutes here and there."
"I must say that I found the program very useful and use it at least twice a week."
"The idea is great and offers a very useful way to kill 10 minutes here and there."

Some students reported problems but were still positive:

"It takes a bit of getting used to - but then again so does riding a bike."
"It did take me a few hours to work out which buttons did which function on my phone, but this was probably down to me rather than the program!!"
"It did take me a few hours to work out which buttons did which function on my phone, but this was probably down to me rather than the program."
"When it opens up you get a Next in the bottom right hand corner and on pressing the corresponding key on the keypad nothing happens, when I hit up arrow it works. It doesn't seem intuitive but once you get going it's great."

A couple of students were slightly negative:

"I've used it a few times, found it useful but a bit limiting."

"I have been unable to use the Exerciser to any great extent and this is because it is not working fully on my phone."

And one student was really did not like it at all:

"I don't like the idea of using my mobile phone for practising sub-netting as the screen display isn't very big and it's definitely not something I'd ever use."

Fortunately, this was a minority representation and several students wanted more topics covered:

"How about expanding the question into other areas besides subnets? Perhaps a choice of categories/questions based alongside CCNA 1, 2, 3 or 4 to help with studies?"
"I would like to see some more practice questions available and the ability to download more questions. These could even cover different subject matter from the CCNA curriculum e.g. router commands."
"Like other people have mentioned, I would like to see some other CCNA 1 - 4 stuff included."

Overall, the Subnet exerciser received a very warm reception from students. Twenty percent of those accessing the original message responded. Some experienced problems, one did not like it at all, but that apart, all recognised the advantages of supplying useful applications on mobile phones.

Occasionally students reported trouble finding the program once it had installed as they were unfamiliar with downloading and running applications on their phones. Fortunately, most phones appear to have a similar file structure to my own and so help could be given. Evidence shows most students have been able to access the application as long as they have suitable phones

Many requested more applications of this type, particularly of the multi-choice answer which would allow them to practise for the various tests that Cisco uses in its Academy on their phones. The teaching exercises seemed of less interest, only a couple of students really appreciating the availability of this feature.

Conclusion

The project achieved what it set out to do: to develop a set of learning objects for mobile devices that would enhance the students' learning experience by developing skills. Each learning object incorporated a different activity to allow rehearsal of each skill necessary to become fluent in subnetting. Student feedback did not tend to specify which aspects were most useful, but the popularity of the multiple-choice-type questions allied to requests for additional subject areas indicates that this may be the most useful activity for students studying with the Cisco Academy, which itself uses this type of formative activity to allow students to check their own progress. I see no reason why the current Cisco materials could not be formatted for mobile use and, as I write, an approach has been made to Cisco.

Practically, students appear not to have had too many problems accessing, loading and running the application providing they followed the instructions. However, the use of Java has meant some students were not able to use the application. Consideration is being given to developing the application to run within the phone's browser which will effectively make the application independent of the platform. This is the subject of my on-going project development.

Working with a third-party developer who is experienced in the area of application development for mobile technologies proved invaluable. The development of the activities and writing of materials was made very simple by using predefined templates and keeping to tried and tested practices. Even now, not all the opportunities offered by the technologies have been explored. Within the question and answer database for the multiple-choice questions, pictures and graphics can be used. Results can be uploaded and banks of questions downloaded depending on the individual student's progress.

This project has shown that there is a place for enhancing students' distance learning by offering them the opportunity to use a mobile platform. Of course it is dependent on students having access to the appropriate technologies, but with the cost of suitable mobile phones now below 50 euros, i.e. the cost of an average textbook, no one should be disadvantaged. That said, an alternative will always be available from The Open University to ensure widest possible student participation.

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Physical media: Using new media to explore science in arts education

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Abstract

This paper presents the use of a dataflow visual programming language and video game controller for investigating physics in a creative context. The programming language allows real-time simulation, analysis and graphical display of a physical system while integrating accelerometer data from the game controller to affect the system. Specifically, a forced damped harmonic oscillator system is developed as an interactive demonstration. Topics covered include vectors, position, velocity, acceleration, differential equations, forces, gravity, Hooke's law, energy, phase space, power and lissajous figures.

Introduction

Digital technologies are changing the way ideas are represented, developed and communicated across academic disciplines and in the general culture. The turn toward computing enables educators in science and mathematics to engage students in new ways and contexts.

New media such as video game technologies, multimedia programming languages, and those offered by Web 2.0 provide powerful tools for developing new modes of teaching. In addition to communicating subject matter, we can demonstrate to students how mathematical and technical literacy bolsters one’s expressive capacity in an increasingly digital culture. Introducing students to new media in a creative context provides opportunities within arts curricula for teaching quantitative reasoning. Specifically, we can exploit an intimate relationship between physics and new media.

The following research represents part of a short course on physics in the context of an undergraduate class in interactive media at Sarah Lawrence College. This particular mode of introducing basic concepts in physics, using new media, could easily be adapted to fit into physics curricula. The three major technologies used are already well known to the physics community as valuable educational tools. They are accelerometer-based game controllers, dataflow visual programming, and Web 2.0 applications. We present the use of these tools to develop a physically responsive simulation of a damped harmonic oscillator.

Previous Work with New Media in Physics Education

Dataflow Visual Programming Languages. As described by Johnston et al. (2004), dataflow visual programming languages (DFVPLs) enable users to develop software projects by assembling directed graphs that specify data processing routines. The schematic representation is constructed on a virtual canvas where boxes, functioning as data operators or user interface elements, are linked together with arrows that indicate routes of dataflow. The computational structure is explicitly shown since the logic and the graphical user interface (GUI) of the program are built side by side on the same canvas. DFVPLs such as Matlab's Simulink or National Instruments' LabVIEW have gained use in the science community for simulation and experiment design. For users without extensive programming experience using text based languages, DFVPLs are exceptionally useful tools for data acquisition and processing. Undergraduate physics curricula have integrated their use in advanced laboratory classes, as detailed by Moriarty et al. (2003) and Essick (1999).

Since the 1990s DFVPLs such as Pure Data and Max/MSP have gained popularity with artists and composers (Winkler, 1998). Though originally developed for composing electronic music using the MIDI protocol, these languages have benefited from mixed private and open-source development and now include a full array of capacities for data acquisition and processing, networking, and graphics. Since Simulink and LabVIEW are cost prohibitive for many institutions, free or inexpensive alternatives from the artistic community should be considered for use in education. Current scholarship in physics education, such as the nearly exhaustive computational resource list by Landau (2008), has failed to recognize the potential usefulness of these languages.

Wii Remote Controller. The Nintendo Wii remote controller is one of many consumer electronic devices (cell phones, cameras, laptops) that now contain accelerometers. An integrated chip in the Wii remote, reports the force of gravity relative to its frame and pseudoforces associated with the frame's acceleration. The Wii remote controller uses an ADXL330 3-axis accelerometer to gain information about the controller's orientation and movement. As reported in the manufacturer's data sheet (Analog Technologies Inc., 2007), the accelerometer measures approximately +/-35 Newton at 0.3 Newton resolution, reporting numbers between 0 and 255 for each axis. These data are transmitted wirelessly to the remote's host, using standard Bluetooth protocol.

The open-source software community has released free programming libraries that permit any Bluetooth enabled computer to communicate with the Wii controller. Physics teachers in the United States (Horner, 2008) and Europe (Vannoni and Samuele, 2007) have taken advantage of these resources, using the Wii remote as a low-cost accelerometer in student lab exercises. In the arts community, Akamatsu (2007) used the open source development to enable data acquisition from the Wii remote through Max/MSP.

Web 2.0. Following O'Reilly (2005), we use the term Web 2.0 to name the array of internet-based technologies that enable collaborative communication and publishing. This includes wikis, blogs, social-networking sites, and video sharing. Web 2.0 is already used in physics education. A number of high school and undergraduate physics educators have set up social networks for their classes to increase participation and deliver online content. As reported by Gintaras and Garret (2008), classroom blogs help students develop more positive attitudes toward physics. Online video sharing has been shown to be an effective tool for delivering educational content in physics. MIT's online physics lectures (Lewin, 1999) demonstrate internet video's efficacy in science education.

Physics for Art Students: Simulation

This course material was presented to college art students without substantial knowledge of physics, mathematics, or computer programming. A DFVPL provides an excellent environment for introducing basic mathematical concepts and procedures to such students since the choreography of a given computation has a visually-explicit operational structure. Below, we review some fundamentals of our specific programming language, Max/MSP; introduce two basic computational modules; and show how we integrate these modules to represent a one-dimensional system.

Spatial Grammar. In Max/MSP, a program is called a patcher. It consists of objects, the basic building blocks of the program, connected by patchcords. The user adds objects to the patcher by means of a drag-and-drop interface and integrates them with one another by clicking and dragging patchcord connections. Data flows in the downward direction, routed from outlets (on the bottoms of objects) to inlets (on the tops of objects). When an object, such as a binary operator, has two inlets (one for the right operand and one for the left operand), it will not output the result of the operation until the left operand is input. Therefore data cascades downward and from right to left.

The Accumulator. Figure 1 shows one the fundamental programming motifs. We call it the accumulator since it accumulates numerical values in a running sum. It is used in almost every programming project in the class, so it serves as a logical starting point for teaching.

The accumulator consists of an addition operator sandwiched between two number objects. The number (float32) object outputs a specified number when it either receives a number through a patchcord connected to its inlet or has a number entered into it manually through the mouse and keyboard. Remember, the addition operator will not output anything until the left inlet receives an input. The accumulator thus functions as follows: First, a number comes into the top number object, and that number is passed down to the left inlet of the addition object. Next, the addition object performs the sum and the result is passed down to the lower number object. Finally, the lower number object displays the sum and passes it back to the addition operator as the right operand.

Given a sequence of incremental values Δx_n, the accumulator performs the summation procedure, $x_n=x_{n-1}+\Delta x_n$, at each step. Students may see how the accumulator works through inspection, by sequentially entering numbers in the top and seeing what comes out the bottom. The challenge here is not only to get students to comprehend the algorithmic structure but also to understand the differential relation between Δx and x as embodied in the accumulator.

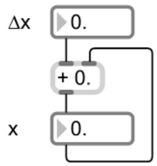

Figure 1. The Accumulator

Graphing. To assist students' learning, we provide a graphing module that helps them visualize the numerical relationships being investigated. The graphing module, used in figure 2, plots the last 256 numbers that are routed into it. The vertical slider, on the left, sets the scale of the ordinate, shown on the right side of the graph. Students may use the graphing module without understanding its inner workings. Those who are curious may double-click on the module to expose the computational plumbing inside. For visually inclined students, combining the accumulator with two graphing modules helps elucidate the relationship between Δx and x.

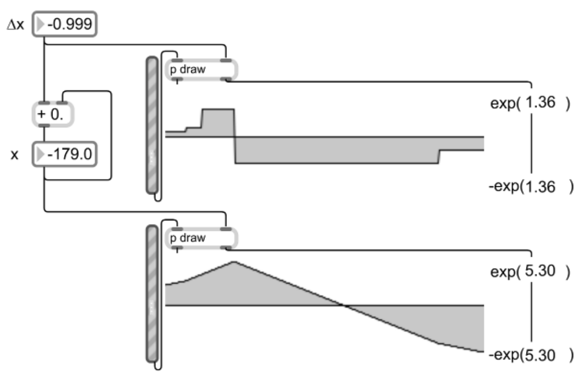

Figure 2. Graphing x and Δx

Acceleration, Velocity and Position. With slight modification, the accumulator can be used to represent the integral relationship between velocity (v) and position (x), $x=\int v*dt$. Of course, we are really only approximating the integral, breaking it up into discrete time intervals over which we assume constant velocity. Here, we use the Riemann sum, $x=\sum v*\Delta t$. The integral relationship between acceleration (a) and velocity (v), $v=\int a*dt$, may also be represented using a modified accumulator, which calculates the Riemann sum, $v=\sum a*\Delta t$. Now we need only connect these two modules to generate a mechanism for calculating a sequence of position and velocity values given a sequence of acceleration values. This is shown in figure 3.

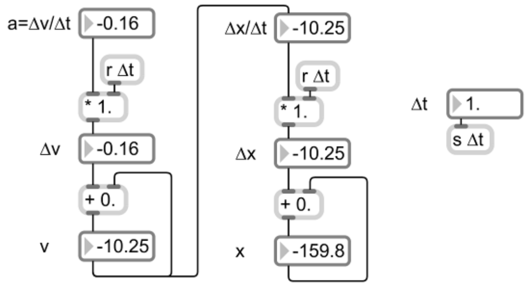

Figure 3. Acceleration, Velocity and Position

Force. Newton's second law tells us that the net forces on a particle are equal to the mass times the acceleration. This is the well-known F=m*a. The acceleration can thus be written a=F/m. Therefore, to complete our simulation of a one-dimensional system, we need only define a force function to determine the acceleration values for each computation cycle. The force, F(x,v,t), may be a function of position, velocity and time. Any number of one-dimensional systems can be simulated using this approach.

Damped Harmonic Oscillator. We model the damped harmonic oscillator system by defining a force function, F=-k*x-b*v. This equation consists of two terms. The first, –k*x, represents a "Hookean" restoring force in which k is the proportionality constant between the restoring force and the displacement from equilibrium, x. The second term, -b*v, represents a damping force in which b is the proportionality constant between the velocity and the damping force. The total force is composed using C-like expressions with the Max/MSP's "expr" (expression) object.

Figure 4 shows a complete simulated damped harmonic oscillator system. Note that, for simplicity's sake, the time increments and the particle mass are taken to be unity, Δt=1 and m=1. After being led through the construction of the simulation, students can investigate the properties of the system by playing with the proportionality constants k and b and the initial conditions for position and velocity. The "qmetro" object is used as a metronome to trigger the simulation's sequential computational cycles. Once turned on, the simulation runs on its own without further intervention. Parameters can be modified while the simulation is running.

Students can observe for themselves the sinusoidal signal that the undamped oscillator generates. It is useful to ask students to explain the qualitative relationship between the spring constant, k, and the frequency of oscillation. In addition, posing the question, "What is changing and what is staying the same in the undamped oscillator?" can help introduce the concepts of conservation and energy.

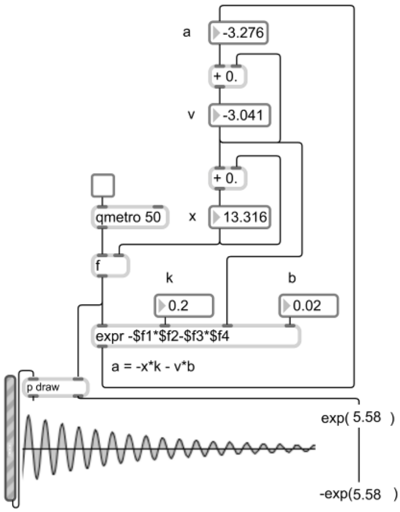

Figure 4. Damped Harmonic Oscillator Simulation

Energy. During each cycle of the simulation, the potential, kinetic and total energy of the oscillator is computed by means of the formulas PE=1/2*kx^2, KE=1/2*mv^2 and E=KE+PE. We use the graphing module to plot the results. Students initially observe a constant total energy for the undamped oscillator (b=0); then application of a damping force (b>0) causes decay in the total energy. In the case of the undamped oscillator, small fluctuations in the total energy are present due to numerical rounding errors. Using Δt as an additional variable minimizes these fluctuations.

Creating a phase space plot--graphing the particle's position versus velocity over time--provides another way by which students can think about energy conservation. The undamped oscillator traces an ellipse in phase space whereas the damped oscillator traces an inward-moving spiral. Students can observe a relationship between the energy of the oscillator and the area of the ellipse carved out in phase space.

Sinusoidal Driving Force. To introduce a driving force requires only that we modify the force function to include additional components. In a physics class, the external force applied to a harmonic oscillator is typically sinusoidal. Following suit, we introduce a driving function of the form A*cos(ω*t+z) wherein the parameters A, ω and t can be modified by the user while the simulation is running.

Students apply the sinusoidal driving force to the undamped oscillator and make observations. Using the graphing module to plot the driving force alongside the position and velocity graphs helps in visualizing the dynamic situation. Students' tuning the driving function by varying the ω parameter, with the goal of increasing the oscillator's energy, is a game that elucidates important behavioral characteristics of the system.

Resonance occurs as the frequency of the driving function approaches that at which the system naturally oscillates. The phenomenon known as beats can be observed near resonance, as shown in figure 5. When the driving force is in phase with the oscillator, energy enters the system; and as it comes out of phase, energy leaves the system. This creates a slowly fluctuating envelope for the underlying oscillation. Once we tune the driving frequency to match the system's natural oscillating frequency, its energy will increase without bounds. As in real life, the simulation will eventually "break," as the numbers exceed what the computer can represent.

With the introduction of damping, students may observe the beats phenomenon (transient solution) giving way to a stable oscillation (steady-state solution) with the same frequency as the driving force.

Physics for Art Students: Interaction

Wii Driving Force. At this point in the project we introduce the Wii remote controller to supply the external driving force. The force measured along one of the axes is calibrated and routed as the external driving force input. Use of the Wii remote not only provides an opportunity to connect physics to everyday aspects of student life (playing video games) but also allows them to interact with the simulation in a way that engages their kinaesthetic sense. As noted by Lastry (2007), this is important to students' development of a good intuition for physics.

Students may begin by holding the remote at a given orientation. This provides a constant external force and simply changes the equilibrium position of the oscillator from that of the undriven oscillator. Again, students are directed to drive energy into the system in its undamped state. After some experimentation, they figure out for themselves that driving energy into the oscillator system requires specific manipulations of the controller. Namely, the applied force must be an oscillating force whose frequency and phase match those of the particle's oscillations. This means that, when the particle is travelling downward, the force must be applied in the downward direction; and when the particle is moving upward, the driving force must be applied in the upward direction.

Students thus receive an object lesson in the meaning of power; they learn how to increase the system's energy over time. We then introduce the equation P=dE/dt. The driving game can also help students understand that power is generated with an applied force in harmony with the particle's velocity, P=F*v.

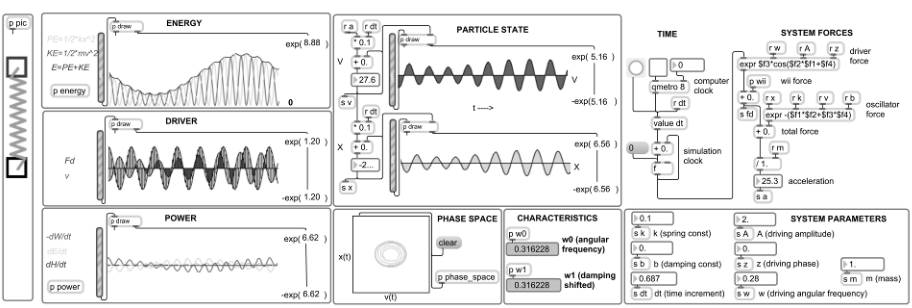

Figure 5. 1-D Oscillator Simulation Near Resonance

Elaborating the Model in 3D. After students have gained some familiarity with the oscillator system and learned how to deliver energy to it, we expand the model into 3-D, using Max/MSP's command of the OpenGL graphics library. In this model, a sphere represents the position of the simulated particle while an Alias/Wavefront .obj file, freely available online, represents the state of the remote. Forces, as measured in the frame of the remote, are animated too. Tracing the position of the particle generates lissajous figures, as shown in figure 6. Although students build the initial, one-dimensional simulation, the 3-D version of the project exceeds their computational capacities. Their development of the initial model does, however, give them the capacity to understand the basic structure of the 3-D simulation.

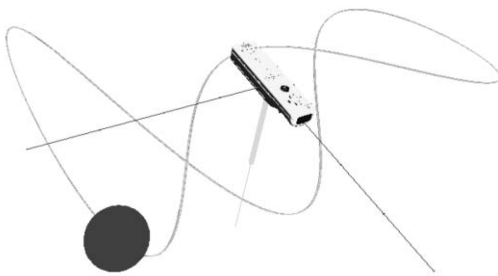

Figure 6. Wii Driven 3D Oscillator Generating Lissajous Figures

The use of Max/MSP as an educational tool is easily integrated with web-based technologies such as blogs and online video sharing sites. The dataflow diagrams, which constitute Max/MSP code, may be cut and pasted as their text based equivalent. This enables users to post computational modules online for others to copy and port back into Max/MSP. In addition, Max/MSP enables users quickly to generate audio/visual content to post online, allowing both teachers and students to communicate complex ideas across the web through video.

Conclusion

As we have shown, Max/MSP is a powerful tool for communicating physics concepts through digital representation. In the context of mathematics or science classes, it provides an environment for integrating simulation, real-time data capture, and rich visualizations. When this tool is used in the context of creative arts, students are challenged to deploy and expand their mathematical and technical capacities. This can encourage students who have more interest in the arts than sciences to enhance their numeracy. We hope this approach can help facilitate greater communication between teachers and students and across disciplines.

Acknowledgments

I would like to thank Sara Rudner, director of the Sarah Lawrence's department of dance, for allowing me to develop their technology and media curriculum. I would also like to thank my advisor Brian Schwartz for encouraging my interest in integrating art and science education. Finally, I thank my students for playfully engaging material that was largely alien to them.

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faculty development

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Research university faculty members' motivation to engage in teaching professional development

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Abstract

Research into the effectiveness of teaching professional development (TPD) for postsecondary faculty has seen substantial growth over the last 40 years; yet little is known about faculty motivation to participate. Even less is known about how to best meet the needs of faculty at research universities and why, given that they are seldom required to engage in TPD, these faculty members bother to participate. This paper reports on the motivations of science and engineering faculty to engage in TPD at a major U.S. research university. Faculty members were motivated to engage in TPD to bring their teaching identities in better concordance with their professional roles as researchers. Once engaged in TPD they increased their competence with respect to their teaching practice. With continued engagement they internalized the values and practices associated with effective TPD. These results seem to confirm premises of self-determination theory.

Introduction

In the United States alone, research universities (hereafter *RUs*) employ roughly one-fourth of all faculty members (hereafter just *faculty*) working at four-year postsecondary institutions and educate roughly one-tenth of all undergraduate students (Russell et al, 1990). RUs also train the majority of future faculty; in the fields of science, technology, engineering, and mathematics (hereafter *STEM*) alone, one hundred RUs train more than 80% of the graduate students who will teach at institutions of higher education in the United States (Gaff & Lambert, 1996). There is concern regarding the role that RUs play in the initial training of these postsecondary educators. Graduate students are expected to focus on their disciplinary research and are offered few opportunities to formally explore issues of teaching and learning during their studies (Weimer, 1990; Cole, 1982). The inadequate preparation of many of these future faculty members to meet the demands of today's higher education environments has been documented (Austin and Barnes, 2005; Menges, 1994; Eble, 1988; Cole, 1982). As practicing faculty members, the dedication of these individuals to teaching and the improvement of their practice may be constrained by commitments to disciplinary research over other obligations, both by these individuals themselves and by institutional reward structures (Halpern, 1994). It is not surprising that underlying the calls to improve higher education instruction overall is the call to improve the pedagogical knowledge and skills of both future and practicing faculty at RUs (Fairweather & Beach, 2002).

One means to improve faculty teaching practice is through professional development for practicing faculty with a focus on teaching and learning. Research regarding the teaching professional development (hereafter *TPD*) of faculty has seen substantial growth since the 1970s (Zuber-Skerritt, 1992) yet little is known regarding faculty motivation to participate in TPD. The motivations of RU faculty, seldom required to participate in TPD and who may even experience professional backlash when they do participate, are of special interest to the higher education research community.

My paper and associated FISER presentation reports on the experiences of science and engineering faculty at a prestigious RU in the United States. I provide insight into their motivation to engage in voluntary TPD, related effects of their voluntary TPD engagement, and recommendations for those committed to the improvement of postsecondary science and engineering education at RUs.

Methodology

Being just one researcher, I selected research participants from one major research university and from certain subsets of all of the available STEM disciplines. I used purposive sampling, identifying my study's participants through the contacts and tools afforded me through my work with a local teaching professional development program created to serve STEM scholars. I had *a priori* research interests and I attempted to involve research participants that I thought could best inform these. I relied on the individual research participants in my study, then, to serve as *instrumental cases* in that I assumed their experiences could provide insight into specific problems (Stake, 1995). Taken as a group of instrumental case studies, my research participants' experiences form a *collective case study* (Stake, 1995).

I attempted to secure a sample that was evenly divided by sex. I envisioned this would be impossible as only about half as many women were professors in these disciplines at the institution of study. Yet women were more than three times as likely to agree to participate (eight of thirteen contacted versus five out of twenty-six men contacted) and my final sample was comprised of eight women and four men. I used two other criteria when choosing my participants. First, assuming that point in career may have an effect on professors' experience regarding TPD, I selected participants across the range of temporal distance from securing tenure, from having yet to secure it (assistant professors) to those that have but with varying distance from that professional milestone (associate and full professors.) The other criterion in choosing research participants concerned their research discipline; I sought a sample comprised of individuals across various science and engineering sub-disciplines. Yet those from the fields of agriculture and engineering were more willing to participate and my sample reflects this bias as well. My final sample consisted of twelve science and engineering faculty who have been voluntarily engaged in TPD to varying degrees. It may be important to note here that ten of my participants are non-Hispanic Caucasians, the overwhelming "norm" in the science and engineering fields at the institution of study. Table 1 lists the sex, point in career, and research disciplines (field) of my twelve research participants. Attempting to protect participants' identity, I have not disclosed their names.

Table 1. Study research participants' characteristics

Point in Career	Females	Field	Males	Field
Assistant Professors	A	Civil Engineering	D	Chemistry
	B	Biomedical Engineering		
	C	Soil Science		
Associate Professors	E	Environmental Studies	G	Dairy Science
	F	Bacteriology	H	Medicine
Full Professors	I	Plant Pathology	L	Physics
	J	Industrial Engineering		
	K	Plant Pathology		

I developed an online survey that assessed my participants' voluntary TPD participation history. Although their past TPD participation varied in terms of number of activities, activity duration, type, and by teaching topic, all reported participation in multiple TPD activities that they had found to be meaningful. I used data collected via the survey to individualize the semi-structured protocol that I used when I conducted interviews with each participant. These interviews lasted from one-and-a-half to three hours in duration. During these interviews, I asked research participants to comment on a wide array of issues with respect to their experiences with TPD; this paper and related presentation, however, is limited to the findings associated with their motivation to participate in TPD and specific effects of TPD participation that further inform the discussion of motivation.

During both the collection and analysis of data, I used *constructivist grounded theory* (Charmaz, 2000) and first coded text using an open, inductive process. After creating basic categories I recoded data using more selective coding, thus checking my emerging categories with empirical findings (Holder, 2000; Charmaz, 2000). When needed, I conducted brief follow-up interviews to delve deeper into select participants' experience and to further refine categories in terms of their relevance (Charmaz, 2000).

Grounded theory does not dictate that a researcher attempt to frame findings within any pre-espoused theory. During my early analysis of data, however, I began to conclude that the premises of *self-determination theory* (hereafter *SDT*) resonated with my interpretation of participants' claims regarding their initial and continued motivation to participate in TPD. As a result, I subsequently recoded my data using SDT as a theoretical lens. Hoping to avoid a significant theory-practice divide (Zuber-Skerritt, 1992) it was my intention that this reanalysis would result in concrete, useable recommendations for those committed to improving postsecondary education at RUs through encouraging faculty to engage in TPD.

A Review of Self-determination Theory (SDT). SDT (Deci & Ryan, 1985; 1991; 2000) is based on the premise that humans are naturally "growth-oriented" and seek experiences that foster growth. Unlike other cognitive theories of motivation, SDT posits three innate human needs as central to motivation. To begin with, SDT postulates that humans naturally coordinate their actions to foster their growth towards a more unified sense of self (autonomy), better understanding of the world around them (competence), and better social integration (relatedness). Humans seek, or have as *goals*, the <u>satisfaction</u> of these needs. Yet the three basic needs of autonomy, competence, and relatedness are correlated with motivation in another way. Like other contemporary motivation theories, SDT considers the goal-related efficacies involved in human motivation. Yet unlike other contemporary motivation theories SDT also considers the *orientation* of goal pursuits, or the underlying attitudes prompting action. Orientation of goal pursuits is influenced by individuals' <u>perception</u> of personal levels of autonomy, competence, and relatedness.

Highly influencing motivation is one's perception of the level of autonomy one holds with respect to action and this speaks to the special role of the concept of autonomy within SDT. According to Deci and Ryan, *autonomy* can be thought as akin to "volition-the organismic desire to self-organize experience and behavior and to have activity be concordant with one's integrated sense of self" (2000, p. 231). Autonomy can also be "equated with the ideas of internal locus of control, independence, and individualism" (2000, p. 231). This second conception of autonomy is akin to what Deci and Ryan and others have termed the *locus of causality*. Intrinsic motivation, by its nature, demands an *internal perceived locus of causality* (or *IPLOC* from deCharms, 1968). One is said to be intrinsically motivated to act if one views the act itself as inherently rewarding, whereas extrinsically motivated behaviors are performed for some outcome outside of the act itself. Although extrinsically motivated behaviors can too be self-endorsed and have an *IPLOC* basis, they are often more interpersonally influenced and, therefore, often have either an exclusively or partially *external perceived locus of causality* (*EPLOC*) basis.

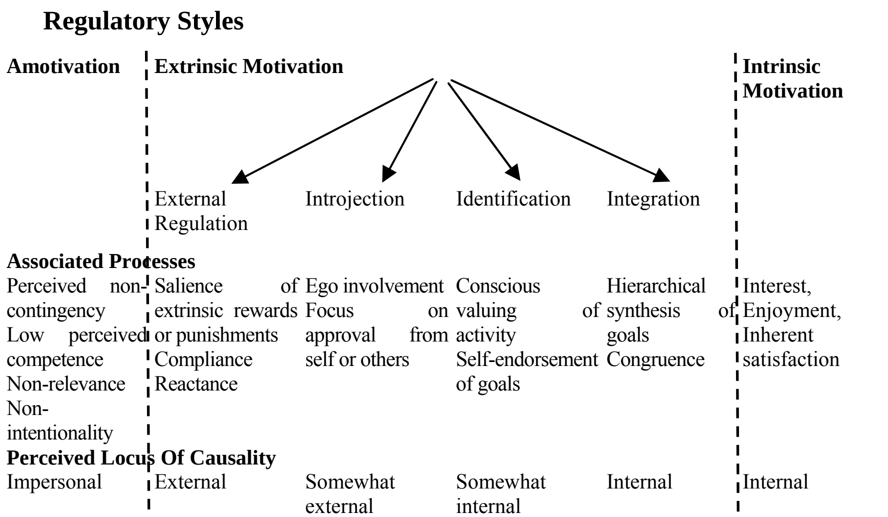

Figure 1. A reproduction of the figure entitled "A Taxonomy of Human Motivation" from Ryan and Deci, 2000

While the continuum above is not a developmental continuum, it is helpful in understanding the various forms of human motivation that individuals will experience, especially in relation to external influences. The *dialectic* between individuals and the social backdrops in which they operate can serve to support or thwart both the perception and the seeking of satisfaction of an individual's autonomy, competence, and relatedness and, thus, support or thwart an individual's motivation. SDT may be helpful when problematizing how to better motivate humans with respect to any action and, ultimately, towards securing their better performance, engagement, and psychological well-being.

Findings and implications

In asking my research participants what motivated their TPD participation I explicitly sought the underlying perceptions that prompted their action. From my research participants' discussion of these underlying perceptions, or associated processes, I interpreted from where the motivation for their behavior emanated, or the perceived locus of causality. An associate professor in environmental studies, as an example, stated that she initially participated in TPD solely to alleviate others' concerns, both those of colleagues and students, about her poor teaching skills. The associated processes to which she most often referred to as motivation for her participation in TPD reflected reactance to external punishments already experienced (such as embarrassment regarding student evaluations) and compliance with the requests of those who could deliver further punishments. The regulatory style of motivation concerning her TPD participation, with its fully external locus of causality, appeared to be *external regulation*. In relation to TPD participation over their entire careers, my research participants cited external motivation that spanned the SDT continuum. Yet with respect to their earlier TPD engagement, the majority demonstrated a regulatory style of motivation with a somewhat external locus of causality, that of *introjected regulation*. While the locus of causality related to most of my participants' motivation to initially engage in TPD was less external than that of the environmental studies associate professor, it was still strongly linked to pressures that emanated from outside of the participants themselves. My other research participants did not portray their motivation to participate in TPD as reactance to the fear of punishments in relation to their teaching practice. Yet they often linked an attempt to garner the better approval from others, including students and colleagues, with their reasons for their initial TPD participation. Their talk also highlighted the critical role of my research participants' ego in the motivation for their initial TPD participation. Interactions with their students and their colleagues, and other institutional factors that helped form their perceptions of what it means to be successful in their professional practices, had altered my research participants' self-esteem and worth. This affect compelled them to bring their teaching practice up to par with both others' more successful teaching practices and with other professional competencies of their own.

My research participants, perhaps seemingly the ultimate TPD proponents at the time of my interviews with them, are, in fact, mostly "converts" to the cause and associated means surrounding TPD. They initially engaged in TPD activities in hope of alleviating discomfort residing in their ego with respect to their pedagogical practice. TPD, they hoped, would provide a fix of their bruised ego and a quick one at that. Most of my research participants had not initially anticipated participating in as many and as vast of TPD activities upon their first participation. Perhaps not surprising, my research participants were not attracted to their academic positions for the teaching opportunities such positions afforded; none were initially drawn to academia as a result of an inherent interest in teaching. Instead, they viewed teaching more as *means* towards pursuing their much stronger interest, that of conducting research in the sciences. In addition, none reported they were intrinsically motivated to participate in TPD initially; they did not anticipate finding TPD, as an activity in and of itself, that interesting or enjoyable. Instead my research participants stated they were motivated to participate in TPD to remedy perceived teaching inadequacies and feelings of disconnect associated with their teaching practice, disconnect both with respect to their professional roles and other likeminded individuals. In seeking to increase their competence and autonomy with respect to their teaching practice, ends *outside* of TPD activity and in relation to issues involving their ego, my research participants demonstrated that their motivation to participate in TPD was, in fact, extrinsic.

This finding stands in contrast to the prevailing view among higher education researchers that faculty must be motivated by intrinsic, rather than extrinsic, motivators and rewards (Hutchings and Huber, 2005; Wallin, 2003; Owens, 2001; Millis, 2001; Zuber-Skerritt, 1992; Cross, 1990). Arguably the assumption that faculty cannot be extrinsically motivated to participate in TPD has helped guard against the potential negative effects of mandating participation. Yet in assuming that faculty motivation to engage in TPD must be intrinsic is to assume that there is little to be done to encourage the majority of faculty at research institutions to participate in TPD. A more accurate understanding of the specifics surrounding the motivation driving RU faculty to participate in TPD is necessary to foster their participation.

Once their more basic pedagogical needs had been met, my participants were free to satisfy other goals via their TPD involvement. Through subsequent involvement they found that TPD addressed other aspects of their teaching practice that they did not initially recognize needed attention and, thus, strengthened, in their minds, the *importance* of TPD. As predicted by SDT, recognition of a pursuit's importance happens as a result of action or actions originally inspired by extrinsic motivation, such as my participants' need to alleviate feelings of discomfort and inadequacy with respect to their teaching. Their perceived locus of causality evolved to be more internal as they adopted the goals and beliefs associated with effective TPD as their own. Thus, my research participants' motivation to continue to participate in TPD was arguably of the more self-determined types, *identification* and *integration regulation*.

As stated previously, SDT does not imply that individuals have to progress through a developmental continuum of motivation. Yet according to Ryan and Deci (2000) "developmental issues are, however, evident…the types of behaviors and values that can be assimilated to the self increase with growing cognitive and ego capacities" (2000, p. 63). My research participants had their basic needs met early on in their TPD participation history and grew in their understanding of the importance of TPD. Meanwhile, they began to *internalize* the values and practices perpetuated in most of the TPD activities as more of their own. As Ryan and Deci argue, greater *internalization*, in turn, yields greater personal wellbeing and improved performance outcomes. My research participants' experiences seemed to confirm that the more they internalized the values and practices associated with TPD the more their confidence with respect to teaching increased.

With the knowledge that RU science and engineering faculty may not find TPD inherently interesting and given the promise that internalization of the values and practices associated with effective TPD may have for faculty, how might other faculty be encouraged to embark on and move down the internalization path? The experiences of my participants indicate that once engaged in TPD, the process of internalization may almost be guaranteed **if** TPD is, in fact, effective in meeting participants' basic needs. Researchers have already documented numerous characteristics associated with effective faculty TPD and a more pressing question now seems in need of asking-*how might faculty be encouraged to participate in TPD initially*? My research participants' experiences indicate that to get faculty to engage in TPD, often of little inherent interest to them, we must appeal to their basic needs they feel with regards to their teaching practice. They indicated that such an "appeal" to teaching needs may be attained in two ways, by 1) helping faculty recognize their basic needs with respect to their teaching practice and 2) empowering faculty to seek the fulfillment of these needs.

My research participants offered means towards helping RU faculty both recognize and act towards securing their basic teaching practice needs. Overwhelmingly, they offered that appealing to research faculty members' strengths as researchers and their resulting need for autonomy, as the appeal to attain an integrated sense of professional self, may be most effective in helping RU faculty recognize that their professional role as a teacher can and should be brought into better concordance with their other professional roles in which they already excel. In addition, they cited environmental (external) factors that may encourage both the recognition of their pedagogical needs as well as increased empowerment to seek the fulfillment of these needs. My research participants claimed that one factor, a better show of support in the form of teaching rewards, financial or not, could alleviate threats to TPD participation. Of even greater importance for my research participants was the potential support of significant others such as senior departmental colleagues, institutional provosts, and national science bodies who could help protect or fight against perceptions by others that a public display of faculty members' pedagogical needs indicates inherent, possibly abnormal, professionally damaging weaknesses. According to my research participants, STEM faculty must be helped to realize that they did not receive adequate preparation necessary to be effective educators and, thus, that they may benefit from intervention to remedy their less-than-adequate teaching practices. In addition, and perhaps more important, STEM faculty must be helped to realize that their less-than-adequate pedagogical preparation is the norm amongst their STEM colleagues. According to my research participants, this last realization may help STEM faculty the most towards feeling empowered in the midst of what they perceive to be a widespread, negatively judgmental stance of their colleagues and superiors towards faculty TPD participation.

In a climate that often discourages faculty TPD participation, my research participants found means to "overcome" more TPD participation obstacles with their continued TPD participation. An associate professor in medicine claimed that "the number one predictor of TPD involvement is TPD involvement" and the experiences of the rest of my research participants confirmed that more TPD participation led to a better realization of the importance of TPD. The take away message may be that the best way to secure TPD involvement is to get people to one meaningful TPD activity. Once there, the potential to recognize the value of TPD with respect to pedagogical needs is strong. My research participants, in light of obstacles, participated again and again in TPD even after having many of their pedagogical needs met. Their personal decisions to continue to engage in TPD in light of obstacles is partially explained by their internalization of the values and practices associated with TPD. They had recognized the greater importance of TPD overall, and continual TPD specifically.

In sharing their experiences, my research participants provided recommendations that may serve as basis to motivate a greater number of faculty members to participate in TPD at RUs. They indicated that faculty like them may first participate in TPD as a result of extrinsic motivation, specifically their negative reactance to factors with an external loci of causality. In lieu of a culture shift, or (possibly, if we are very hopeful) in conjunction with one towards the rebuilding of RU environments into ones that truly value and encourage faculty TPD participation, we must appeal to faculty needs for competency and autonomy with respect to teaching in order to motivate faculty TPD participation. If we can get faculty to recognize their needs, we may be able to get them to the TPD table. Once there, they are likely to grow in their realization of the importance of improving their teaching. As a result of their internalization of the values and practices championed in their TPD activities, they are likely to keep participating in TPD and improving their teaching practice and, through their professional associations, encouraging others like them to do the same.

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Technicians' perceptions of their role in a science department

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Abstract

Technicians in a science faculty are frequently described as 'the most important people in the department' and 'we couldn't do without them' yet there appears to be a gap between these statements and the technicians'perceptions of their working roles. They are frequently left feeling frustrated and underused as they feel that their talents and considerable qualifications are not being recognised in the school setting. When some of these technicians were interviewed about their roles in a science department there was a almost total unanimity in their feelings, within a sample of different schools. The schools were chosen as ones in which I had built up a working relationship with the technicians, and they felt able to talk to me freely and in with confidence.

Introduction

A statement very frequently made by secondary school teachers is that 'technicians are the most important people in the science department – they are the people who really run it – we couldn't do without them'. Yet science technicians and laboratory assistants in schools feel that, in practice, teachers pay very little attention to this statement. Pupils themselves often have very little knowledge of the vital role technicians play in the preparation of their lessons (if indeed they can find the technicians' base) and often refer to them as 'the man/woman in the white coat in that room along the corridor'. To some staff, the technicians are the people who organise the tea and coffee supplies and the 'nights out'. In such activities and interactions with the teaching staff, technicians appear to be the cohesive elements in a science department, but is this the role in which they wish to be considered?

In my own 20 years of working in schools both as a science teacher and as a teacher educator it has been my experience that the reality of technicians' self-perceptions is that they feel undervalued, report a lack of involvement in their departments and are frequently given routine tasks which are not commensurate with their qualifications. Research carried out in the United Kingdom bears these impressions out. A comprehensive survey of science technicians' roles in schools and colleges undertaken in the United Kingdom by the Royal Society/ASE (2002) stated that a well trained, professional technician support service was essential if students were to experience a variety of experimental and investigative work. Such work is recognised, therefore, as important. Yet the survey also found that many technicians were working to job descriptions that were not entirely relevant and often out of date, and, importantly, that the profession of science technician was failing to attract young recruits. There are also suggestions in the literature that school science technicians are under-used: a relatively recent survey, also conducted in the United Kingdom, by the National Foundation for Educational Research (Moor et al 2006), found that 70% of technicians rarely or never carried out learning support tasks in the science department, although the technicians were keen to do work of this kind.

Aims of the research

Having worked closely with science technicians in my own teaching career as a Principal Teacher in a science department, I found the topic of science technicians' roles in schools an interesting one. Additionally, although the literature review carried out in preparation for the study reported here found several detailed studies focused on technicians' duties, job descriptions and definitions, **(CLEAPS, ASE reports)** there seemed to be little research that investigated technicians' own views of their work. For both these reasons, it was appropriate for my research to ask the question 'What are science technicians' self-perceptions of their roles in school science departments?', and it is this that is the focus of this paper.

Methodology and Method

The study originated as one of several separate and very different investigations undertaken by a research group working collaboratively within a large and busy School of Education Department. The collaborative group came together in conversation, at roughly six-week intervals over about a year, to explore the kind of research culture that would best suit its members and examine what barriers hampered staff who wanted to undertake research. Within this overarching framework individual staff conducted their own enquiries, the progress of which was brought back to the table at each meeting, for discussion. The research into the work of school science technicians is one of these enquiries.

The collaborative work was conducted using a number of methodological principles, namely action research, action enquiry and reflective practice It was a cyclical process in which involvement and subsequent posing of further questions were central and in which the research journey was as important for the researcher as any outcomes which might ultimately be gained .

Although the method adopted for the school science technicians' research was distinct from that of the overarching framework, it was informed by similar principles of inquiry and involvement. The focus of the technician research was on technicians' understanding of their own situations. Hence the methodology did not allow, nor seek to allow, generalisation.

Data were gathered through loosely structured interviews with science support staff in three Scottish secondary schools. There were two parts to the interview process.

The first was designed to clarify the essential elements of a school technician's role. The technicians interviewed were shown a series of photographs of the tasks they were likely to be most commonly involved in, and were asked the question 'Which of these tasks do you see as being the most important ones in your work?' The series had been devised with the help of a group of university science technicians, and hence it reflected what they thought were the core tasks of their own work. These tasks are listed in Table 1 below.

Table 1. Science technicians' core tasks

• animal/fish/plant care	• maintaining a departmental budget
• checking chemicals in and out	• preparing trolleys of equipment
• storage of chemicals using safe procedures	• storage of equipment
• preparing apparatus/ chemicals etc requisitioned by staff	• checking supplies of equipment/glassware etc. available in laboratories
• making up stock solutions	• servicing of equipment
• ordering apparatus, chemicals and other equipment items	• unpacking and checking apparatus and chemicals which have been delivered
• constructing apparatus	

Technicians are, of course, involved in many other tasks which may vary from school to school and department to department.

When they had been shown these cards, staff were asked three questions:

- Do all these activities apply in your work situation?
- Which are the most important tasks?
- What other activities do you carry out?

This took approximately half an hour.

The second part of the interview focussed on staff perceptions of their role. Interviewees were asked about this directly through the single question 'How do you perceive your role in the science department?'

Overall, the interviews took approximately one hour. All were recorded using a digital voice recorder so that comments could be later transcribed. These were analysed manually.

The sample

The three schools that took part in the study were ones where I had worked as a supply teacher in the science departments, so had built up a working relationship with the science technicians. This meant that I had their confidence and they felt at ease in talking to me. In all 6 technicians and one laboratory assistant were interviewed.

The schools' main characteristics varied somewhat, as is shown in Table 2 below.

Table 2. Characteristics of the three sample schools

	School A	School B	School C
School type	Fully comprehensive, mixed gender	Fee-paying (private) mixed gender	Fully comprehensive mixed gender
School setting	Large urban	City	Small urban
Number of pupils	800	1800	850
Number of science technical support staff	2	7	2 technicians, one laboratory assistant
Science technical support staff interviewed	2, one male, one female, both over 40 years old	3, all female, both over 40 years old	2 (1 technician, 1 laboratory assistant). Both female, both over 40 years old

Responses to the photographs

Two main themes emerged from the analysis of these: the lack of technicians' visibility in the schools, and the amount of work they did. Commenting on visibility, some of the staff offered neutral statements about their work, such as 'These activities are not visible to other staff – we work very much behind the scenes' and 'It is the nature of our job to be invisible as we have to deliver and collect apparatus etc. when no one is around, or in the labs'. Other comments carried tones of resentment, however. 'We are only noticed if we are off work and the apparatus isn't delivered or cleared away,' said one technician. Another was more clearly critical of the way others saw her role. 'We are not valued because people don't see our work, because we do all these activities,' she said.

With respect to workload, those interviewed were unanimous in agreeing that the tasks they undertook were multiple and varied. In the words of one, 'We do all the tasks shown. And more besides, too numerous to mention!' Indeed, several people gave examples of their work that were not captured in the photographs. These included

- Shopping for materials that were not dealt with in apparatus catalogues, such as flowers and foodstuffs
- Dealing with last-minute requests from staff
- Responding to general staff queries
- Dealing with the disposal of broken apparatus, chemicals and so on
- Tidying laboratories after classes
- Giving out stationery
- Organising the coffee and biscuit money.

Technicians' views of their roles

The dominant theme arising from responses to the question 'How do you perceive your role in the science department?', and expressed in one way or another by every one of those interviewed, was one of dissatisfaction. There were several reasons for this, largely to do with a feeling of being undervalued. All those interviewed pointed out how little use was made of their abilities, so that 'We are not using our skills and training' and 'They are not using our expertise' was a common complaint. The technicians believed this to be partly because the extent of this expertise was simply not known. As one of those interviewed put it, 'Most of us are qualified to degree and HND level … It's just that so few people take the time to find this out.' But some suggested that this was part of 'a general lack of knowledge about what we do'.

A further strong reason for dissatisfaction, possibly related to the lack of recognition of their existing skills, was that technicians were offered so few opportunities for professional development. 'CPD is not encouraged … You have to fight your case,' said one technician, while another remarked 'Nobody discusses our training needs with us'. One wondered if the school ever even thought about it. 'We really need and want some continuing professional development,' she said, 'but do we even figure in the school's CPD budget?' In relation to this, one person pointed out a potential hazard for the school. 'Some pupils tell us things they don't or won't tell staff,' she said. 'So we need to be trained in child protection issues.' The technician who told us how hard she and her colleagues tried ‘to keep up with curriculum changes’ added that it was ‘an uphill struggle when we find it difficult to get hold of information’ painted a depressing picture of people doing their best, with little encouragement.

Indeed, it is hard not to read into these interviews a disheartening picture of staff treated as lowly by some teachers and pupils, and very much on the fringes of school life. ‘We are at people’s beck and call,’ ‘We don’t have any control over our activities,’ ‘Some teachers talk down to us,’ and ‘We are treated as servants, skivvies,’ were typical comments. Less typical, fortunately, was the remark that ‘Some pupils are appallingly rude to us.’ It did not help that technicians’ working bases were ‘sometimes isolated and away from the main working area’ and that ‘information does not filter down to us … we are the last to find [anything] out’.

On a more positive note, it was clear that several of the technicians longed for greater involvement in school life. When they were so involved, it seemed to give great satisfaction. ‘We are sometimes involved with school visits and fieldwork, which is very enjoyable,’ said one, while another added that technicians ‘would like to be in at the planning stages of new courses and so on’. More ambitiously, one said technicians in her school would ‘like to work in the classes with teachers particularly at Higher and Advanced Higher levels’. Many people pointed to specific ways in which they could contribute. Being very used to working in laboratories, they generally knew a lot about safety there, sometimes more than the teachers. They were often trained and skilled in First Aid techniques, and provided pastoral care in that sick children often came to them. They sometimes acted as what one called a ‘safety net for teachers’ moans, usually abut each other’.

Yet still, the sheer anonymity of the role could reduce these skilled and responsive people into ‘the technician’. ‘We seem to lose our personalities when we put our white coats on,’ one person said.

Discussion

The definition of the science technician’s role supplied by the National Foundation for Educational Research(2006), namely that science technicians ensure science lessons run smoothly by looking after and setting up equipment and helping out with the demonstrations and practical classes, is largely in line with what the technicians interviewed said they did. Whether this definition is as wide as it could usefully be, however, is a different matter. The technicians interviewed were proud of their knowledge and skills and eager to put them to greater use, but for the most part were denied the opportunity to do this. If what they reported is accurate, why should this be? Why would teachers refuse their offers of further help? Why would they not include technicians in curricular planning? Why would they not give technicians more involvement in class activities and older pupils’ project work? The answer may lie in the grey area of professional boundaries, and teachers may be reluctant to ask support staff who, however skilled and knowledgeable, are not qualified teachers to do tasks that might encroach on teaching. If this is so, is there a case for revisiting the definition of the science technician’s role?

It is striking that CPD opportunities for technicians are perceived to be so infrequent. This may be connected to the way that schools see the work that technicians do: a low-level job rather than a career for professionals. If so, this view stands in stark and striking contrast to the way that the technicians interviewed for this study see themselves. The question here is: what would best serve pupils and schools?

I have pointed out that research shows that the profession of science technician is failing to attract young recruits. If school managers and potential recruits view technician work as low-level, without development opportunities and with no career ladder, then the situation is likely to continue. And if, as the Royal Society and Associate of Science Education aver, schools need well-trained professional support, this matters. Without adequate numbers of science technicians in schools and colleges, students learning experiences will be impaired, achievement levels will be more difficult to raise, and safety in school and college laboratories will be compromised.

At the very least, this research points to a waste of human capital. If, as was claimed, many technicians are qualified to degree or HND level, for schools not to be using and building on this suggests a squandering of opportunities for both technicians and schools.

On a purely human level, it is unlikely to good for the life of a school if its support staff feel undervalued and excluded. It is also unlikely that head teachers and senior managers wish to create an ethos of this kind, and it would be interesting to know whether school policies on ethical matters such as inclusion extend to the place of support staff, and if they do, how compliance with such policies is ensured.

But how far were the technicians interviewed for this research justified in their views? Do schools see technician roles as low-level? This small study investigated only the technicians' perspective, and in only three schools. It may be that head teachers and staff would have very different views and be surprised at what these technicians were saying. It may also be that the situation is very different in other schools, other areas and other countries. Further research, widening the focus, would help round out the picture, and I hope to undertake this in the future.

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Using teacher training courses as levers for faculty educational development – an example from the University of Copenhagen

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Abstract

This article describes the use of action research elements in a teacher training programme to support faculty educational development. Empirically the article is based on examples from the teacher training programme (TTP) for assistant professors and post-docs at the Faculties of Science, Life Sciences, and Pharmaceutical Sciences (University of Copenhagen). Three examples are described, displaying various levels of generality and impact – from the very specific outcome for a relatively limited group of teachers, to general faculty development initiatives. The first example concerns the development of a set of specific suggestions for developing a course at the Pharmaceutical Faculty. The second example concerns the projects made by assistant professors in relation to the teacher training programme. The third concerns the recent change of grading scale in Denmark, and the faculties' need to educate staff in relation to this. The article describes the utility and motivational aspects of using such embedded activity research elements and concludes that they can be important elements of faculty educational development.

Introduction

In spite of the fact that most tenured teachers at the university spend at least half their time teaching, it can still be a challenge to motivate scientific staff to engage in teacher training courses and development of teaching in research intensive environments like the University of Copenhagen. This is not because the scientific staff does not find teaching important. Most staff members seem to agree that the teaching obligations of the universities are at least as important as the research obligations from a third-person perspective. However, from the first-person perspective, the case is different. The general stress level and workload of tenured staff often make them stay away from, at least voluntary, teacher training courses. The teaching obligations of many newly employed staff members (particularly post-docs) are relatively limited, and the feeling is that what counts in order to achieve tenure (associate professorships) is the length of the publication list. One participant in our teacher training programme (TTP) has expressed it like this: "The research demands that the [newly appointed assistant] professor must meet are very clear. For example, the [assistant] professor must publish 1.7 articles in journals with peer review every year. Considering the fact that most articles have two or more authors, this number is *de facto* closer to 3 articles in journals with peer review every year. If these criteria are not met, financial penalties may be enforced, either on group level, institute level or even department level. [..] This is in contrast to teaching performance where the criteria that must be met are less well defined, and where no financial penalties are enforced in the case of poor teaching. From this, I can personally only reach one conclusion. No matter what they say: research comes first!!! [..] A newly appointed [assistant] professor can only obtain adequate research funding by applying for external funding and the only way to document academic competence within the research area in question is a publication list that clearly demonstrate scientific competences. For such applications, teaching competences are utterly irrelevant. The way I see it, the university reinforces the statement 'research comes first' because society demands it. What is a boy to do?"

We find that this statement provide an accurate description of the mixed feelings towards teaching that many participants in our compulsory TTP have, and such understandably strategic feelings towards the time spent on teaching are quite widespread. Thus, the challenge for developers is two-fold: (1) To motivate our participants in our quite extensive compulsory course to engage in personal development, and (2) to disseminate new ideas and methods in teaching to tenured staff.

In this article we will provide some examples of what we are doing to ensure that participants in our TTP feel that the time spent is worth the effort. Specifically, it is our ambition that the teacher training programme at Copenhagen University should not just be "a course to follow", and unrelated to their own teaching practices, but of relevance to these practices and constitute an integral part of the faculty educational development efforts.

We will start by outlining the development of higher education teacher traning programmes in Denmark, and describe briefly the structure and content of the teacher training course in the sciences at the University of Copenhagen. Then we will provide three examples of how the teacher training course is used as a lever for faculty educational development at the three faculties involved in the TTP.

A brief history of the development of higher education teacher training programmes in Denmark

In the Danish Job Structure, in the description for assistant professors, it is stated that "Supervision is provided, as well as the opportunity to enhance pedagogical competencies with a view to [i.e. leading to] a written assessment of the assistant professor's teaching qualifications." (Universitets og bygningsstyrelsen, 2006). Thus, from the legal perspective, universities are obliged to provide assistant professors with supervision on their teaching, opportunities to enhance their pedagogical competencies, and make a statement about their teaching qualifications. This statement on teaching qualifications should be taken into consideration when employing associate professors (e.g. tenure). The above rather vague description about supervision in the Job Structure has, in slightly modified form, existed since 1993. In the period from 1993 to 1997 there was little consensus among the universities on how this should be interpreted. However, in 1997 The Danish Rectors' Conference decided upon a set of general recommendations for the organization of teacher training courses for assistant professors in higher education in Denmark (Rektorkollegiet, 1997). In these recommendations, it was suggested that the TTPs for assistant professors should include supervision as well as pedagogical courses, workshops etc., and have an estimated workload of 250 hours for participants. Thus, a basic distinction was made between a practical part (supervision) and a more theoretical part (courses etc.) was established. Beyond that, the Rectors' conference provided no specific recommendations for content or structure, but left it specifically to the institutions: “The content and pedagogical structure and the practical planning of the programme should take into consideration the special nature of the institutions and the disciplines.” (Rektorkollegiet, 1997). Thus, in the period from 1997 the different universities have developed a number of quite different TTPs – some organised on a faculty basis, others on central university basis. Typically, the courses have developed gradually over the period in a political process varying from university to university, and with only a few TTPs reaching a volume as recommended by the Rectors' Conference (250 hours); the typical volume is around 180 hours. Trowler and Bamber's (2005) description of the cumbersome development of compulsory higher education teacher training programmes in Norway bears many similarities to the Danish development, except perhaps that the Danish programmes have taken even longer to develop. There are several reasons for this, but one important reason is probably, that whereas the Norwegian model only requires a 100 hour workload of participants, the Danish aim has been for 250 hours.

The teacher training programme in the sciences at the University of Copenhagen

The faculties of science and pharmaceutical sciences at the University of Copenhagen have had a formal cooperation about a joint teacher training programme since 2003. As of 2008 the faculty of Life Sciences has joined the programme, so that now the TTP addresses three science oriented faculties at the University of Copenhagen. The TTP is currently the most extensive programme at the University of Copenhagen both in terms of enrolled participants and in workload for the participants, and is comparable in scope to the most extensive programmes at other Danish Universities.

Figure 1 outlines the different elements in the teacher training programme at the three faculties. The *theoretical part* of the programme consists of a Course in University Pedagogy in Science (CUPS), containing a pre-project on student learning and a final project where participants investigate a problem related to their own teaching. In addition the participants organize peer supervision of each others' teaching. Furthermore, a separate 4-day 65 hour course in practical pedagogy (Introduction to University Pedagogy) focussed on lesson planning and teaching has to be passed. Some participants have followed this course while doing their Ph.D study. The workload in relation to the theoretical part is around 185 hours.

In the *practical part* of the course, two senior staff members with appropriate pedagogical background supervise the teaching of the assistant professor. On the basis of the supervision and the participant’s developed teaching portfolio, a statement about the teacher’s teaching qualifications is made (in accordance with the legal obligation). The workload in relation to the practical part is estimated to around 65 hours.

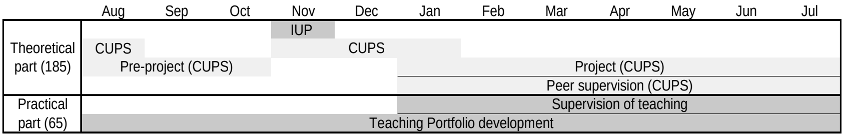

Figure 1. Outline of the TTP for assistant professors in the sciences at the University of Copenhagen

Table 1 shows the intended learning objectives for the TTP as a whole. The different elements of the TTP contribute variously to the teaching and learning activities in the different bullets of the intended learning outcomes. For instance, the last two bullets are addressed in the CUPS course, but may also be addressed in the supervision, and in the participants' projects. These two bullets are very closely related to general faculty development efforts, and constructive alignment implies that if participants should learn how to engage in such developmental work, they should also be engaged in teaching and learning activities that support this in the course.

Table 1. Intended learning outcomes for the teacher training programme (TTP)

At the end of the course participants should be able to:

- Plan, carry out and evaluate teaching at tertiary level within the participant's subject area
- Employ a repertoire of planning, teaching, assessment and evaluation methods, and demonstrate understanding of the possibilities, limitations, strengths and weaknesses of the various methods in relation to curriculum, learning objectives, participants' previous knowledge and the institutional limitations.
- Justify choice of content, sequencing, teaching methods and modes of assessment on the basis of a pedagogical knowledge base and understanding of the students' previous knowledge.
- Reflect upon students' learning in relation to the teaching activities, and assess the students' learning outcomes in relation to the learning objectives. Can plan suitably challenging learning activities for the students.
- Adjust the teaching in real-time, in order to improve student learning.
- Reflect upon own teaching and the teaching of others, drawing upon relevant pedagogical literature.
- Can take part in the development of courses, modules or entire study programmes, and relate to the interplay between the objectives and assessment methods of the study programme as whole and its constituent parts.
- Can take part in discussions of the development of the faculties' study programmes, quality assurance and the external factors and conditions influencing the development of the study programmes.

Course in University Pedagogy in Science (CUPS)

The Course in University Pedagogy in Science is organized around 5 authentic case based themes, as illustrated in figure 2. The participants' work with the different themes is typically based on a PBL session in groups of 3-6. For each theme, several different cases are available for the students to choose from. Thus, for instance, in relation to theme 1 on teaching methods, there are cases related to problems with lectures, tutorials, laboratory work, use of ICT, and clinical teaching. In this way the participants may choose to work with the case that is most relevant in relation to their own actual teaching.

Introduction (1 day)	Ordinary course days (4 days)				Final retreat (2 days)
Poster-session	Pre-project presentations	Theme 1: Teaching methods	Theme 2: Assessment	Theme 3: Constructive alignment	Theme 4: Supervision
Introduction to pre-project	Exercise in peer supervision				Theme 5: Optional
Group formation	Theme 1: Teaching methods	Theme 2: Assessment (sum. and form.)	Theme 3: Constructive alignment	Theme 4: Supervision	Introduction to projects
Introduction to ICT					Exercise in peer supervision

Figure 2. Outline of the Course in University Pedagogy in Science (CUPS).

The basic textbook used in the course is Biggs and Tang (2007), but a wide range of supplementary literature is provided as suggested reading for the treatment of the cases, and participant find relevant literature on their own – depending on the learning objectives they decide upon.

The use of the TTP for more general faculty educational development has its roots in the CUPS course from which we shall present three examples of such faculty development efforts.

Example 1: Helping improve a specific course in one of the Faculties

In the PBL session on theme 1 (teaching methods) in 2008 (see figure 2), the participants were presented with an (actual but slightly modified) e-mail sent to one of the authors. The e-mail was from a group of teachers who requested help on developing their course at the pharmaceutical faculty. The course had many lectures, and somewhat fewer tutorials, and was attended by around 150 students. Many students fail the course, and the teachers wrote as part of their request “We wish to change the teaching, particularly the tutorials, so that the students take responsibility for their own learning.” At the CUPS course, three PBL groups were formed around this case, one focusing on improving the tutorials, and two groups on improving the lectures. In their presentations, the first group considered how students could be motivated to work independently, and had several suggestions for how the teaching could be organized in new ways, allowing for increased student activity. The groups on lectures focused on getting the students to work during lectures, for instance by solving problems in smaller groups, and peer-instruction like approaches. One group had also found the slides from the lectures on the web, and had suggestions on to how one could focus more on the core mechanisms and concepts, leaving the rest to the students’ work out of class. The other group considered the use of ICT in class and out of class. The three presentations have been sent to the teachers of the involved course. It is a motivation to the participants in the course to work on an authentic case, where they could actually help their colleagues develop their teaching, instead of an “artificial” case just for their own learning. Furthermore, because the problems in the case are relatively typical, the case had a generality that made it relevant to the participants’ own teaching. While the case in this way helped colleagues outside the course develop their teaching, it is obvious that this is not the way to bring about faculty educational development on a grander scale. But for the involved participants and for the teachers who had the problem it is useful, and because of the generality of the problem the methods and the results may be used many other similar situations encountered by the participants in the future. In this way such cases do have a faculty educational development potential, and are definitely worthwhile in the CUPS course.

Example 2: Providing in-depth development of a number of courses at the Faculties

The projects in the CUPS course (see figure 1) constitute an important part of the teaching and learning activity in the TTP. As stated in the last two bullets of the intended learning outcomes, the participants should be able to *take part in the development of courses, modules or entire study programmes*, and to *take part in discussions of the development of the faculties' study programmes and quality assurance*. The project is an important opportunity to practice these skills. They are typically made individually, but some are group-based.

The project is based on the participants' development of and reflections on his or her own teaching. It is a specific requirement for attending the TTP that the participant must be allowed to plan and design his or her own teaching – of course in relation to given frames and programme requirements. Sometimes the framing of the teaching does not allow for all the changes which the participant consider relevant. For instance, if the participant teaches only a fraction of a larger course, assessment method and content may have been decided by other (and more senior) colleagues. Then the participant may argue his or her suggestions for change as recommendations for future development in the project. It is quite often the case that participants in this case manage to influence and change important elements in subsequent implementations of the course.

It is possible to write a project which addresses issues beyond concrete changes to a specific course. In a few cases, participants have chosen to write on e.g. a curriculum analysis on the programme level. For instance, one participant analysed the progression in the curriculum in human physiology in the study programme in sports and exercises, and concluded that there was ample room for improvement in terms of alignment by increasing integration of the theoretical courses with the practical exercise courses. On another occasion, a group conducted an empirical survey of the students' ability to solve the same mathematics problems when written in English and Danish respectively. Results showed that students in general overestimated their own language skills and that the institutions' general assumption that the teaching language in teaching does not play a major role in learning could be questioned.

The 88 projects made in the period from 2003 all involve revisions which result in more student centred teaching and/or increased constructive alignment. The project brings appropriate literature to bear, often on deep and surface learning and constructive alignment, but also more content oriented theories such as the Theory of Didactical Situations (Brousseau, 1978). A typical project results in revisions within the given frames of the traditional teaching, for instance introduction of peer instruction or other types of interactive lectures, but also changes to the tutorial recitation format is quite typical. The more outstanding projects are shared with subsequent participants in the course literature, and thus gain impact beyond the specific course. We present a number of such examples below.

Example A: Traditional tutorial or problem solving classes represent huge challenge to the participants. In the "ideal format", students bring their individual solutions to a number of typical end-of-chapter text book problems and volunteer to take turns in presenting their solution to the class which takes proper notes. The teacher supervise the process and help students when they get stuck. Most often, however, students are poorly prepared, refuse to present at the blackboard and quickly force the instructor to present the correct solutions to the class which thereby get the solution – with notes. Most instructors are unhappy with this situation, but feel powerless and quickly resign. However, the participants in CUPS quickly realise that even the ideal format is not very student centred.

In one project a participant designed the following format: Students come to class more or less prepared, but are told that they should at least try to solve all problems beforehand, and if they get stuck on a problem, note why. In class the students are first divided into groups based on the type of their difficulties: Students, who only experienced difficulties in the most advanced problem are grouped together, likewise are students who experienced problems in the more basic problems. The groups then work on the problems for one hour (of two), facilitated by the instructor. Difficult parts of the problems are then presented by the different groups in the second hour, supervised by the instructor. The participants' class was one of three parallel sections, and students were assigned randomly to a section, but were free to change. Initially the students were thus evenly distributed in thirds, but the CUPS participant ended up teaching more than half the entire group of students enrolled.

Example B: Revisions of cook-book labs have been the theme of several projects. In one project an entire course for 50 students was revised and the former cook-book labs were replaced by more open-ended exercises, where studens had to design their own experimental setup. The number of exercises was lowered, but the study showed a much better and more useful learning outcome, which was better aligned to the study programmes overall learning objectives.

Example C: Course alignment was the theme of a project where assessment procedures in the participants' course were evaluated and revised to become in accordance with the new national rules for assessment which ruled out the hitherto used assessment method. The previous assessment was a pass/non-pass assessment of a group report, but the new rules stressed a requirement for individual assessment. The project took results from the participants' pre-project into account where it was found that the group project played an important part in the students learning process. Therefore, the new assessment is an individual oral exam based on a group based report. Furthermore, a new course element with individual presentations of smaller case studies allowing for formative assessment of the students' oral presentation skills was added.

Example D: Other significant projects implied introducing case- or PBL-based learning, for instance in a crucially important course on drug formulation at the pharmaceutical faculty; these activities now play an important role in the structure of the whole course, and has also spread to other courses in the department.

Faculty development on a course by course basis may seem almost futile given the enormous number of courses in the three faculties. The number of courses at the three faculties exceeds 1000. However, it is our experience that the ideas for new student centred approaches developed in relation to the participants' projects, actually have a tendency to spread to other courses – an effect that may otherwise be difficult to establish. An important reason for this is of course, that the teachers have developed these new initiatives themselves, and bring the ideas with them to their colleagues and to the new teaching responsibilities the meet. In this way, the former participants in the course become "ambassadors" of student learning at the departments. In addition, over the past year the enrolment to the TTP has increased dramatically, mainly because of the increased recognition of the importance of the TTP by the faculties. Thus, this year (2008/2009) the number of participants in the course is around 80, and the age profiles at the faculties suggest that this number may even increase in coming years. In a not so far future, the number of courses which has been through the critical eye of a student focused teacher in each programme will have reached a critical number, were "traditional teaching" is not really the tradition any more, and where the former participants in the course will be the citizens rather than ambassadors. In this perspective the future seems quite promising, even for the most confirmed pessimists (i.e. the authors).

Example 3: Helping initiate a large scale educational development projects at the faculties: Implementation of a new grade system

In 2007 a new grade system was implemented in the Danish educational system (The Ministry of Science, Technology and Innovation, 2007). The introduction of a new grade system was mainly lead by a wish to coordinate the Danish grade system with European standards (ECTS) and was a result of several years' ministerial work, hearings phases and debate (Undervisningsministeriet, 2006).

At the university level the implementation was to be finished and in use to the exams in fall 2007, however the implementation process in itself was up to the individual universities to decide. At the University of Copenhagen it was laid out to the different faculties and the Department of Science Education was appointed the task of initiating an implementation process at the departments at the Faculty of Science. The Didactical Unit at the pharmaceutical faculty played a similar role, in cooperation with the head of studies. The authors played key roles in these development projects.

The main new aspect of the new grading system is that it is based on an absolute scale and that this scale must be related to learning objectives described for the course involved. Learning goals had at the time been described for all courses at the faculties but were of a varied quality seen from an educational development perspective. Many teachers experienced the task of making learning objectives as a purely administrative task that had nothing to do with their teaching practice.

Based on these experiences we decided to use the task of leading the implementation process of the new grade system at the Faculty of Science to stimulate the use of constructive alignment, where learning objectives, teaching and learning activities and assessment reflected and reinforced each other. Thus, the relatively mundane challenge of implementing a new grading scale was taken as an opportunity to create educational development at the faculties.

Accordingly, the implementation of the new grade system at Faculty of Science was established in three steeps: Development of prototypes at the CUPS course, by using resource persons at the departments, and providing workshops for all members of scientific staff at the faculties. A similar, if slightly less ambitious, process took place at the Pharmaceutical Faculty.

The process of initiating the work with constructive alignment linked to the new grade system was started at the CUPS course (theme 3, figure 2). Each of the participants was given the task of looking at one of the courses at his/her department - preferably a course that he/she was directly involved in or related to in one way or the other. The task was to assess the existing learning goals if such goals existed, and to formulate more appropriate ones and then relate them to the exam measurements. The assignment involved individual work, group feed-back and plenary discussions where participants received feed-back from the facilitators and other participants. This exercise dealt with around 25 different courses at the Faculties of Science and pharmaceutical sciences and actually meant that all departments within the faculties had a staff member who had considered the question of defining learning objectives and accompanying operational grading criteria in detail. This process was finished at the beginning of 2007.

At the Faculty of Science, the next step in the process was to appoint resource persons at each of the Departments. Some of these resource persons were assistant professors from the TTP (or former TTPs), others were teachers involved in the administrative parts of the teaching organisations or pedagogically trained departmental supervisors from the TTP (see figure 1). In this process two persons from each of the involved 8 departments were involved. Individual meetings and feed-back sessions were held with the resource persons and they were guided to formulate learning goals and reflect on the process involved in order to be able to present it to their colleagues at department workshops.

During the spring 2007 the Department of Science Education conducted workshops at the faculty's Departments. Each workshop was focused on letting the teachers work with formulating the learning goals for their courses in groups that teach on the same course, and letting them discuss the relation between learning goals and assessment criteria. The point of departure was taken in presenting the learning goals and the reflections of the process from the resource persons from that particular department. So after a short introduction to the prototype case developed by the resource person, most of the day was spent actually working on the learning goals and discussing. The process went very differently at the different Departments – from very productive and centred on constructive and valuable discussions to reluctance and even resistance to working with the learning goals. In this process, the insights from the assistant professors' CUPS cases were invaluable in trying to feed into and facilitate the process. At a number of the departments it was mandatory for the teachers to turn up to the workshop, and in that respect this process meant that a large number of courses that were reconsidered and reworked. At the most sceptical departments, the effect of re-formulating learning goals and trying to get the teachers to link them to the assessment criteria was not great, but in each department we observed great differences between different groups of teachers.

At the pharmaceutical faculty, two theme-days were held for scientific staff where participants from the TTP presented their work, and teachers were informed and discussed the new system and the process of change.

The TTP thus played a crucial role in the development program at the two faculties, in helping staff make sense of the new grading system. The task of formulating learning goals and relate these to the teaching and learning activities and the assessment in ones own course is still a part of CUPS. In this way all new members of the departments' teachers gets training and experience with this increasingly important part of educational practice. Both for the benefit of specific courses, but also in order for the assistant professors to be able to participate in department discussions of future educational practices.

Conclusion

In this article we have given an account of how the teacher training programme at the faculties of science, life sciences and pharmaceutical sciences at the University of Copenhagen is used as a lever for general faculty educational development efforts at the faculties. The three examples provided range from the relatively limited impact of developing a specific course, to larger scale individual developments in the participants' projects with substantial and growing impact. Finally, an example is given of how a specific faculty educational development project at the faculties was coupled with activities in the TTP. The coupling of the TTP and the general faculty development efforts will be developed further in the years to come.

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teacher training

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What exactly do prospective secondary mathematics teachers understand from angle measurement?

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Abstract

Angle concept has been taken on different meanings in its historical development (Keiser, 2004). In this respect, the measuring of it is a challenging task, due to various definition of the angle. The purpose of this study is to investigate what exactly prospective secondary mathematics teachers understand from angle measurement? Five prospective secondary mathematics teachers were choosen to purposeful sampling for the aim of this work and phenomenography used for the design of the study. The data analysed with content analysis in which participants' point of views were categorized, compared and interpreted. At the end of the analysis it is observed that prospective secondary mathematics teachers' responses about angle concept are consistent with these three categories: a quantity, a quality or a relationship. The understandings of the angle measurement of them related to these categories. Also, results revealed that prospective secondary mathematics teachers' representations about an angle were limited to their pre-university familiarity.

Introduction

Understanding the inclusion relations in concept of geometric figures plays a key role in mathematics. This understanding helps students to abstract these figures from shapes in daily life. It is not a strenght matter if you are talking about "a square" or "a triangle" but what about a complicated concept, like "angle"?

Angle is a single word that includes various meanings inside and this feature of word makes it a multifaceted concept. It is one such concept that has been defined differently over the centuries and, depending on the mathematical situation at hand, can still today take on different meanings (Keiser, 2004). Then, does nature of this multifaceted concept form any problem in students conceptual learning or can students appropriately grasp the properties or samples related with angle? These kinds of questions have shaped the start point of this study and in this paper the problem of how prospective teachers develop an understanding of angle measurement has been discussed.

There are many authors who have been bothered with analysing these mentioned problems. Clements and Battista (1992) say that school students have great diffuculty in learning angle concept and Fyhn (2004) supports them stating that angle concept is really difficult to understand for young students. According to Mitchelmore and White (2000) the focus on identifying the two lines of angle needs to be modified. It appears difficult for a student to identify angles without already having a "sense of angle". Another study that was executed by Keiser (2004) compares sixth-grade students' understandings about angle with historical definitions of concept. The study claims that angle is highly complex for students and can be approached from a variety of vantage points.

All of these precedings studies put forward that students have great difficulty about having a sense of angle. Then, why? Is it just because the concept's various facets? These findings or observations compel the mathematics education researcher dealing with again the same problem: How mathematics is taught at school is just as important as what mathematics is taught.

There is no doubt that one of the essential elements in improving students' understanding at school is the teacher. Even the teacher has the responsibility of creating a classroom environment in which students develop an appropriate understanding of mathematical concepts. This learning environment created by the teacher is the most important factor that effects the student performance..

Because the future's teachers are prospective teachers in present, great emphasize must be given to the prospective teachers' knowledge of subject matter knowledge and pedagogical knowledge. The studies of prospective elementary and secondary teachers' mathematics subject knowledge indicate that they lack a conceptual understanding of many topics in elementary mathematics (Ball, 1990).

Based on these ideas, in this study it is aimed to study prospective mathematics teachers' conceptual knowledge on measurement of angle. It is believed that this study is going to lead mathematics educators to pay attention prospective secondary mathematics teacher's framework of concept knowledge and how their individual approaches difference when a complex concept is asked about. Thus, in this research study, prospective secondary mathematics teachers' own sentences and representations which they used to reason about their understanding of angle measurement were presented. Briefly, this study has been formed around the answer of following question:

-What exactly do prospective secondary mathematics teachers understand from angle measurement?

Angle Concept and Angle Measurement. Definitions of concepts are cornerstones of pupil's concept building. It is believed that if pupils construct their concept development on to a well-comprehended concept definition, they can manage problems more successfully. Well then, what can a student do against a concept that which's definition has been a diffucult process for mathematicians during its' history?

Owing to its' multifaceted nature, Keiser (2004) states that defining angle is a diffucult problem because all definitions put limitations on the concept by focusing more heavily on one facet more than any of the others. The concept of angle is so complicated that gaining a deep understanding for it is a diffucult task. It has been taken several meanings not only due to complexity of the concept but also the daily usage of the word.

Approaches about angle definion are adjusted with three main fields: An amount of turning about a point between two lines(dynamic); a pair of rays with a common end-point; and the region formed by the intersection of two half-planes (both static conceptions) (Mitchelmore & White, 2000). Besides that, the early

Greeks who defined angle tended to weight their definition into one of the these three categories: A relation, a quality or a quantity. Thought many mathematicians categorize an angle in only one of these categories (Keiser, 2004).

In this study these categories will be taken up and prospective secondary mathematics teachers' understandings about angle measurement will be evaluated from these perspectives.

Methodology

In this study qualitative research methodology was choosen because the aim was to gain an in-depth understanding of the prospective secondary mathematics teachers' angle measurement comprehensions. In particular, a phenomenographic approach is used in which the participants' point of views were categorized, compared and interpreted. Five prospective secondary mathematics teachers were choosen to purposeful sampling (Patton, 2002) for the aim of this work and they were voluntarily participated in the study. The underlying rationale for choosing the prospective teachers was their experience(academic success level, classroom and daily observations) in the undergraduate program. Four of them are male and one of them is female. Their ages ranged from 21 to 22.

These prospective teachers were enrolled in an undergraduate teacher education program in Ankara, Turkey at the end of the fall semester of 2007-2008 academic year. In Turkey, when prospective secondary mathematics teachers graduate from the university program they are potential teacher candidates who can teach mathematics at upper elementary and middle grade levels. These students who were participated in the study had already completed most of the courses offered by the teacher education program, they were in their 3rd prade of five-year-education.

For the design of the study phenomenography is used because phenomenography is the empirical study of the limited number of qualitatively different ways in which we experience, conceptualise, understand, perceive, apprehend etc, various phenomena in and aspects of the world around us. These differing experiences, understandings etc are characterised in terms of categories of description, logically related to each other, and forming hierarchies in relation to given criteria. Such an ordered set of categories of description is called the outcome space of the phenomenon, concepts in question. Although different kinds of data can be used, the dominating method for collecting data is the individual interview which is carried out in a dialogical manner (Marton, 1992). This is the rationale of choosing interviews during the data collection.

As mentioned, data were obtained from individual, semi-structured interviews. The interviews lasted around an hour and were tape-recorded. During the interview following questions were asked to participants:

- How do you define angle concept? Could you please share your opinions with me?
- In your opinion, what exactly is being measured when talking about an angle's size? For instance, what do you perceive when "$\hat{A}$ is 60 degrees" is said?

- In your daily life, what time, in which cases and how do you need to use angle concept?

During the study for each participant a nickname was given and their real names have never been used. The data taken from the interviews were parted into meaningful units and according to these units, the data were coded and categorized; after that the categories were analyzed and interpreted with content analysis (Patton, 2002).

Content analysis is the systematic description of behavior asking who, what, where, where and how questions within formulated systematic rules to limit the effects of analyst bias. The content analyst views data as representations not of physical events but of texts, images, and expressions that are created to be seen, read, interpreted, and acted on for meanings, and must therefore be analyzed with such uses in mind. It is the preferred technique for analyzing semi-structured interviews and cognitive testing interviews(Krippendorff, 2004).

To ensure the validity and reliability of the study some methods were used. Firstly, the findings and interpretations were read by participants and approved. After that, the whole data were coded and categorized by another research assistant who is also a Doctoral Student at the department of Mathematics Education; new categories compared to researchers' categories and a similarity above 80 % was noticed.

Findings

As stated above, prospective secondary mathematics teachers' understandings about angle concept and its' measurement have been evaluated from three perspectives: A relation, a quality or a quantity. Preceeding studies and prospective teachers' responses have guided researchers to categorize findings in these three subheadlines. Each of five prospective teachers understandings' have been presented at belonging subheadline.

Angle as a quality. After five prospective teachers' responses to interview questions were analysed it has been determined that some of them occasionally perceive angle as a quality. Keiser (2004) points out that defining angle as a quality is a problem because if one accepts such a definition s/he has a problem when it comes to angle measure. According to him if an angle is a quality, then it is something that where you can have more or less of angle… or one angle is more of an angle than another.

In the study, when he was talking about angle measurement, a male prospective teacher (Musa) drew acute, right and obsute angle pictures and he explained the relations between them (Figure 1). He said that obsute angle was bigger than acute one because its' rays were more separated from each other. His explanation informes that he considers one angle is more of an angle than another.

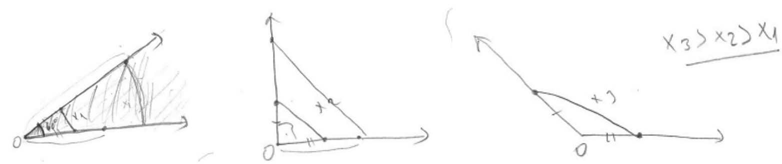

Figure 1. Musa's drawings about angle measurement

Angle as a quantity. In the study it is noticed that most of the prospective teachers see angles as quantities. They consider an angle could be expressed as a size which could be measured in some way. When these teachers' responses are investigated it can be seen that they relate the angle's measurement with "space or distance between the rays" or "arc length that the rays of angle limits on a circle".

Below, there are some sentences and drawings of prospective teachers which support these findings. Two of prospective teachers used "space between the rays" when they were defining angle but they became seperated from each other during its' measurement definition. One of them said measurement was the shaded space between two rays where the other said it was arc length limited by two rays. The following interesting dialogue puts forward prospective teacher's confusion about measurement.

Nafi: As I have defined just now, angle is the space between two rays. Measurement of angle is… it can be the region which is formed by the rays (Figure 2a).

Researcher: Ok, can you draw it please?

Nafi: Of course, I can draw it at the coordinate axises, like this.

Researcher: Okay, let's think about these two rays again. You say angle's measure is the space that these two rays constitue.

Nafi: Yes.

Researcher: Well then, do these two rays form only one space? For example I make rays' arms longer, what can you say about the new formed space? Is it different from previous one?

Nafi: It is absolutely different.

Researcher: Then what about angle's measurement? Does it change?

Nafi: No… hımm, how can it be?... Measurement is not the space then…

Researcher: So, what is it?

Nafi: … can we define like this; it is the two rays' distance from each other… oh, but we can't. You will ask the same thing. Which distance it is?(Figure 2)

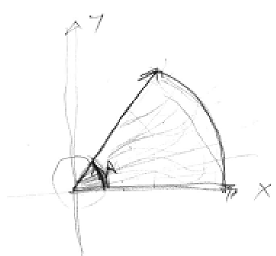

Figure 2a. Nafi's first drawing about angle measurement

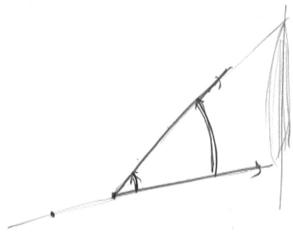

Figure 2b. Nafi's second drawing about angle measurement

Keiser (2004) points out the same trouble in his study: Students get in trouble defining the angle if they accept the quantity face of angle. On the other hand, the other prospective teacher who has expressed angle as a quantity overcomed the problem in an appropriate way.

Researcher: Let A be an angle. What is been purposed from A angle's measurement?

Yasin: The same… Arc length (Figure 3).

Researcher: Can you show?

Yasin: Yes, of course.

Researcher: Okay, well then, I draw another circle making the ray's arrows longer and say that this arc length is a measurement for angle A, too. Have these measurements different quantities?

Yasin: But we study with unit circle…

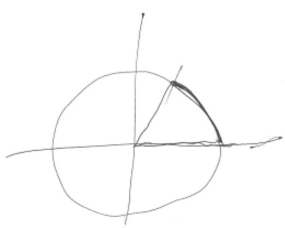

Figure 3. Yasin's circle drawing for angle's measure

Angle as a relation. Expressing an angle as a relation means dwelling upon the relationships of parts of angle. For instance, if one defines measurement of an angle as a seperation of rays from each other s/he particularly emphasizes the relationship between the rays. During the data analysis it has been revealed that prospective teachers could give meaning the measurement of an angle as a relation, too. One of the prospective teachers used "the picture of two rays that intersect in one point" expression for angle's definition afterwards he prefered to use "removeness of one ray from the fixed one" explanation for its' measurement. (Figure 4) His understanding about measurement angle declared that he epmhasizes the rays and especially their relationship between each other. Following sentences of the prospective teacher support the mentioned finding.

"Increasing of the distance between rays means the measure of an angle gets greater. I mean, let this ray as the fixed ray [he points OD] then the more this one[he points OC] getting distant from this[OD] the larger the size of angle. " (Figure 4)

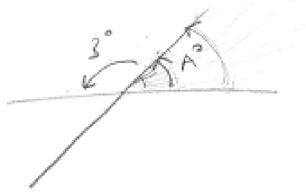

Figure 4. Selçuk's drawings of angle measurement

Another important statement is that prosective teacher points a shaded region in his angle definition. It is a shock that he substitues a representation into the concept (Figure 5). It is exposed that the appropriate usage of representations is vitaly important for conceptual understanding.

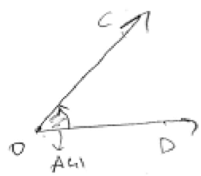

Figure 5. Selçuk's drawing about angle concept

It can be said that a prospective teacher defines an angle sometimes as a quality, a quantity or a relation, either sometimes as both of these or as all of them together. S/he states his/her understandig about angle fits a guantity view but in somewhere else s/he can use it as a relation. For instance, Zeynep defined angle as "the distance between two rays" but she used the "movement of a ray" term while she was talking about measure of it. The common problem of procpective secondary mathematics teachers is having difficulty with using the appropriate words for angle definition. They make a concept definition but this definition leaves them in the lurch when its' measurement is in question. It is believed that concept's multifaceted nature prevents the concept development of prospective teachers directly. Even the following dialogue is seen considerable fort this finding:

Researcher: What would you say about it if I asked you the angle that is determined by two rays?

Yasin: That place (He shows the smaller region between two rays)… But you will ask then, what is that place?

Researcher: Yes, I'm afraid I will.(Smiles)

Yasin: … I don't know to define then.

During the interviews another interesting observation was that all of the participants have prefered to use acute angle in their drawings. They can't imagine for instance the part of reflex angle at first sight. The case has been asked them and Zeynep's response was the most thought-provoking one. She reproached her teachers and said

"I have never seen a teacher drew an obtuse angle on the board while s/he was describing angle concept"

The whole fiindings indicate the teachers' role for students' concept development. It is so important for pupils to comprehend a concept with its' all suitable representations. These representations and symbols must be discussed together with pupils.

Conclusion

Because of representations of concepts have vital importance in mathematics (Akkuş & Çıkla, 2004) they are crucial for understanding mathematical concepts (Lesh et al., 1987). There is no doubt that to give appropriate representations, teachers should have deep knowledge on the concepts. Based on findings above, we could deduce that prospective secondary mathematics teachers have insufficient conceptions on angle measurement and these missing conceptions limit their angle representations.

As stated before, all of the participants have trouble with giving convinced explanations when a concept is in question. Thus, findings of the study suggest the reconsideration of the courses offered to the procpestive secondary mathematics teachers. Concept-based courses should be offered to them so prospective teachers could been taught these concepts at a university level. In Turkey, these students studied geometry in upper secondary school, and they will encounter geometric concepts only once more in univesity before they are certified to teach.

Particularly, because angle is a multifaceted concept it must be presented with all of its' representations. In a concept-based geometry course prospective teachers may be permitted in course environment to share and discuss their ideas. This environment supplies them to constuct their concept knowledge in an appropriate way.

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Didaktik analysis an alternative ways of improving pre-service physics teachers in Malaysia

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Abstract

Despite on-going efforts to improve physics education through training of pre-service teachers, significant challenges remain. Much previous research about pre-service teacher education and training has focussed on improving their pedagogical content knowledge. In this work we report the development of Malaysian pre-service physics teachers training that is based in the German *Didaktik* tradition. This model involved the process of *didaktik analysis* - a detailed analysis of specific science content contained in curriculum specifications and textbooks along with analysis of literature on students' alternative conceptions. These analyses were used to develop lesson plans and developing teaching sequences which the pre-service teachers then enacted in microteaching, and in a practicum. The research findings suggest that the pre-service physics teachers that participated in this work valued the process of didaktik analysis and this increased their confidence to teach secondary school physics and development as reflective practitioners.

Introduction

One of the secondary science education programmes of the School of Education, University of Malaysia Sabah (UMS) is physics education. There are two cohorts of pre-service teachers enrol to the science education programme: third years and fourth years. The third years are pre-service teachers who come to the programme with secondary school qualifications (Matriculation or Higher School Certificate), and who were former primary school teachers. Their entry into science education courses (physics, mathematics, chemistry and biology) is thus based on their science teaching experience at the primary level, with a few did not actually teach science at primary schools, and had only a general science learning background at the secondary. These third years are sponsored by the Ministry of Education under a scheme called the *Special Conversion Programme for Non-Graduate Teachers*. Under the Scheme, they are required to enrol in a physics content course as a *minor*, and mathematics as a *major*, a condition imposed by the Ministry because the fact that their enrolment was compulsory, means that they are not doing such courses by choice. The need to study physics and physics education purely to satisfy the Ministry's rules, might mean the third years were not particularly positive in terms of attitude-toward physics and learning, and physics teaching. A key limitation in training is the limited science content background of pre-service teachers such as these third years.

The second cohort was the fourth years, who also had matriculated or gained Higher School Certificate, but who had learned more science at secondary school (e.g., physics, chemistry & biology). This cohort had a different major to those from the three year programme: some took physics as a major and mathematics as a minor, and others vice versa. They had learned physics at secondary school, mostly at the SPM (Malaysian School Certificate) level. However, some had not learned physics at the STPM (Higher School Certificate) level, but all who matriculated had experienced some physics learning. They had to complete physics and mathematics courses in the School Science and Technology before enrolling the physics teaching methods course at the School of Education.

The writer along with previous experience as a trainer of teachers resulted in concerns about the third years' capability and willingness to teach physics. They claim that the training of Malaysian pre-service physics teachers can be improved, not only the practice of teaching, but also their content-specific knowledge by drawing upon the notion of *didaktik analysis* (Colomb, 1999; Klafki, 2000). Research suggests that the didaktik analysis within the didaktik tradition is effective in improving the practice of science teaching and consistent improvements in students' learning (Leach & Scott, 2002; Viennot & Rainson, 1999). Before going on to explain didaktik analysis a brief overview of literature about 'traditions' that form the basis of pedagogical approach in comparison to the didaktik approach to teacher training, is provided. From this, the importance of science content and its role in science teaching becomes evident.

Overview of pedagogical approach in curriculum tradition and didaktik tradition

Teacher training programs world wide (at least in English speaking countries) have been dominated by the use of a pedagogical approach to teacher training within the curriculum tradition (Fensham, 2004). In Malaysia, this tradition has been sought to equip pre-service teachers with knowledge of a variety of pedagogies, in the hope that such knowledge will allow them in the classroom to use the approach they think best suited to the content and their students' needs. For example, pedagogical approaches in the curriculum tradition, according to Jones and Baker (2005) include: teachers employ their own and students' awareness of ideas about a phenomenon, situation or learning process; students' learning experiences familiar with, and/or personally meaningful contexts, and aware of purposes for learning; engages students in purposeful dialogues with the teacher and/or their peers; helps students build bridges between their own world and the cultural of science; introduces less content; and allows the students discuss their learning in their first language. The researcher argues that, for example, although the mentioned literature suggests that teachers introduce less content may result in students' learning experience more successful, in fact the view of less content is against the aims and objectives of science content to be learned. Students' understanding of scientific knowledge remain limited as the content of school science aim at providing students with further academic studies rather than understanding of scientific ideas relevant to contextual factors such as their everyday life experience.

As a result of less content, Fensham (2004) argues that one fundamental reason science concepts may be poorly learned is that *the problematic nature of the content itself is often ignored* or lack of ability on part of the teachers to interpret and convey complex science concepts into a fascinating way (Wellington & Osborne, 2001). In addition, the claim effective pedagogical approaches mentioned above are related to the conduct of educational research, but not science research which are two distinct fields, and that are typically viewed from different perspectives (Fensham, 2004). The notion of less content in this curriculum tradition may provide a new direction for pedagogies in which science content is not only viewed as stated in 'the curriculum specifications' as well as places emphasis in teacher training on pre-service teachers' ability to transform (content of instruction and strategies of instruction) science content knowledge through planning, preparing and teaching lessons, but also concerns the process of transposing or transforming the science content structure into a content structure for instruction or schooling in the teacher training as embedded in the didaktik tradition (Duit, 2007; Kansanen & Meri, 1999; van Dijk & Kattmann, 2007). In addition, there are relatively few studies in the literature on the improvement of practice, particularly in science teaching, within the didaktik tradition, and those studies that are reported are confined to Central and Northern European educational contexts (Lijnse, 2000; Tochon, 1999). Thus, the researcher suggests that teaching and teacher training within the didaktik tradition deals mainly with the teaching and learning of specific content knowledge.

If the didaktik tradition provides some guidance to decide the core tasks of pre-service teacher training, as Westbury (2000) argues, then Hopmann and Riquarts (2000) ask some critical questions: What do teachers know about the content they are teaching?, and what do students see and comprehend when they are confronted with that content? To answer these questions, Marton and Ramsden (1988) note that one needs to have a 'subject' didaktik (e.g., physics didaktik). As a result, they conclude that the practice of teaching and learning in the classroom within the didaktik tradition can be enhanced. It is from this conclusion that the didaktik of physics within didaktik tradition becomes important for "it defines the analysis and mapping of the different ways students experience and conceptualize various content domains" (Marton & Ramsden, 1988, p. 283). According to Marton and Ramsden (1988), the *didaktik of physics* is not the intersection of a teaching physics methods course, educational psychology, and subject matter. It is more a distinctive discipline, a kind of 'science of education', in its own right. It is concerned with how specific content is taught and learned. Didaktik of physics as a discipline in teacher training is thus seen as another field of scientific endeavour. In a similar way, Tochon (1999) defines didaktik of physics as the analysis of, and theorizing about, the phenomena of teaching and learning specific to the content knowledge of physics. In other words, it describes and designs the actualized or virtual learning and teaching relationship between a disciplinary content, students, and a teacher. Additionally van Dijk and Kattmann (2007) view didaktik of physics as a scientific discipline that brings together physics and physics education by studying empirically students' alternative conceptions, their motivation, and the effect of using media methods. Finally, Lijnse (2000) simplifies this term as someone who deals with the improvement of physics education through research, curriculum development and teacher training. The didaktik relationships between the teacher, students and content are described as the didaktik triangle. Some didaktik scholars (e.g., Kansanen & Meri, 1999; Uljens, 1997) suggest that this triangle can be used in teacher education to explain to pre-service teachers of how to prepare lessons.

Klafki's (2000) didaktik analysis

One conception of didaktik tradition is Klafki's (2000) didaktik analysis, to be used in pre-service teacher courses as a guideline for preparing lesson plans, and concerned with specific science content. Klafki developed a series of *fundamental questions* ('five sets of questions') concerned with the specific science content - based on the notion that different science content requires different pedagogical strategies. The five 'sets of questions' are:

1. Exemplary importance: What are the general ideas, meanings, facts, problems, basic phenomena, general laws, criteria, methods, techniques or attitudes that the content specifically represents?
2. Contemporary relevance: What is the significance of the relevant content or the experience, knowledge, ability or skill to be acquired through this respective content in the lives or minds of students? What level of significance of the relevant content should have from a pedagogical point of view?
3. Future importance: What is the significance of the relevant content for the future of the students?
4. Structure of content: How is the content structured if viewed from the pedagogical perspectives outlined in questions 1 to 3? What prior knowledge is required?
5. Accessibility: What special cases, phenomena, situations, experiments, persons, elements of aesthetic experience, and so forth, can be used to make the content interesting, clear, stimulating, worth questioning, understandable, and vivid for the particular students at their level?

Methodology

As this study involved an intervention of nearly six months' duration, an interpretive-based approach using a qualitative methodology was regarded as best means of data collection. Here the researcher followed the suggestions of Janesick (2003), and employed the notion of 'stretching exercise' in contrast with the notion of a 'pilot study' as typically used in quantitative research. The idea here is that a researcher needs to develop and solidify rapport with those involved directly and indirectly in the study. In this work this included the pre-service physics teachers who enrolled the physics teaching methods course, the Dean of the School of Education, the academic and non-academic staff at the School of Education. Additionally, the researcher required practice in methods such as interviewing, making observations, examination of written reports and refinement of research instruments. Prior to interviews with the pre-service teachers, the researcher tested the audio-tapes and held meetings with selected pre-service physics teachers. Expertise in purely technical things was required, and so the researcher spent time with a technician, an expert in video editing at the UMTP (Educational Technology and Multimedia Unit) university unit - and this helped the researcher to see how to get video clips transferred from a video camera to CD.

The pre-service physics teachers consisted of two groups: special conversion for non-graduate teachers (three years programme), and fresh students (four years programme). Some of the special conversion for non-graduate teachers were former primary school teachers, sponsored by the Ministry of Education. Their entry into science education courses (physics, mathematics, chemistry and biology) was based on their experience of teaching science at the primary level. While some did not teach science at primary schools, others had done science education programmes based on the natural sciences (physics, chemistry and biology) or had a general science background. During their first year, they enrolled in physics content as a minor, and mathematics as a major. They have to enrol these two subjects, a condition the Ministry of Education imposed on them because secondary schools lack teachers for these subjects. The pre-service physics teachers in the four year program group entered science education courses were based on their qualifications either through matriculation or STPM (Malaysian Higher School Certificate). They had learned physics in secondary schools, mostly at the SPM (Malaysian School Certificate) level. However, some may not learned physics at STPM level but those of matriculation had experienced learning physics. Some of them enrolled physics as a major and mathematics as a minor, and vice versa. They had to complete all courses relating to physics and mathematics conducted by the School Science and Technology before enrolling physics teaching methods course at the School of Education.

There were 29 groups of pre-service physics teachers who completed the didaktik analysis assignment. These consisted of two cohorts: 35 participants (15 males & 20 females) in the three year programme called special conversion for non-graduate teachers, and 78 pre-service physics teachers (18 males & 60 females) in the four year programme. The pre-service physics teachers in three years programme had learned physics in the university based on a revised new curriculum. Some of them had not experienced learning physics in secondary school. Those who were in four year programme had taken physics based on an old curriculum: all of them had learned physics in secondary school. The three years programme group in a revised new curriculum learned mechanics whereas the four years programme group did not: this was the essential difference in the teaching of the groups.

Data-gathering instruments

The intervention took place from December 2005 until March 2006. The aim of the intervention was to make pre-service teachers knowing how to treat the problems of teaching and learning physics using didaktik analysis during attending this course. They were given an overview of the course learned prior to the intervention. Klafki's (2000) model of didaktik analysis was used as the basis of an intervention employed in a physics teaching methods course (TT4133) at the School of Education, University of Malaysia Sabah (UMS). The intervention consisted of the 14 week course: first seven weeks on theoretical aspects of teaching methods, followed the usual course synopsis, but with modifications in content resulting from didaktik analysis, and the remainder dealt with microteaching; and 8 weeks practicum. During this time, the pre-service physics teachers were given assignments on written lesson plans and didaktik analysis.

They were asked to plan and carry out a sequence of between 1 and 3 lessons using the didaktik analysis framework. The assignment of lesson plans was on individual, while the didaktik analysis was in a group of 4 or 5 pre-service physics teachers. Another part of seven weeks were spent on aspects of practical teaching, micro-teaching. During the micro-teaching session, a representative of each group transformed the didaktik analysis and written lesson plans into staging teaching activities. The researcher did an observation and this session was video taped by the voluntarily pre-service physics teacher. A focus group interviews about pre-service physics teachers' beliefs were conducted after each micro-teaching session ends. Only ten of them identified had been interviewed. During this time, aspects asked in the interview were about their confidence to teach physics and their feelings during the process of teaching.

To illustrate the use of didaktik analysis in the training programme, the specific physics content in the areas of *force and motion* was provided as an example, showing how this was presented to the pre-service physics teachers in the programme. Although an extensive data were collected, here the researcher only presents findings for pre-service physics teachers' reflections on experience from assignments of conceptual analysis of physics content and analyses of literature on students' alternative conceptions. In addition, transcripts of interview after ten selected pre-service physics teachers finished their micro-teaching were not included in this article.

Findings

Fifty nine out of 105 pre-service physics teachers provided their reflections at the end of the semester: some 40 pre-service physics teachers thought that conceptual analysis of physics content would help them improve teaching practice. Only one was unsure as to whether or not conceptual analysis would improve his teaching practice because he felt preferred teaching methods are based on what individuals find convenient (based on experienced with his or her teachers' teaching). A further 33 pre-service physics teachers commented on the Form Four physics textbook, with 25 of them noting that the analysis helped to improve their understanding of physics content, and 30 pre-service physics teachers commented on the importance of identifying and addressing students' alternative conceptions.

Conceptual Analysis of Form Four Physics Content: The content analysis from 10 pre-service physics teachers' comments, revealed five factors about how the conceptual analysis of Form 4 physics might improve teaching practice, by the enrichment of the existing physics curriculum "making a comparison between Malaysian physics curriculum and international physics curricula [which] is linked with enrichment or improvement of the existing Form Four physics curriculum" (R1). This it was felt, would result in "better understanding about physics content and clarifying some misconceptions held by pre-service teachers" (R27), and make the "teaching and learning process more organised" (R7, 4th F). This would involve using a variety of teaching methods and "many strategies and information [that were] learned from this assignment" (R43), which might mean participants would increase in confidence to teach as a result of "mastering physics content" and becoming "more confident in teaching" (R14).

Some 28 out of 40 pre-service physics teachers experienced difficulties with the conceptual analysis of specific physics content including finding "resources inaccessible" (R1), these resources being things such as "electronics journals, journals, reference books not according to specific physics content" being "very hard to access in the University's library" (R2), as well as "few journals related to the topic" (R13). Such problems resulted in a "lack of knowledge on this topic" (R4), together with English language barrier since some felt that they "cannot speak English very well" (R29), meaning they were "sometimes confused about how to explain" (R6), and to "apply physics content in plain English" (R12). Overall then it was felt pre-service physics teachers "needed more resources in order to understand physics concepts" (R11) together with cooperation amongst group members and advice on "how to get group members to cooperate" (R40), otherwise "it was impossible to do analysis on all about specific physics content, if cooperation between pre-service physics teachers was required" (R58). Pre-service physics teachers felt they needed to know how to transform specific physics content into different teaching sequences, for example, "how to conduct activities or experiments, and to make students understand physics" (R37), and "how to find activities which are more fun and involve all students" (R39). Fear of not being able to cover the syllabus as the result of other contents surfaced along with a perceived "need to follow the sequence of physics teaching from the curriculum specifications", meaning that "if some other content were added which thought to be very important, then we will be facing problem in completing the syllabus" (R42). However, gathering information on alternative conceptions meant they needed to know "how to find misconceptions in physics content" (R40), and as a result of the conceptual analysis some came to believe that "some concepts are very difficult to understand" (R30).

Analysis of Form Four Physics Textbook: Some 11 out of 33 pre-service physics teachers commented on why analysis of Form Four physics might improve their physics content knowledge. The data analysis about this didaktik analysis component suggests that it would improve participants' physics content knowledge in terms of providing deeper study of specific physics content as a result of comparing material from a variety of textbooks or journals: "I needed to study deeper of physics contents [so] I can compare the variety sources content of physics" (R1), because "the textbook is the main method of teaching in the classroom" (R6), and that it serves as "a reference for the basic physics" (R24). On the other hand, eight participants thought analysis of the Form 4 textbook would not improve their physics content knowledge, suggesting that some did not understand or were confused about how this component of didaktik analysis could help their teaching. These pre-service physics teachers felt that the Form 4 physics textbook did not explain in the content enough detail: "It is not enough to depend only on the textbook, but also to refer to other sources such as reference books, articles and websites" (R3), and that the "textbook does not explain in detail about the content" (R11), noting that "some content may not be updated" (R12), meaning that it "cannot fulfil the needs of the students"(R16).

The Importance of Identifying and Addressing Students' Alternative Conceptions: Some 17 pre-service physics teachers noted that analysis of literature on students' alternative conceptions helped them to improve teaching practice because a lesson developed in advance could take into account students' alternative conceptions: "I can design a lesson [to] avoid misconceptions of students" (R1). Information on students' alternative conceptions also was felt could provide guidance for the teachers in planning a teaching sequence which might "guide the skills or activity to be carried out during the teaching and learning process" (R6). Hence, this component of didaktik analysis might help teacher correct alternative conceptions held by students and help them in teaching practice: "It can correct the wrong concepts held by the students and [the] students remember their alternative conceptions and they do not repeat them" (R7, 4th F). This it was thought, might be useful because "it helps to differentiate between scientists' conceptions and students' alternative conceptions" (R13). Some 14 of 30 participants experienced difficulties gathering research findings on students' alternative conceptions. Perhaps these difficulties related to such negative experiences as: Seven participants described their struggles with searching for "resources, especially electronics journals, journals, and reference books" (R1).

Discussion

Teaching practices, it seems, were shaped by the participants' beliefs about their experiences of the methods course generally, and the didaktik analysis specifically. Successful outcomes were enhanced conceptual understanding of specific physics content, as a result of the components of the didaktik analysis done in the assignment. These components were; conceptual analysis of specific content, analysis of textbooks, analysis of the literature on students' alternative conceptions, and lesson plans. It seems these activities enhanced the participant's ability to access such existing resources and materials, and provided them with the opportunity to learn more physics content. As the topic of the assignment differed for each group participant, experiences and beliefs about their didaktik analysis assignment also varied from content to content, such as force and motion, force and pressure, heat, and light. Such topics may to some extent reflect some different participants' conceptual understanding, and subsequently their interest in physics teaching.

Pre-service physics teachers believed that the conceptual analysis of specific physics content done during the assignment on didaktik analysis improved their teaching practice in the microteaching and practicum. Along with improving their understanding of specific physics content, the assignment increased their science vocabulary, improved their understanding of the syllabus' requirement, and improved their attitude-toward-physics and physics teaching. It also helped them in identifying problems of student learning, and increased their confidence to teach physics because they felt they had a better understanding of the problems their students might encounter.

Difficulty in conceptual analysis was linked generally with lack of understanding of some of the methods course content, and specifically with the conceptual analysis component of didaktik analysis, including specific physics content as well as the English language barrier. Other difficulties with the assignment were to do with a perceived lack of reference material in textbooks, difficulty in locating material in electronic journals and journals related to specific physics content, and knowing how to transform specific physics content into a teaching sequence. Analysis of textbooks revealed their strengths and weaknesses, as well as understanding of the curriculum specifications. The advantages of this analysis were deeper study of specific content as a result of comparing a variety of material from textbooks or journals, and having the opportunity to choose good textbooks. Some identified weaknesses of the textbooks were: insufficient specific physics content; some content was outdated; there were few activities; not much on problem-solving; and the presentation was unattractive and boring. Other problems with textbooks were a lack of examples, and a lack of clear explanations or detail about the content such as the concepts, laws and principles, meaning instruction based on the textbook would probably result in students having difficulty understanding the physics content.

The pre-service physics teachers' ability to analyse the literature on students' alternative conceptions from websites or journals suggests that this was useful in terms of preparing lesson plans, changing prior views about how to do lessons, and improving teaching practice in the microteaching and practicum. This didaktik analysis component, like the analysis of textbook, seemed to improve participants' understanding of specific physics content, improved their attitude toward physics, and helped them in identifying problems of students' learning. Subsequently participants were more confident to teach secondary school physics. This component of didaktik analysis (analysis of literature on students' alternative conceptions), together with the conceptual analysis of physics content, thus seems essential.

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Background knowledge of undergraduate students of mathematics teaching department about student centered teaching

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ABSTRACT

This study aims to investigate the background knowledge of the undergraduate students at the department of primary education mathematics teaching about student centered teaching. The participants of the study were 132 senior students of primary education mathematics teaching department, Faculty of Education at Ataturk University. The findings were obtained by means of ten open ended questions called "Student Centered Teaching Form". The answers to these questions were then categorized. The result showed that the participants could define the students centered teaching correctly however; it was found that as for the application of the process, their knowledge is insufficient.

Introduction

In student centered teaching, the student is active but the teacher is passive. While students are taking the information that teacher gives, they do not need to question and criticize it. Teachers think instead of students and the students passively get what is given. On the other hand, in student centered teaching, learning is a unit where students are active, and is a creative process in which students organize information patterns. (Seidel& Shavelson, 2007). Therefore, unlike teacher centered teaching, cognitive, affective, physical and social learnings are intensively experienced. Students play an important role in learning, they do not transfer knowledge, since their previous knowledge has been internalized by experiencing it, other learnings are affected by it, and their former understanding is not holistic. They make effort to form knowledge patterns to use (Feldman, 2002).

In order that students can join teaching, learnings need to be valuable for students, students need to focus on learning eagerly, learning needs to be not boring, student needs to know about their achievement, the driving elements need to be emphasized and their stress should be diminish and individual learning should be encouraged. It should be kept in mind that teaching is an interactive process in which the teacher synthesizes the requirements of the program and his/her students' special needs and abilities (Nuthall, 2004). To be able to form the desired abilities and qualities in learner centered teaching, teachers have certain roles and responsibilities.

As for the in-class roles and duties of the teacher, the method and the strategy, classroom environment, teaching materials and the questions to be posed, the followings can be stated:

A good teacher is a multidimensional working person who can adapt the educational situations (student, subject etc.) to certain situations (Barnett & Hodson 2000). A good teacher should determine the strategies and methods effectively. That the teacher can organize the classroom setting is of great importance. In such an environment, students can be motivated and made active (Ryan and Patrick, 2001).

Technologically supported tools are more effective than written instruction**.** Putnam and Borko (2000). Therefore, to use several instruments which will save the class from being monotonous are very useful.

Teacher's questions should unearth thought provoking activities where critical evaluation takes place. In this case, critical thinking occurs and critical thinking encourages students to criticize (Jay and Johnson 2002). The followings as for the teacher feedback, motivation, student evaluation and extracurricular activities can be given:

In the classrooms where voluntarily learning occurs, students tend to synthesize what they have learnt and critical thinking (Brown ,1992). Therefore, in student centered teaching, the feedback which may discourage students should be avoided, but it should be positive and guiding Education not only includes information and ability, but also includes enthusiasm (Berg 2002). While the teacher motivates his/her students, the students meanwhile should act according to the educational purposes, in that positive student-teacher relation gets to the desired purposes. (Fraser and Walberg, 2005)

As for the evaluation, quality should also be considered. As students can build information patterns with their contemporaries, teachers, materials and their parents (Park et al, 2007), their extracurricular activities should be organized in this way.

The roles overtaken and fulfilling the duties affect teaching, otherwise it will be negatively affected. Our purpose is to investigate the level of pre-service teachers' background knowledge about professional capabilities and efficacy in student centered teaching.

Aim

This study aims to investigate the background knowledge of the undergraduate students at the department of primary education mathematics teaching about student centered teaching.

Method

*Subjects***.** The participants of the study were 132 senior students at the department of primary education mathematics teaching at Faculty of Education at Ataturk University.

*Data***.** The findings were obtained by means of ten open ended questions called "Student Centered Teaching Form"

Analysis. The answers to these open ended questions were categorized. The answers in each category were numbered and analyzed by means of SPSS 16.00 statistical program. Chi-square analysis type was used.

Findings

The question "What is student centered teaching?" was posed to the undergraduate male and female students of department of primary mathematics education and it was seen that 98% of them answered correctly.

Table 1. Answers given to the question "What is student centered teaching?"

Gender		What is student centered teaching wrong	right	Total
Female	n	1	47	48
	%	2,1	97,9	100,0
Male	n	2	82	84
	%	2,4	97,6	100,0
Total	N	3	129	132
	%	2,3	97,7	100,0

S.D.=1

The answers of the undergraduate male and female students to the question " what are the student centered teaching strategies?" were analyzed and the results show that 20% of the participants did not answer correctly, the ratio of the students who could write three correct strategies was only 2%.(table 2)

Table 2. Answers given to the questions "what are the student centered teaching strategies?"

Gender		"What are the student centered teaching strategies?" wrong	invention	investigation	invention/ investigation	invention/ investigation/ effective teaching	Total
Female	n	10	4	3	30	1	48
	%	20,8	8,3	6,3	62,5	2,1	100,0
Male	n	16	12	6	48	2	84
	%	19,0	14,3	7,1	57,1	2,4	100,0
Total	N	26	16	9	78	3	132
	%	19,7	12,1	6,8	59,1	2,3	100,0

S.D.=4 χ^2=1,138 p>0.05 meaningless

The answers of the undergraduate male and female students of department of primary mathematics education to the question "what are the teaching methods in student centered teaching?" were examined and the results show that 30% of the participants wrongly answered, and they could only mention 4 teaching methods. No student was able to give 7 methods. (Table 3). They provided problem solution, discussion, drama, case study, and cooperative study. However, the option of scenario was not included among students' answers; the chi-square scores were found to be statistically meaningful as for the answers of both sexes.

(χ^2=11,862, p<0.05). While male students provided utmost 2 methods, female students could answer 3 or 4 methods.

Table 3. Answers given to the question "what are the student centered teaching methods?"

Gender		What are the student centered teaching methods? wrong	1 method	2 methods	3 methods	4 methods	Total
Female	N	15	11	10	10	2	48
	%	31,25	22,92	20,83	20,83	4,17	100
Male	N	25	29	25	3	2	84
	%	29,76	34,53	29,76	3,57	2,38	100
Total	N	40	40	35	13	4	132
	%	30,30	30,30	26,52	9,85	3,03	100

S.D.=4 χ^2=11,862 p<0.05 meaningful

The answers of the undergraduate male and female students of department of primary mathematics education to the question " how should the sitting order be in student centered teaching?" were analyzed and the results show that 12% of the participants did not know the correct answer, and they could provide utmost 2 sitting order types. For the correct answer, no student was found who could write three sitting type together. (Table 4). They provided U shape and round sitting. However, rectangular type sitting was not given for the answers.

Table 4. How should the sitting order be in student centered teaching?

Gender		How should the sitting order be in student centered teaching? wrong	U shape	round	U shape / round	Total
Female	n	6	23	13	6	48
	%	12,5	47,9	27,1	12,5	100,0
Male	n	10	46	19	9	84
	%	11,9	54,8	22,6	10,7	100,0
Total	N	16	69	32	15	132
	%	12,1	52,3	24,2	11,4	100,0

S.D.=3 χ^2=0,620 p>0.05 meaningless

The answers of the undergraduate male and female students of department of primary mathematics education to the question "how should the materials be in student centered teaching?" were evaluated and it was found that 27% of the participants gave wrong answers, but they could provide 1 or 2 features. As for the five correct answers, five items were not given by any student. They told that materials should provide an independent and inspiring learning environment and be prepared considering students' needs, interest and abilities. None of the answers included problems solution through group discussion and the characteristics which develop personal and social attitudes.

Table 5. Answers given to the question “How should the materials be in student centered teaching?”

Gender		How should the materials be in student centered teaching wrong	1 feature	2 features	Total
Female	n	14	28	6	48
	%	29,2	58,33	12,5	100
Male	n	23	58	3	84
	%	27,4	69,05	3,57	100
Total	N	37	86	9	132
	%	28,0	65,15	6,82	100

S.D.=2 χ^2=4,144 p>0.05 meaningless

The answers of the undergraduate male and female students of department of primary mathematics education to the question “where should the teacher be in student centered teaching?” were analyzed and it was found out that 75% of the participants gave wrong answer. The correct answer, analysis, synthesis and evaluation were not given by the students. (Table 6).

Table 6. Answers to the question “At what level should the teacher ask question in student centered teaching?”

Gender		At what level should the teacher ask question in student centered teaching?” wrong	1 feature	2 features	3 features	Total
Female	n	33	6	6	3	48
	%	68,8	12,5	12,5	6,25	100
Male	n	66	11	4	3	84
	%	78,6	13,10	4,76	3,57	100
Total	N	99	17	10	6	132
	%	75,0	12,88	7,58	4,54	100

S.D.=3 χ^2=3,298 p>0.05 meaningless

Considering the teacher feedback in student centered teaching, the answers to the open ended questions show that 50% of both female and male students gave correct answers (instead of insulting and scaring feedback, positive and guiding feedback should be employed.) (table 7)

Table 7. Answers to the question “how should the teacher feedback be in student centered teaching?”

Gender		how should the teacher feedback be in student centered teaching? wrong	right	Total
Female	n	20	28	48
	%	41,7	58,3	100,0
Male	n	46	38	84
	%	54,8	45,2	100,0
Total	N	66	66	132
	%	50,0	50,0	100,0

S.D.=1 χ^2=2,095 p>0.05 meaningless

The participants’ answers to the question “how should the teacher motivate the students in student centered teaching?” show that 10% of female students and 25% of the male students gave wrong answer, and they could only utmost 4 features for motivation. None of the students could give the accurate answers which was 15 features (Table 8). They wrote the features as follows: the teacher should manifest the desired behaviors prior to students and become a model, share his/her expectations with the students, show value of the course to the students, respect himself/herself, benefit from students' interest, draw upon students' feeling of curiosity, use reinforcement, competition and remove stress.

Table 8**.** How should the teacher motivate the students in student centered teaching?

		How should the teacher motivate the students in student centered teaching?					
Gender		wrong	1 method	2 methods	3 methods	4 methods	Total
Female	n	5	33	7	2	1	48
	%	10,4	68,75	14,58	4,18	2,09	100
Male	n	21	50	11	2	0	84
	%	25,00	59,53	13,09	2,38	0	100
Total	N	26	83	18	4	1	132
	%	19,70	62,88	13,64	3,03	0,76	100

S.D.=4 χ^2=5,833 >0.05 meaningless

The participants' answers to the question "how should the evaluation be in student centered teaching?" show that 65% of the female students and 58% of the male students were unable to answer correctly. They could provide utmost 2 features. None of the students could give all the features. They stated that evaluation should be based on students' own learning pace and type, students should evaluate themselves, and the evaluation should not be based exam but it should be giving information to the teacher and should be a complementary part of the education. Among the answers, the features for example, the teacher should not decide the type of evaluation but students can sometimes evaluate each other did not include.

Table 9. Answers to the question how should the evaluation be in student centered teaching?"

		How should the evaluation be in student centered teaching?"			
Gender		wrong	1 feature	2 features	Total
Female	n	31	17	0	48
	%	64,6	35,42	0	100
Male	n	49	33	2	84
	%	58,3	39,29	2,38	100
Total	N	80	50	2	132
	%	60,60	37,88	1,52	100

S.D.=2 χ^2=1,460 p>0.05 meaningless

The question "how should the extracurricular activities be in student centered teaching?" was analyzed and it was seen that 50% of the female students and 39% of male students were unable to answer correctly. None of the students could provide three items. They stated that students can join the activities in which students, teachers and the other social figures exist and projects and assignments where information is obtained and interpreted by the students, and team work should be emphasized.

Table 10. Answers to the question "how should the extracurricular activities be in student centered teaching?"

Gender		"How should the extracurricular activities be in student centered teaching?" wrong	1 feature	2 features	Total
Female	n	24	23	1	48
	%	50,00			100
Male	n	33	49	2	84
	%	39,30			100
Total	N	57	72	3	132
	%	43,20			100

Conclusions and suggestions

Almost all of the students could describe student centered teaching correctly. The proportion of the students who knew all the teaching strategies of student centered teaching is 2% and 20% of the students do not know any strategies. It was also seen that as for the student centered teaching methods, they could knew only four methods, none of them knew all of the methods, and the 30% of them knew nothing about the methods. As for the sitting order in this approach, 12% of them did not know anything and some of them mentioned U shape and round sitting orders.

As for the materials in student centered teaching, 27% of the students did not know anything and they stated that student should be able to use materials independent from teachers, an investigatory learning should be provided and the materials should be prepared on the basis of students' needs interest and abilities. However, students did not know anything about at what level the teacher should ask question.

As for the teacher feedback in student centered teaching, 50% of the students had certain information. However, motivation related issue in student centered teaching is not that much, thus, 25% of the students did not know how teachers should motivate their students and they stated that the teacher should manifest the desired behaviors prior to students and become a model, share his/her expectations with the students, show value of the course to the students, respect himself/herself, benefit from students' interest, draw upon students' feeling of curiosity, use reinforcement, competition and minimize stress. As for how evaluation should be made in student centered teaching, 61%of the students did not know about it, likewise 43% of the students did not know about the extracurricular activities, and they stated that students can join the activities in which students, teachers and the other social figures exist, and projects and assignments where information is obtained and interpreted by the students, and team work should be focused.

In order to enhance available information about the application of student centered education, from the first year, students should be taught adequately. Also, as for the application of the obtained knowledge, certain activities should be done.

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The influence of an in-service training programme on the standard of mathematics education.

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Abstract

In South Africa only 4,5% of grade 12 learners passed mathematics on higher grade and 22% on standard grade in 2007 in spite of several in-service training programmes since 1994. This can be attributed to a variety of factors amongst which unmotivated teachers/learners, insufficient subject knowledge of teachers, difficult circumstances in schools. Several attempts have been made to help teachers improve their skills and knowledge through in-service training programmes. This investigation aims to set up a profile of a motivated mathematics teacher from literature. Furthermore the aim is to determine what influence a specific part-time in-service training programme has on the motivation of the teachers in the programme. These teacher's subject knowledge, self-concept, self-efficiency and attitudes towards change were investigated. The results showed that their motivation was and has remained high and that their subject knowledge has improved. In spite of the fact that they have benefited from this programme, negative factors such as overcrowded classrooms, few/no teaching aids and a lack of safety and discipline in schools influence the attempts of these teachers to teach effectively.

Introduction and background

In spite of years of educational reform since 1994 and several in-service training programmes in South-Africa, still only 4,5% of grade 12 learners passed Mathematics on higher grade in 2007 (Tyakume, 2008:1). This state of affairs can be attributed to a variety of factors, of which the insufficient subject knowledge of teachers is just one (Tyakume, 2008:4; Howie, 2003:1-2).

The Sediba-project of the North-West University in South Africa is an in-service training programme for Mathematics and Science teachers that originated after it was found that 31% of the teachers in the North-West Province are neither academically nor professionally competent to teach these subjects (Smit *et al*., 1997:71). The programmes within the project are offered over two years on a part-time basis, and include distance as well as contact learning (40 hrs). The programme especially focuses on improving subject knowledge, in other words the Mathematics knowledge needed to teach Mathematics for grade 10 to grade 12 efficiently. Professional behaviour is strongly emphasised.

There is a relationship between teacher motivation and learner motivation and teachers play an important part in the maintenance, improvement or decrease of learner motivation and achievement (Atkinson, 2000:46; Steyn, 2002:83). Mastering subject knowledge and good classroom practices should improve teachers' self-concept and self-efficacy, which would in turn lead to improved teaching (Benadé, 2008:38). The researcher looks at a profile of a motivated mathematics teacher and the factors that influence the motivation of teachers in in-service training programmes.

In-service training

In-service training is an instrument that is frequently used to empower teachers to improve on professional terrain (Rhodes, 2003:94; Palmer, 1978:215) and should not be seen as a substitute for initial teacher training, but rather as supplementary (Broudy, 1978:59-61; Jegede & Taplin, 2000:290). In South Africa there are mainly two models for in-service training, namely the defect model that aims to rectify flaws in the initial training, and the growth model, which aims to stimulate sustained development (Jackson, 1971:21-33).

The Sediba-programme is based on both these models. Research by Smit *et al.* (1998:3) indicates that an improvement of qualifications and knowledge of teachers is crucial. In order to rectify the defects in the initial training, the programme pays much attention to the improvement of subject knowledge (defect model) and focuses on the development of specialised theoretical and practical knowledge that the teachers need in their professional career.

Hofmeyr and Pavlich (1987:86-88) reviewed research done internationally and locally and consequently constructed a set of core elements against which an ideal model for in-service training in South Africa can be measured. The Sediba-project has been evaluated according to these core elements, and the findings show that theoretically the programme comes very close to an ideal model.

The profile of a motivated Mathematics teacher

Without qualified, competent and motivated teachers, quality teaching and learning can not take place. Only motivated teachers will be fully involved with all the facets (academic and non-academic) of the teaching process and in so doing ensure classroom efficiency and effective teaching and learning (Ofoegbu, 2004:81; Gorham & Millette, 1997:257). Four aspects have been identified from literature to compile a profile of a motivated Mathematics teacher (Figure 1): the role of subject knowledge, the person's self-concept, self-efficacy and attitude towards change.

The role of subject knowledge. The subject knowledge that a teacher needs for the purpose of teaching differs from the knowledge that a subject expert needs. Teachers should have a thorough knowledge of the concepts and procedures of Mathematics. They must know how to use this subject knowledge and how to combine new subject knowledge to prior knowledge. Teachers should also be able to understand the underlying principles and meanings of Mathematics and know how the different mathematical ideas can be connected to each other (Plotz, 2007:236; Ball, 1990:458). Their subject knowledge should be "deep" enough so that they will be able to teach the material suitably and in different ways to their learners. Their knowledge should further be of such a nature that it would be possible for them to interpret different learners' attempts and to clear away misconceptions (Murphy, 2006:229). If teachers have the necessary subject knowledge as described above, their learners' achievement should improve and this can contribute to the improvement of the teacher's self-concept.

The role of self-concept. Self-concept is seen as an individual's view of his/her personal abilities and characteristics, in other words a person's integrated perception of him/herself (Pintrich & Schunk, 2002:407). One's perception of himself influence the ways in which he acts and his acts influence the ways he perceives himself. Persons judge their achievements and character according to frames of reference or standards from the environment, and this influences self-concept. A person's self-concept is therefore influenced by how he thinks other people judge him and is further shaped by failures and successes from the past. The mastering of problem situations and tasks helps a person to develop his/her self-concept. Teachers with a high self-concept are convinced of their personal abilities and believe that they can succeed. If they have enough subject knowledge and their self-concept is high, they should behave self-efficiently (Benadé, 2008:38).

The role of self-efficacy. Self-efficacy is a person's ability to organise and implement behaviours as they become necessary for reaching certain goals (Bandura, 1994). Success strengthens self-efficacy where repeated failures undermine it (Bong & Skaalvik, 2003:5). Persons with high self-efficacy experience difficult tasks as a challenge that should be mastered instead of a threat that should be avoided, they set higher goals for themselves and usually keep to them. They will put in more effort and persevere in the execution of a task. Teachers who are self-efficient believe that they can make a difference in children's lives, and the way in which they teach demonstrates this. They accept challenges and do not give up on difficult tasks, they easily accept increased responsibility, continually use new teaching methods and function without supervision. What teachers believe about their competence, is a strong predictor of their efficiency as a teacher (Gibbs, 2002:3).

The above-mentioned three factors play an important part in a teacher's measure of motivation. Teachers are positively motivated when they can see that they make a difference in the classroom and that they have a part to the success that learners attain. However, Robinson and McMillan (2006:330) say that change brings uncertainty amongst teachers about their competence, and this influences their self-concept. A post-apartheid political and social system in South Africa necessitated fundamental changes in the educational system in order to meet everyone's expectations. These changes put pressure on teachers in many schools. Teachers with traditional views were expected to change their view of teaching methods, syllabi were changed and teachers had to stay informed of new tendencies. It is not within human nature to welcome change with open arms.

The role of motivation on teachers' attitude towards change. Change is a complex process that includes more than just the acquisition of new skills but often means a change in attitudes, persuasions and personal theories (O'Sullivan, 2002:224). Change places question marks around the heart of acquired skills, philosophies, persuasions and views of education. It causes great uncertainty amongst teachers, which can contribute to a decrease in motivation. Motivated teachers do not feel that their identity is threatened so easily, are more receptive to change and promote the implementation of changes (Jesus & Lens, 2005:120). If these teachers see change as relevant, desired and as an improvement on the existing circumstances, they will cooperate to make a success of it (Robinson & McMillan, 2006:330).

SUBJECT KNOWLEDGE	SELF-CONCEPT	SELF-EFFICACY
- Has sufficient subject knowledge and skills - Knows how to organize and use this content knowledge - Can combine new subject matter knowledge with prior knowledge - Use opportunities for personal growth	- Is convinced of personal abilities - Has an expectation to reach success - Is convinced that inputs will result in desired behaviour - Attaches value to the outcomes that can be reached	- Accepts challenges - Perseveres with difficult tasks - Follows curriculum less rigidly - Uses new teaching methods - More easily accepts increased responsibility - Is not dependant on supervision

THE MOTIVATED MATHEMATICS TEACHER

- Wants to be a mathematics teacher
- Has sufficient subject knowledge and skills
- Self-concept is high
- Can perform given tasks at designated levels
- Is very dedicated
- Is curious and has a need to explore and to know more
- Sets challenging goals
- Contributes to the success that learners attain
- His/her learners are motivated
- Experiences his/her work as a teacher as meaningful
- Is valued and respected in the work environment
- Will, more than what is expected take part in all the facets that contribute to the improvement of the entire school

CHANGE

- Agrees with change if it is relevant and desired
- Guarantees successful implementation of changes

Figure 1. Profile of a motivated mathematics teacher

The impact of hygiene factors on a motivated teacher's performance. Hygiene factors are related to the work environment and include factors such as salary, status, safety, work circumstances, policy and administrative practices as well as interpersonal relationships (Herzberg *et al.*, 1959:113-119). These factors can not be ignored when the performance of a teacher is addressed. The lack of hygiene factors causes dissatisfaction and although hygiene factors are not a precondition for motivation, the lack of such factors makes it impossible to focus on the work itself. Work satisfaction has a direct influence on teachers' performance and therefore the work circumstances of the teacher should be of such a nature that it contributes to work satisfaction (Wevers, 2000:38).

Empirical study

An availability sample, which consisted of mathematics teachers who were registered for the Sediba Mathematics programme for 2006/2007, has been used for this study. There were 34 teachers who participated in the study. Most of the teachers in the programme have a three year teaching qualification with mathematics as major. A combination of qualitative and quantitative research methods was used. A Mathematics competency test and a self-compiled motivation questionnaire were handed to the teachers to complete on the first day of their first contact session (January 2006). During the last semester of their first year, the same questionnaire and mathematics test were handed to them for completion (September 2006). The results of both were then statistically processed and interpreted. Interviews were conducted with 13 teachers to check the findings and to place it in context.

Quantitative research

Mathematics competency test. The mathematics competency test developed by Dr C.K. van Wyk of the department Mathematics at the North-West University in cooperation with the Student Consultation Service, was modified for use in this study. The test consists of 30 multi-choice questions based on the knowledge and application of important mathematical principles in algebra, geometry and trigonometry. This test provides an efficient indication of a student's previous exposure to and retention of specific mathematical learning material that is regarded as necessary for further study in mathematics (Van Wyk, 1988:110).

Table 2. Comparison of mathematics test results (January and September)

	January 2006	September 2006
Average (%)	46,7	60
Number tested	34	34
Number of distinctions (75%+)	3	6
Number who passed (50%+)	15	24
Number who failed	19	10

The test results are shown in Figure 2 and shows that the teachers' marks profile increased significantly.

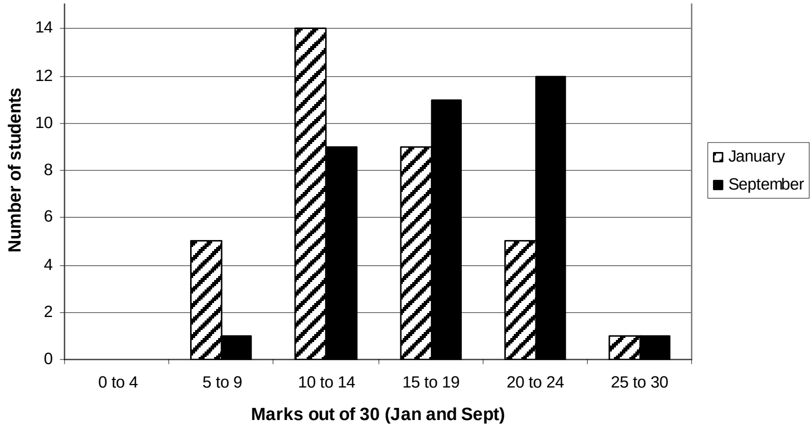

Figure 2. Marks profile of teachers (January and September)

Motivation questionnaire. The questionnaire used in the study consisted of two sections. Section A included information regarding biographical details, including school based factors. In this part there are specifically questions regarding hygiene factors, such as basic needs, work circumstances, security and discipline, which can give an indication of the needs that exist. Section B includes questions on the motivation of the teachers. The content theories of Maslow (Maslow, 1954) and Herzberg (Herzberg et al., 1959) were used as guidelines for the questions in order to gain a better understanding of the teachers' behaviour and attitudes. This section had to be judged on a scale of one to four. A four-point scale is generally advised to see to it that respondents do not only choose the average value, but are forced to take a definitive stance.

It is notable that the initial scores (out of a maximum of 4) were very high at the beginning of the year (column $\overline{X}_1$ in Table 4). The teachers used in this research were therefore initially very motivated. In spite of difficult circumstances, much extra work, sessions that have to be attended during holidays and the fact that personal time over weekends had to be spent on studies, the motivation of the teachers remained high. It even improved towards the end of the study (column $\overline{X}_2$ in Table 4).

Table 4. Effect sizes of different constructs

	$\overline{X}_1$	$\overline{X}_2$	$\lvert\overline{X}_{d,j}\rvert$	s_1	d_j
Self-concept (general)	3.03	3.22	0.19	0.44	0.43
Self-concept (module)	2.97	3.15	0.18	0.53	0.34
Self-efficacy	3.25	3.34	0.10	0.44	0.23
Intrinsic motivation	3.56	3.56	0.00	0.32	0
Task value	3.25	3.35	0.11	0.51	0.22
Change	2.95	3.11	0.16	0.54	0.30

From the research thus far it seems that the subject knowledge of the teachers increased and that their motivation remained high. The question then is why there are still not satisfactory results in schools in spite of the inputs of several similar programmes?

Qualitative research

Semi-structured interviews were employed to gather more information on the improvement of the teachers' self-efficacy and self-concept, as well as the influence of hygiene factors (security, work circumstances, etc.) on performance.

Interviews. The feeling of the teachers who were interviewed was that the Sediba project had a positive influence on their performance and motivation. They felt that their pupils also benefited from it, but that there are other factors that cause learners not to achieve. The interviews confirmed that the teachers' motivation is high:

- Not one of the teachers is taking part in the programme for extrinsic reasons, but rather to be better teachers.
- They persevere in their task, in spite of difficult circumstances.
- Their self-concept has improved – these teachers are convinced that they are now better teachers than before.
- Previously these teachers did not see their way clear to tackle difficult topics and parts of the curriculum were left out completely, but now they do these parts and persevere through difficult times. In spite of the fact that there is no significant improvement in achievement nationally, these teachers feel that their own learners' achievement has improved since they became part of the Sediba programme.
- All the teachers who were interviewed believe that the learners ultimately benefit from their teachers' training. These teachers experience their task as meaningful because they believe that they have a significant influence on the lives of their learners.

The interviews also confirmed that the hygiene factors have a great influence on the teachers' performance. They have identified the following problems:

- Basic resources and aids, such as calculators and study materials, are not available. Due to poverty in the communities few learners own their own calculators, which hinder successful teaching.
- Overfull classes with large numbers of learners causes children to be stuffed into classrooms. The problem of overfull classrooms is the result of a shortage of trained teachers together with the fact that there are not enough classrooms available at schools. Small classrooms plus few teachers equals overfull classrooms.
- Shortages in well-equipped classrooms have the result that quality teaching is not possible all the time. Teachers have to get by with few aids, especially equipment such as overhead projectors and computers.
- Shortages in trained teachers result in a situation where one teacher has to teach different subjects to different grades, which hampers thorough preparation.
- The problems around safety at some schools are a great crisis.
- A shortage in discipline at schools hinders teachers' attempts at providing quality education.
- Teachers experience academic jealousy from their colleagues. In stead of sharing their knowledge with other teachers, they are scared of doing so and in the process no-one else benefits from the teacher's improved knowledge and skills.

Conclusion

The Sediba in-service training programme contributes to the improvement of the teachers' subject knowledge, self-concept and self-efficacy and increases their motivation. Poor discipline, overfull classrooms, few facilities, problems with safety, a limited number of trained teachers in specialist subjects, absence of learners and a lack in professionalism of many teachers are further factors that place limits on the successful teaching and learning of mathematics. Although a very small sample was used, and the results can therefore not be generalized, it is true that the circumstances in many schools in South Africa are the same. Before these aspects do not receive urgent attention, the standard of mathematics teaching will not easily improve, in spite of several attempts by different institutions with the creation of in-service training programmes all over South Africa.

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Transforming mathematical content knowledge into mathematical content knowledge for teaching

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Abstract

South African learners underachieve in mathematics. Research shows that many South African mathematics teachers are not adequately qualified to teach mathematics. To improve this situation, retraining of teachers should be a priority. The most pressing problem is the lack of a comprehensive theoretical model that describes how in-service teachers in South-Africa can be retrained to improve their mathematical content knowledge. The researcher address part of this problem by unpacking the term "mathematical content knowledge for teaching" (MCKT) with a view to identify characteristics of this very important kind of knowledge, that mathematics teachers must have. Results from a research study conducted on a group of mathematics teachers shows that teachers' current mathematical content knowledge states are inadequate for teaching mathematics with understanding.

Introduction

South African learners underachieve in mathematics (TIMMS report, matriculation results). They do not have an in-depth understanding of mathematics that allow them to apply it in practice, nor do they possess a repertoire of effective strategies for processing information, solving problems or detecting mistakes (Strauss and Fourie, 1998). Teachers form an important link in the success of any curriculum, as it is teachers who filter the curriculum through to the learners (Du Plooy, 1998).

Important aspects of research in the field of teacher training to address these problems, is the debate around the quantity and quality of teachers' mathematical knowledge (Delaney et al, 2008). Most people involved in teacher education agree that a teacher needs sound mathematical content knowledge (MCK) in order to be a good teacher (cf. Michael de Villiers, 2006; Fennema and Franke, 1992; Ma, 1999; Rowan et al, 1997) because one cannot teach what one does not know (Fennema and Franke, 1992). However, it is not always clear what type of MCK is referred to. Adler and Pillay (2007) acknowledge the wealth of literature trying to disentangle and categorise the different knowledge components needed by teachers particularly in mathematics.

A new discourse has emerged in the global arena (Fennema and Franke, 1992; Ma, 1999, Ball and Bass, 2000, Kahan et al, 2003; Ball et al, 2008), attempting to distinguish and define a distinctive form of MCK used in the act of teaching. This article is an attempt to describe the characteristics underlying this particular type of MCK and to highlight the assessment of teachers' current MCK states so that teacher educators can work towards transforming teachers' prior knowledge into mathematical content knowledge for teaching (MCKT).

Historical development of the notion of MCKT

Shulman's (1986) notion of pedagogic content knowledge (PCK) was the first acknowledgement of a different kind of knowledge needed for teaching. However, researchers are likely to interpret the nature of PCK differently, thus engendering a variety of meanings (Park and Olive, 2008). The main idea behind PCK acknowledges the gap between subject matter content knowledge (SCK) and the practice of teaching (Ball et al, 2008).

A general belief is that teachers should learn more mathematics: that the higher the level of mathematics a teacher knows the better teacher he or she becomes (Vistro-Yu, 2005). This, however, may not necessarily be true. While the mathematician knows very high levels of mathematics, a teacher's role involves taking complex subject matter relevant to school mathematics and translating it into representations that learners can understand (Fennema and Franke, 1992). This translation of mathematics into understandable representations is what distinguishes a mathematics teacher from a career mathematician.

Fennema and Franke (1992) emphasises that teachers' current MCK states are not necessarily useable in the teaching and learning of mathematics. It first has to be transformed to a usable form that learners would be able to comprehend. Therefore how teachers' knowledge is constructed may matter more than how comprehensive their knowledge base is (Hill and Ball, 2005; Adler and Davis, 2006). In other words, teaching quality might not relate so much to performance on standard tests of mathematics achievement as it does on whether teachers' knowledge is procedural or conceptual, connected to big ideas or isolated into small bits, compressed or conceptually unpacked (Ball, 1990; Ma, 1999).

In our opinion, MCKT is less than PCK, as it does not touch on pedagogy or what the teacher does in the act of teaching, but concentrates on the way in which the teacher's MCK has to be restructured in order to make it useful for teaching. Two assumptions can be made regarding the relationship between MCKT and PCK: Firstly, MCKT can be the force behind PCK because it will influence the way you are going to teach and secondly, underdeveloped MCKT might make it difficult to attain appropriate PCK. In the process, changes in mathematical pedagogical content knowledge occur as a result of changes in or restructuring of teachers' knowledge of mathematical content with consequential growth in MCKT.

Unpacking the characteristics of MCKT

The following characteristics were identified as being important in the development of MCKT (Plotz, 2007):

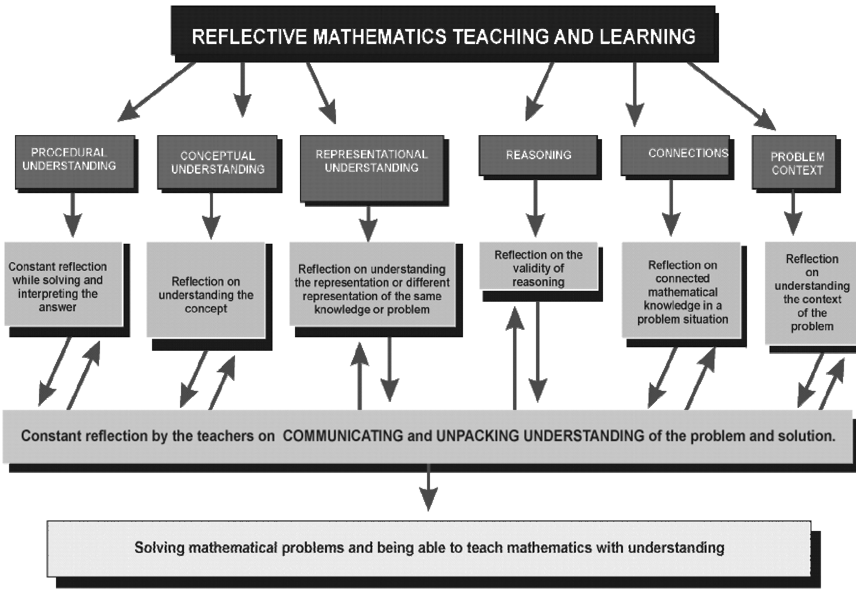


Figure1. Characteristics of MCKT

A comprehensive analysis of the characteristics of MCKT is beyond the scope of this paper and part of an article to be published later this year.

In short, developing reflective practices (knowing how and knowing why) and being able to unpack mathematical knowledge and understanding is key characteristics of MCKT. The focus of reflection should be on developing the characteristics of MCKT. Further characteristics of MCKT involves a focus on mathematical content (procedural and conceptual understanding of mathematical content) as well as a focus on the cognitive processes, which implies the various ways through which mathematical understanding can be developed. The cognitive processes involve building understanding by reasoning about mathematical topics, taking connections between various mathematical topics and being able to represent mathematical topics in various ways. This should enable a mathematics teacher to communicate mathematical understanding to learners. Consequently, mathematical problem solving and teaching mathematics with understanding should benefit from transforming teachers' current MCK states, focussing on the characteristics of MCKT.

Assessing teachers' current MCK states

Transforming teachers' prior knowledge or current MCK states into MCKT is driven by the strong believe that MCK is the first knowledge base for teaching. But to be able to work towards this transformation, diagnostic assessment of teachers' current MCK states, regarding the characteristics of MCKT, should take place. Some research findings from a study conducted in South-Africa on a group of in-service high school mathematics teachers will follow:

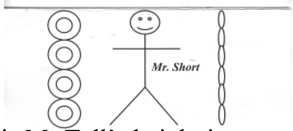
Information on the population, the MCK chosen and the diagnostic instrument used. The current MCK states of a group of 128 mathematics teachers were investigated. These teachers were all part of the Sediba Project of the North-West University (Potchefstroom Campus) at the time of the research and all willingly took part in this study. The research on the teachers was conducted during September 2005 and January 2006. Sediba is a two-year (part time) professional development program, aimed at improving the quality of mathematics teaching in schools. Through the Sediba Project, a mathematics teacher can obtain an ACE (Advanced Certificate in Education) with specialization in Mathematics. The qualifications of a Sediba mathematics teacher are thus upgraded from a [matric plus] 3 year qualification to a [matric plus] 4 year qualification. The course is offered on a part-time basis, comprising of both distance and contact teaching. The lectures take place during school holidays on the Potchefstroom campus. The Sediba Project is aimed at retraining previously disadvantaged high school mathematics teachers mostly from the North-West Province in South Africa. These teachers have to adhere to certain criteria before they are enrolled to take part in the program. They should all be in possession of a three-year teacher's diploma in mathematics teaching and they should also be teaching Grade 12 mathematics learners. The majority of black secondary teachers trained under Apartheid only had access to a three-year College training diploma. The selection criteria for these teachers result in a reasonably homogeneous group of mathematics teachers, except for differences in their schooling backgrounds.

Proportional reasoning and functions were chosen to form the MCK under investigation. Proportional reasoning was selected as a topic due to the demand for the application and understanding of this concept across the school curriculum and beyond. Functions were chosen because of the representational aspect involved in functions.

A diagnostics content analysis was conducted, to be able to analyse at best the teachers' current MCK states according to the pre-determined characteristics of MCKT. There was no standardized instrument in the literature that could give sufficient information about teachers' current MCK states in terms of the characteristics. A 34-item diagnostic test (instrument) was constructed by the researcher with some items adapted from sources on proportional reasoning and functions (Plotz, 2007) The diagnostic test items were set for a specific target group, namely secondary school mathematics teachers. There was a time limitation on completing the items. Teachers were allowed to rely only on their prior knowledge to complete the test. The format of the items was mostly free response questions and also some multi-choice questions. The items had to meet the following important requirements: (a) teachers' responses to the items had to reflect information about each characteristic of MCKT that was assigned to each of the items, (b) the items had to reflect information about a teacher's MCK on proportional reasoning and certain aspects of functions.

A qualitative diagnostic content analysis of teachers' responses to questions. A few examples of the questions used will be given with some of the responses of some the teachers:

Question 32. Robert Karplus (as quoted by Wikipedia free encyclopedia, 2006)
Mr. Tall is 6 buttons tall. Mr. Short is 4 buttons tall.
Now measure Mr. Short with paper clips. He is 6 paper clips tall.



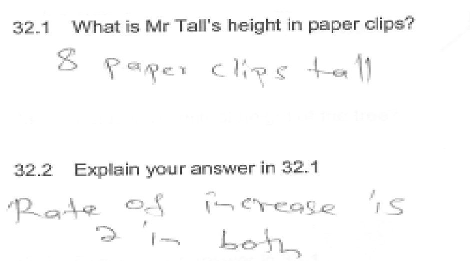
32.1 What is Mr Tall's height in paper clips?
32.2 Explain your answer in 32.1

Table 1. Teachers' performance on Question 32 in terms of the assigned characteristics of MCKT.

Question	Characteristics	Evaluation of teachers' responses 1 if	% of teachers awarded a1 for the attribute Whole group
32.1	Conceptual knowledge	Teacher indicates that a multiplicative relationship exists.	24
32.2	Procedural knowledge	Could choose a procedure to determine the correct answer.	22
32.2	Procedure solved	Made no procedural mistakes in determining the correct answer.	21
32.2	Interpretation of answer	Interpreted the answer correctly.	23
32.2	Problem solving	Could solve the problem.	21
32.2	Unpacking	Could unpack the problem context and solve the problem.	19

Rather than a multiplicative method, some teachers an additive strategy, to solve this problem. They arrived at a final answer of "8" as the solution to the problem. Teachers used the words "add 2" or "2 more" in their unpacking of the answer in 32.2. The teachers who got the right answer, used the cross-multiplication method.

The example of a response below shows the teacher's additive proportional thinking and inability to communicate the proportional situation (use appropriate language) in using the word "ratio" while not recognizing a proportional situation.

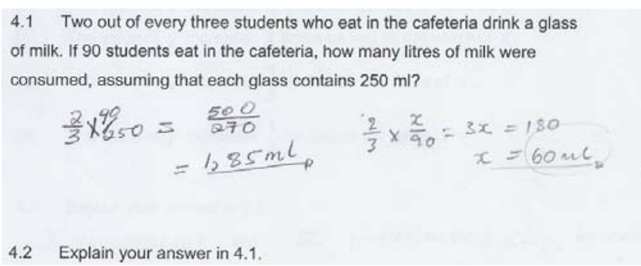


Question 4.
4.1 Two out of every three students who eat in the cafeteria drink a glass of milk. If 90 students eat in the cafeteria, how many litres of milk were consumed, assuming that each glass contains 250 ml?
4.2 Explain your answer in 4.1.

Table 3. Teachers' performance on Question 4 in terms of the assigned characteristics of MCKT.

Question	Characteristics	Evaluation of teachers' responses 1 if	% of teachers awarded a 1 for the attribute Whole group
4.1	Problem solving	Could explain how to get the correct answer of 15 liter.	46
4.2	Conceptual knowledge	Applied proportional reasoning skills and got 60 or 45 students.	63
4.2	Procedural knowledge	Use the following procedure: $\frac{2}{3}\times 90 = 60 \times 250ml = 15000ml = 15l$.	73
4.2	Procedure solved	Made no mistakes in finding an answer of 15 litre.	45
4.2	Interpretation of answer	Correct interpretation of the answer been 15 litre.	30
4.2	Unpacking	Could unpack understanding and explain how to get to an answer of 15 litre.	46

The reason why teachers performed better in the second part of Question 4 is because they could get a correct mark although their answer in Question 4.1 was not right. In Question 4.2 the researcher looked for any indication that the teacher could unpack his understanding of the problem. Two consecutive procedures need to be executed. First $\frac{2}{3}\times 90 = 60$ and then $60 \times 250ml = 15000ml = 15l$. Indications are that the teachers have difficulty doing these consecutive procedures. This problem requires multi-level comparative thinking from these teachers. Some teachers clearly had a problem in this area.


4.1 Two out of every three students who eat in the cafeteria drink a glass of milk. If 90 students eat in the cafeteria, how many litres of milk were consumed, assuming that each glass contains 250 ml?

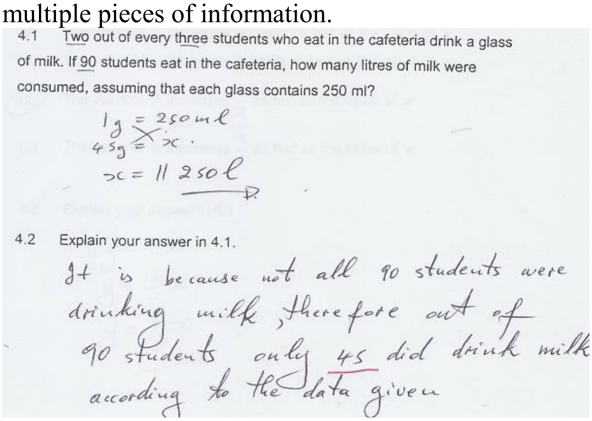
$\frac{2}{3} \times \frac{90}{250} = \frac{500}{270} = 1,85ml$

$\frac{2}{3} \times \frac{x}{90} = 3x = 180$

$x = 60ml$

4.2 Explain your answer in 4.1.

Teachers had difficulty translating the problem from the linguistic representation to a mental representation because they needed to coordinate multiple pieces of information.


4.1 Two out of every three students who eat in the cafeteria drink a glass of milk. If 90 students eat in the cafeteria, how many litres of milk were consumed, assuming that each glass contains 250 ml?

1g = 250 ml

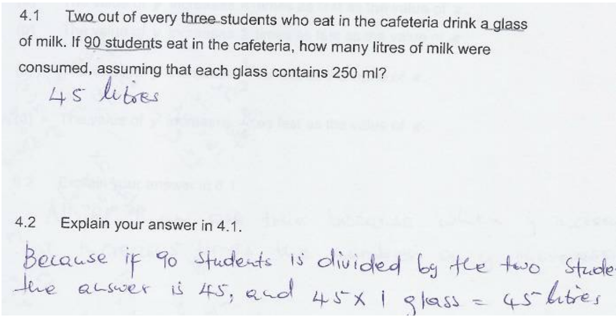
45g = x

x = 11 250 l

4.2 Explain your answer in 4.1.

It is because not all 90 students were drinking milk, therefore out of 90 students only 45 did drink milk according to the data given

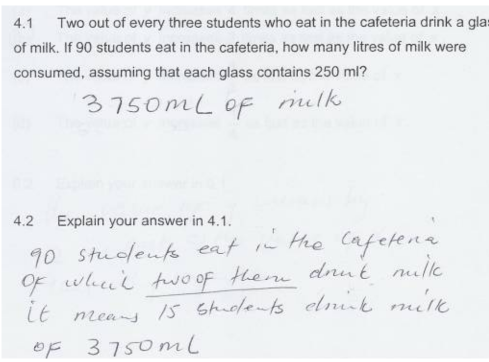
The teachers substituted the words “a glass of milk” with 250 ml.


4.1 Two out of every three students who eat in the cafeteria drink a glass of milk. If 90 students eat in the cafeteria, how many litres of milk were consumed, assuming that each glass contains 250 ml?

45 litres

4.2 Explain your answer in 4.1.

Because if 90 students is divided by the two stude- the answer is 45, and 45 x 1 glass = 45 litres


4.1 Two out of every three students who eat in the cafeteria drink a glas of milk. If 90 students eat in the cafeteria, how many litres of milk were consumed, assuming that each glass contains 250 ml?

3750mL of milk

4.2 Explain your answer in 4.1.

90 students eat in the cafeteria of which two of them drink milk it means 15 students drink milk of 3750mL

The teachers could not unpack the problem and work with multiple pieces of linguistic information to transform it into a mathematical representation.

Question 3. A car travels 10 kilometres on one litre of petrol. It has a petrol tank with a capacity of 55 litres. The car starts on a journey with a full tank.
3.1 Complete the table below. (The table should show the number of litres remaining for at least four different points of a trip of 500 kilometres.)

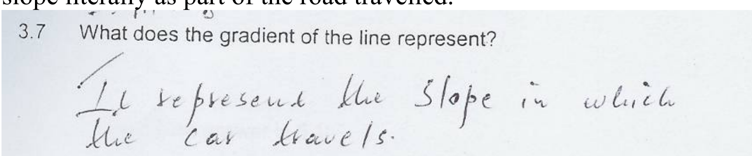
Kilometres	**Litres remaining**
0	55
100	
300	
400	
500	

3.2 Plot the data from the table in 3.1 on the graph below.
3.7 What does the gradient of the line represent?

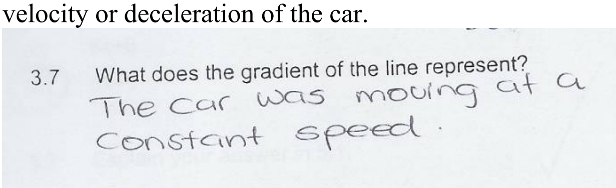
Table 4. Teachers' performance on Question 3 in terms of the assigned characteristics of MCKT.

Question	Characteristics	Evaluation of teachers' responses 1 if	% of teachers awarded a 1 for the attribute Whole group
3.1	Representations	Could take the necessary information represented in the word sum to complete the table.	59
3.2	Representations	Could understand the representation of the information in the table to draw the graph.	55
3.7	Communication	Could communicate understanding of the connection between the constant rate at which the petrol becomes less and the gradient of the straight line.	59
3.7	Unpacking	Could make the connection that the constant rate at which the petrol becomes less is represented by the gradient of the line.	25

Some of the teachers responded that the gradient of the line represents "the slope at which the car is travelling". This implies a serious misconception in the teachers' mathematical content knowledge base. These teachers interpret the slope literally as part of the road travelled.


3.7 What does the gradient of the line represent?
It represent the Slope in which the car travels.

Some of the teachers stated that the gradient is an indication of the speed or velocity or deceleration of the car.

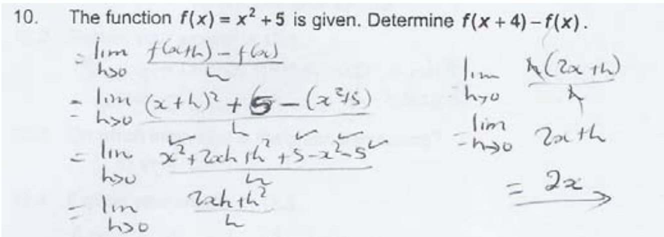

3.7 What does the gradient of the line represent?
The car was moving at a constant speed.

Question 10. The function $\mathbf{f(x) = x^2 + 5}$ is given. Determine $\mathbf{f(x+4) - f(x)}$.

Table 6. Teachers' performance on Question 10 in terms of the assigned characteristics of MCKT.

Question	Characteristics	Evaluation of teachers' responses 1 if	% of teachers awarded a 1 for the attribute Whole group
10	Procedural knowledge	$f(x+4) - f(x) = ((x+4)^2 + 5) - (x^2 + 5)$ $= x^2 + 8x + 16 + 5 - x^2 - 5$ $= 8x + 16$	57
10	Procedure solved	No procedural mistakes were made and an answer of $8x + 16$ was given as the solution.	43
10	Problem Context	The problem context was familiar to the teacher.	74

The surface features needed to activate appropriate procedural knowledge to be able to solve the problem made for interesting results from the response - some of these teachers wanted to determine the derivative from first principles ($f'(x)$) to solve the problem.


10. The function $f(x) = x^2 + 5$ is given. Determine $f(x+4) - f(x)$.

$= \lim_{h \to 0} \frac{f(x+h) - f(x)}{h}$

$= \lim_{h \to 0} \frac{(x+h)^2 + 5 - (x^2+5)}{h}$

$= \lim_{h \to 0} \frac{x^2 + 2xh + h^2 + 5 - x^2 - 5}{h}$

$= \lim_{h \to 0} \frac{2xh + h^2}{h}$

$\lim_{h \to 0} \frac{h(2x+h)}{h}$

$= \lim_{h \to 0} 2x + h$

$= 2x$

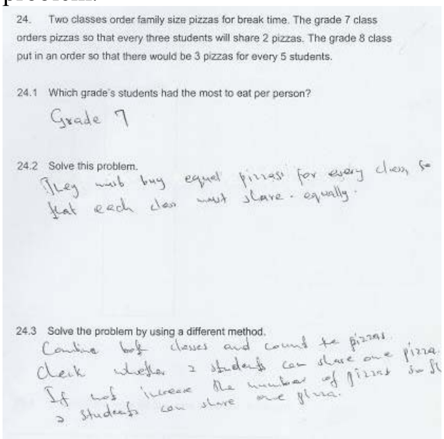
It clearly shows that teachers memorise procedures and rules rather than reflect if the outcome makes sense. These teachers recognised that $f(x+4) - f(x)$ looks like a part of the formula for determining the derivative of a function from first principles ($\lim_{h \to 0} \frac{f(x+h) - f(x)}{h}$). It is clear that these teachers have learned arithmetic procedures for determining limits and the derivative of a function from first principles by rote rather then by constructing them on the basis of conceptual understanding of a limit or a derivative. These teachers did not have the conceptual knowledge needed to increase the usefulness of their procedural knowledge in the context of this problem. This is an example of how knowledge that is not conceptually connected plays a role in familiar and unfamiliar problem contexts and solving mathematical problems.

Question 24. (Van de Walle, 2004:302)
Two classes order family size pizzas for break-time. The grade 7 class orders pizzas so that every three students will share 2 pizzas. The grade 8 class put in an order so that there would be 3 pizzas for every 5 students.
24.1 Which grade's students had the most to eat per person?
24.2 Solve this problem.
24.3 Solve the problem by using a different method.

Table 7. Teachers' performance on Question 24 in terms of the assigned characteristics of MCKT.

Question	Characteristics	Evaluation of teachers' responses 1 if	% of teachers awarded a 1 for the attribute Whole group
24.1	Conceptual knowledge	Teacher knew that a numerical comparison ratio should be used.	68
24.2	Procedural knowledge	Could choose a procedure to determine the correct answer, $\frac{2 \text{ to } 3 \text{ ratio for grade } 7}{3 \text{ to } 5 \text{ ratio for grade } 8}$.	63
24.2	Procedure solved	Made no procedural mistakes in determining the correct answer.	53
24.2	Interpretation of answer	Interpreted the answer correctly.	39
24.2	Problem solving	Could solve the problem.	39
24.2	Unpacking	Could unpack the problem context and solve the problem.	33

A potential interaction between Question 24 and the social situation in which Question 24 were set, interfered with the teachers' search for a solution to the problem.


24. Two classes order family size pizzas for break time. The grade 7 class orders pizzas so that every three students will share 2 pizzas. The grade 8 class put in an order so that there would be 3 pizzas for every 5 students.

24.1 Which grade's students had the most to eat per person?

Grade 7

24.2 Solve this problem.

They must buy equal pizzas for every class so that each class must share equally.

24.3 Solve the problem by using a different method.

Combine both classes and count the pizzas. Check whether 2 students can share one pizza. If not increase the number of pizzas so that 2 students can share one pizza.

The teacher in the preceding response stated that the solution to the problem is to buy enough so that each student can get the same size of pizza. It was thus not a mathematical solution to the problem, but rather grounded in a social context of equal pieces of food for every person involved.

An overall evaluation of the results

For this group of teachers, proportional reasoning is a case of computational fluency in a familiar problem context rather than intuitive recognition of a proportional situation. Indications are that these teachers would use additive rather than multiplicative reasoning in an unknown problem context because their first quantification in proportional reasoning items is not multiplicative in nature, but additive - an additive structure of $(\mathbf{a}-\mathbf{b})$ rather than a ratio $\frac{\mathbf{a}}{\mathbf{b}}$. The problem context and the nature of the numerical relationship influenced the teachers' ability to solve the proportional problems. Teachers' use of the cross-product algorithm is largely mechanical and stripped of meaning. Results indicate that the cross-product algorithm is not sufficiently understood by the teachers and is not generated naturally. Although it should not be understated that it is an efficient procedure, it is clearly used as a means of getting an answer rather than to understand the problem. The findings largely indicate that the teachers have an instrumental rather than a relational understanding of proportional problems because of their inability to translate their knowledge to new contextual situations. Teachers can only use the most basic properties of proportion. It is very likely that these teachers' school based exposure to proportional reasoning problems has been and are only procedural, without sense-making. It is also likely that they will teach learners in the same way. These teachers can be regarded as novices in solving proportional reasoning problems.

Teachers' solutions to some of the problems show a lack in their ability to communicate or unpack understanding to problems. An absence of a tendency to reflect on a required answer is evident among these teachers. There is inconsistent behaviour to reflect on an answer and evaluate it for its validity or to make a correct interpretation of the answer.

The social setting of a problem provides a barrier in mathematically solving problems. Problems set in the context of food makes for social justifications like equal amounts of food for every person involved seemed to overshadow the mathematical solution. The teachers have difficulty to work with multiple pieces of linguistic information and are unable to translate these multiple pieces of linguistic information into corresponding mathematical language.

Various misconceptions in the teachers' mathematical knowledge base prevail. These teachers have gaps in their mathematical knowledge base concerning primary and middle school mathematics: their tendency to use additive reasoning when dealing with unfamiliar proportional problems and also their inability to convert millilitres to litres. This has implications for the development of appropriate MCKT as a sound knowledge base in school mathematics is important for the development of MCKT. These findings have serious implications for the development of MCKT.

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Teaching the inquiry approach in the chemistry laboratory and its contribution to teacher's professional development

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Abstract

This study is a part of a bi-national program (with King's College London) in which a continuous professional development (CPD) program was tried in six different domains. The main goal of the study was to investigate the professional development along time, of chemistry teachers who were involved in this program. We focused on teachers who implemented an inquiry-type approach in the classroom laboratory, for the first time. The teachers' development was followed by protocols assembled in a portfolio that was used to demonstrate evidence-based practice in the inquiry-based chemistry laboratory. Fourteen experienced chemistry teachers participated in a workshop. Several teachers were videotaped, and were interviewed immediately after the laboratory session. In this paper we will elaborate on a case-study of one teacher – Judy, which demonstrates the challenges and the comprehensive change in the way of teaching and in perceiving the role of teachers in the laboratory.

Introduction

In the last 15 years, chemistry teachers in Israel have been involved in a reform regarding the way chemistry is taught. This included integration of inquiry-type experiments into their chemistry classroom-laboratory, termed the Inquiry Chemistry Laboratory (ICL). In this study we focused on one teacher – Judy (a pseudonym). Judy was a chemistry teacher for more than 30 years. It is well known that inquiry centred laboratories have the potential to enhance students' meaningful learning, conceptual understanding, and their understanding of the nature of science, but it also requires that teachers gain new teaching skills, i.e., new pedagogical knowledge and new content knowledge (Hofstein and Lunetta, 2004). The content knowledge refers to the inquiry skills that the teacher should gain and develop while teaching according to the inquiry approach. In general, the laboratory is considered to be a unique environment in which teachers' behavior differs from their classroom behaviour, which is much more student-centred (Hofstein et al., 2004; Hofstein et al., 2005).

The CPD program

The chemistry group, in the Department of Science Teaching at the Weizmann Institute of Science, Israel, developed an evidence-based continuous professional development (CPD) program (Taitelbaum et al., 2008). This development was part of a three-year cycle of collaborative research and development activities conducted by King's College, London, UK and the Weizmann Institute of Science, Israel (Harrison et al., 2008). The key goal of the CPD program was to develop teachers' knowledge and pedagogy, so that they will be able to scaffold their students in acquiring the inquiry skills.

One component of the CPD program was a workshop that was offered to chemistry teachers who were novice to the inquiry approach. The workshop lasted for two years, taking place once a month, for three hours. At the workshop the teachers received guidance and support throughout the entire phase of the initial implementation. An important aspect of the workshop was to improve the ability of the teachers to reflect upon their own work. As part of the CPD program, the teachers were asked to present pieces of evidence regarding their professional development, as they saw it from their point of view. Each piece of evidence was based on at least one artifact brought from their classroom. An artifact could consist of a student's laboratory report, a vignette from a video, teachers' worksheets, etc. (Taitelbaum et al., 2008).

The Study

Our main research goal was to better understand the process of change and the professional development that teachers underwent while practicing the inquiry approach in the chemistry classroom laboratory and participating in a CPD program. More specifically, we focused on the following question: *What changes in Judy's classroom laboratory practice took place as a result of the CPD?*

Research tools. Judy's professional development was analyzed using several qualitative research tools: (1) Videotaped classroom laboratory observations - during the two years of the workshop, Judy was videotaped at her classroom-laboratory. The video-tapes were analyzed using the software "Videograph" (Rimmele, 2003), based on our newly developed set of categories; (2) interviews - Judy was interviewed immediately after the videotaped observation regarding her teaching and her students' activity. We named this kind of interview a "hot reflection". Judy was also interviewed at the end of the second year, when she finished her first cycle of implementing the inquiry approach. During this interview she was asked to reflect upon her teaching experiences and feelings throughout these two years. All interviews were transcribed and analyzed according to Chi (1997), using the same categories as in the video analysis, and some other categories that could not be detected from the video analysis; (3) documentation of the workshop and pieces of evidence - in the workshop, Judy and the other teachers shared their reflection regarding their practice with the participants. All the discussions in the workshop were recorded, and analyzed using the same categories.

The videotaped classroom laboratory observations were a source that enabled us to follow Judy's actual practice as it was enacted in the classroom. Judy's reflections were obtained from her interviews, portfolio, and workshop documentation. Each research tool was carefully chosen in order to contribute to our understanding of the changes Judy underwent. Taken together, the research tools enabled us to create data triangulation regarding the changes Judy underwent. The results will be presented with respect to the two domains: (1) changes in pedagogical knowledge and (2) changes in content knowledge. As previously mentioned, the content knowledge refers to the inquiry skills needed in the inquiry approach.

Findings

Judy started to teach using the inquiry approach because she found herself under a lot of pressure from her school principal, her colleague, and her students. So, with some hesitation, Judy decided to join the inquiry program. She first participated in an intensive and comprehensive summer induction course on the inquiry approach. During the opening conversation she shared her fears with all participants and said: *"I will now be brave and enter the 'cold water'. In my old age, it is not easy to start a new way of teaching … It is comforting for me to know that I will get help from my colleagues at school"*. Throughout the summer induction course Judy experienced the same skills, knowledge, and thinking habits as her own students will experience. Moreover, she experienced the entire inquiry process, so that she could instruct her students better. At the end of the summer course, Judy decided to join the CPD workshop. Based on the analysis, we could see that Judy was very much challenged by teaching according to the inquiry approach, and underwent a comprehensive change in her way of teaching, as follows:

Changes in pedagogical knowledge:

- Judy improved her ability to organize collaborative teamwork.
- Throughout the two years, Judy's teaching became increasingly student-centred rather than teacher-centred.
- Judy could rationalize why she decided to choose a certain inquiry-type experiment out of a series of 100 inquiry-type experiments that were developed for the ICL program in Israel.

Changes in content knowledge, i.e., inquiry skills:

- The video analysis revealed that Judy managed to promote students' questioning skills. The fact that she was able to do that implies that she developed content knowledge through the summer induction course. In the interviews Judy claimed that she gained a lot of information regarding the inquiry approach and skills in the summer induction course.
- Yet the video analysis also revealed that at the beginning, Judy had difficulties in discussing with her students their inquiry question. Towards the end of the two years, however, Judy was much more confident in the discussions with the groups and in fact became deeply involved in the discussions while relying on the content of the inquiry approach.

Conclusions

Teaching science using the inquiry approach presents challenges for both the teachers and their students (Clough, 2002; Hofstein and Lunetta, 2004; Krajcik et al., 2001; Lunetta et al., 2007). It is suggested that providing teachers with the opportunity to reflect upon their experience as well as assessing their own work (via the videos) can serve as important tools for enhancing teachers' professional practice and development. The results indicate that a change in the content knowledge such as phrasing inquiry questions is not immediate, and participating in a summer induction course is not enough for this change to occur. Involving teachers in a reflective-type process accompanied by continuous support and scaffolding can promote the necessary professional development, which should include both content knowledge and pedagogical knowledge. Teaching using the inquiry approach is much more complicated and different from traditional classroom teaching. The teacher is required to possess different kinds of skills and a high level of expertise (Crawford, 2000). This is why teaching by the inquiry approach is very stressful, and it takes time for the teachers to become familiar with and comfortable in teaching it. We believe that Judy could develop the pedagogical knowledge and the content knowledge needed just through experience in class, but our research showed that Judy's professional development occurred faster and was much more meaningful through her participation in a CPD program.

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contemporary issues

FISER'09-Frontiers in Science Education Research

Mathematics for language, language for mathematics

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Abstract

The author discusses the balance and mutual influence of the language of instruction and mathematics in the context of CLIL, Content and Language Integrated Learning. Different aspects of the relationship of language and Mathematics teaching and learning are discussed: the benefits of using a foreign language of instruction, as well as the advantages of using Mathematics as a tool to teach a foreign language. Based on research among pre-service teacher trainees, the author presents different approaches to CLIL-lesson planning, pointing out the focus of the teacher trainees on content and/or language and the development throughout the ongoing course of CLIL at the University, with respect to the different specializations of the teacher trainees.

Introduction

"In an integrated world, integrated learning is increasingly viewed as a modern form of educational delivery designed to even better equip the learner with knowledge and skills suitable for the global age." (Mehisto, 2008)

Content and Language Integrated Learning (CLIL) is a trend of growing importance in European education; it is a result of both European and American influence in fields of philosophy, psychology, education, and language learning.

CLIL refers to situations where subjects, or parts of subjects, are taught through a foreign language with dual-focussed aims, namely the learning of content, and the simultaneous learning of a foreign language. (Marsh et al, 1999).

In this paper, we shall discuss the mutual influence of Mathematics and foreign language in the context of a CLIL lesson and analyze the approach to a CLIL lesson planning of English-teacher trainees enrolled in a CLIL course.

CLIL Methodology

With its dual focus, CLIL draws on language teaching methods as well as the content subject didactics. According to Mehisto (2008), the core features of CLIL methodology are: its multiple focus, safe and enriching learning environment, authenticity, active learning and scaffolding. By scaffolding Mehisto understands building on students' existing knowledge, skills and experience, responding to different learning styles, fostering creative and critical thinking, and challenging the students to take a step forward.

Do Coyle designed a 4C Framework for CLIL. The four Cs stand for Content, Communication, Cognition and Culture. The Cognition factor corresponds to Mehisto's active learning and scaffolding. Coyle (2006) states that "all 4 Cs must be carefully considered in the planning and conceptualization stages of the teaching…content is the starting point, the effectiveness of what follows relies on the interconnectedness of the other Cs." Coyle uses Culture as a general term for a number of aspects ranging from the mother tongue of the learners, through a variety of socio-cultural variables to the learning environment and school curriculum. This factor is specific for every CLIL lesson, it refers to its unique context; however, the remaining three are universal for all CLIL activities. Let us discuss the mutual influence of these aspects, with focus on Mathematics as the content subject.

English for mathematics

According to the CLIL Compendium website, CLIL provides opportunities to study content through different perspectives, allows access to subject-specific target language terminology and prepares for future studies and/or working life. The last two aspects being self-explanatory, let us focus on the first one: how the content subject can actually benefit from a change of the language of instruction.

Hejný (Hejný et al, 2001) points out that the learners' superficial knowledge of the concepts and their properties is an issue frequently discussed in Mathematics. In this context, the word "formal" is used in the sense of "learnt by heart, without understanding the concept". CLIL can become a powerful tool of discovering such formalisms in knowledge and also a tool to eliminate them.

On the following examples, we shall illustrate how CLIL provides a different perspective in Mathematics, allowing for deeper insight and understanding. Marsh claims that "CLIL does not only promote linguistic competence. Because of the different thinking horizons which result from working in another language CLIL can also have an impact on conceptualization, literally how we think." (Marsh et al, 1999). The examples also illustrate the variety of benefits of CLIL for Mathematics in the context of Czech curriculum. Together with the Cs framework, the first example shows the content in different notation, the second one pictures the enriching experience of differences between the mother tongue (L1) and the language of instruction (L2) and the last example presents the cognitive changes that CLIL can bring.

In other words, learning Mathematics in a different language provides the learners with a different perspective on the content area; different vocabulary creates further associations; different methods necessary for instruction through a foreign language can trigger more active approach and deeper understanding.

Example 1 – The area of triangle. Formulas learnt isolated, as a segment of text learnt by heart, are often forgotten, misunderstood or altered by the students. CLIL forces the learners to go behind the formula, since with the change of the language of instruction, the labels and names of objects change, too. For example, the universally used Czech formula for the area of a triangle is this one: ($\boldsymbol{a}$ being the base of the triangle, and $\boldsymbol{v_a}$ standing for the height)

$$S = \frac{a \cdot v_a}{2}$$

However, in English, this formula looks different, although the concept is the same: one half of the base (***b***) multiplied by the height (***h***).

$$A = \frac{1}{2} b \cdot h$$

The foreign language of instruction does not allow students to rely on memorized letters of the theorem: it leads them to more concentration in the lessons and to understanding the underlying concepts.

Example 2 – The square. In Czech, there are different words for *square* as the geometric shape ("čtverec"), *square* as in the square power ("na druhou", "druhá mocnina") and a *square* as the part of the city ("náměstí"). There is no etymological, phonetic or visual bond between the individual Czech words, and subsequently, for many students the connection between the first two concepts is often formal, artificial. In this specific situation, using English makes the complexity of the notion very clear.

Example 3 – The shapes and their properties. The learners' non-proficiency in the language of instruction can also be used to advance their description skills and support their looking at the subject matter from different perspectives. In a CLIL classroom, groups of learners were given pictures of flat shapes and solids, and asked to describe them, first in their mother tongue (L1), and then in the language of instruction, in this particular experiment, English (L2). They were not pre-taught the L2 names or given dictionaries. Whilst the L1 descriptions typically featured only the name of the shape and provoked no discussion within the group, the L2 descriptions were intensely argued about in the group and the learners focused on the properties of the shapes, comparing them, counting individual parts, giving their relative position etc. Higher thinking skills (according to Blooms taxonomy) were activated in the foreign language: in L1, the Knowledge level was applied (define, label), whereas in L2 the learners spontaneously employed learning activities associated with Analysis, Synthesis and Evaluation levels (compare, contrast, examine, formulate, argue, select).

Mathematics for English

The CLIL compendium mentions the following points of the language dimension of CLIL: improvement of overall target language competence, development of oral communication skills, deeper awareness of both mother tongue and target language, and development of plurilingual interests.

These general notions have been specified by numerous researches. Dalton-Puffer (2006) claims that among the language competences favourably affected by CLIL are above all vocabulary, morphology, creativity, risk-taking, fluency, quantity and emotive/affective outcomes. On the side of the productive skills, Dalton-Puffer further argues that with regard to speaking, CLIL students often display greater fluency, quantity and creativity and show higher risk-taking inclination.

Learners of a foreign language often meet problems when faced with "real" communication. According to Hyde (2000), one of the reasons might be the artificiality of linguistic environment of a language class, where language is seen as the target, not a tool for real communication.

CLIL shifts the focus; the content factor provides the context and the subject; hence, a CLIL lesson naturally creates the need for new information: for example, in the abovementioned example 3, the situation triggered students asking for the vocabulary. In such situation, language is not formally learned but rather acquired though meaningful activities.

Furthermore, Mathematics facilitates CLIL by a wide range of its own symbolic notation and visual input: in a Mathematics lesson, the language of Mathematics (LM) creates a natural bridge between the mother tongue (L1) and the language of instruction (L2). This can help relieve the learners' stress of not knowing how to express the concepts or processes: they can rely on LM in the first stages and gradually expand their knowledge of L2.

CLIL for cognition

As far as the cognitive dimension of CLIL is concerned, the CLIL Compendium stresses its role in complementing individual learning strategies, diversification of methods and forms of classroom practice, increasing learner motivation, and improving learner attitudes to both the language and the content subject.

We have illustrated how the change of the language of instruction can trigger higher thinking skills. It has been proven that CLIL learners reach more often the limits of their expressive ability, which most frequently leads to intensified mental construction activity; they work more persistently on tasks, show higher tolerance of frustration, and have higher procedural competence (Vollmer et al, 2006).

Nixon (1998) claims that by teaching subject through a foreign language we not only simulate the conditions under which our pupils are likely to meet the language outside of school: we build their confidence and extend their knowledge, engage their curiosity and increase motivation. Novotná and Hoffmannová (2002) further prove that by employing diverse approaches CLIL provides a motivating environment that can address various learning-type students. Hence, CLIL can change attitudes of many students towards Mathematics in a positive way. (Novotná et al, 2002). In her research, Tejkalová (2006) has confirmed that CLIL Mathematics lessons have generally been perceived as motivating and challenging by the learners.

Having presented the benefits and interrelatedness of the individual aspects of CLIL, we shall analyze the teacher trainees approach to designing a CLIL lesson.

The experiment: Teacher trainees' lesson plans

The experiment was realized during one semester as a part of the teacher training programme at the Faculty of Education, Charles University in Prague as a part of an ongoing research targeted at the need of specific CLIL training for CLIL teachers. The aim of this experiment was to confirm that the specific-content teachers can plan a more balanced CLIL lesson and to explore how the teacher-trainees lesson plans develop with gradually intensified exposure to CLIL.

Under the supervision of Department of Mathematics and Department of English, a CLIL course has been carried out. During this course, the students were expected to prepare and teach a CLIL lesson (specifically, a Mathematics through English–English through Mathematics lesson).

Groups and methodology. In the Czech Republic, secondary-school-teacher trainees specialize in two subjects; in the case of the experimental group one of the subjects was always English, whilst the second specialization differed. The group included 4 students of Mathematics, 2 of Humanities, one of Music and one student of German. All students prepared a CLIL lesson of Mathematics in English aimed for learners aged 13-14, with pre-intermediate level of English, and no previous CLIL experience.

First, the students attended lectures and seminars on CLIL specifics and analyzed video studies of various CLIL lessons. Second, they prepared their own teaching experiments and presented them (in a shortened version) in a peer-teaching session. A collective reflection on the lesson plans and the teacher trainees' performance in the session followed; each teacher trainee was then asked to elaborate on their materials, methods and strategies, incorporating the comments.

Next, they carried out the lessons at a secondary school. Each teacher trainee then wrote a self-reflection on the course of the lesson, focusing on the original targets, expectations, and the final results. They were also asked to comment on how they would change their preparation, were they to teach the lesson again. Simple questionnaires (in the mother tongue) were distributed among the participating secondary school learners, asking about the subjective difficulty of the lesson on the scale: very easy – easy – OK – challenging – difficult, the proportion of English and Mathematics in the lesson, the enjoyability of the lesson, and the difference of the methods employed in this lesson from the ones they are used to in their regular classes. The reflections and learners' questionnaires were then used in the CLIL course for a shared analysis a posteriori.

Results and evaluation. As expected, the initial lesson plans reflected the students' second specialization. Mathematics students (group M) opted for more complicated mathematical concepts corresponding to the actual level of the learners, and in terms of language they focused mainly on introducing and practicing the specific vocabulary. Despite the variety of Mathematics topics covered in the lessons, all of them were a revision for the learners, but allowed for different solving-strategies. The rest of the students (group H) aimed at easy Mathematics (primary school level), and incorporated ample non-mathematics-related language activities; they also managed to cover more language skills (Speaking, Writing, Listening, Reading) in their lessons. Whilst group M relied mainly on listening and writing, all members of group H included a reading assignment in their lessons. All students started their lesson in a lock-step approach, shifting later to individual, pair or group work, ending the lesson again in a whole-class activity. None of the original lesson plans analyzed the cognitive component of the lesson.

After the series of peer-teaching sessions, the students expanded on their lesson plans. Both groups scaffolded their presentations with more visual resources, 3 out of 4 members in M-group newly incorporated group work with role-assignment into their plans. There were generally more changes in the M-group lessons plans, reaching more balance between Mathematics and English and more variety in methods employed, admitting inspiration in the H-group peer teaching. In the H-group no further Mathematics concepts or problems were added, but the language part was elaborated on.

In the students' reflections, the most frequent issue was time-management. All of the students claimed to have designed a longer session than planned and had to manage the situations, usually by omitting some of the tasks or assigning them as homework. Three of the six students who opted for group-work faced problems creating the groups and admitted they had underestimated the necessity of clear and firm instructions. All of the students managed to fulfil at least 60% of their original aims. Seven of the eight students admitted that part of the tasks had been misunderstood or unclear for the learners.

Suggestions for their further CLIL lesson plans included more balance between the content and the language, paying more attention to non-mathematics vocabulary, the need of finer adjusting of the level of English for the learners, and the need for a more flexible lesson plan, allowing for customizable time-management.

The learners' questionnaires revealed the differences between the M-group and H-group lessons perceived by the students. The M-group teaching experiments were generally evaluated as "OK" or "challenging"; the average ratio of Mathematics to English was 65 % Mathematics to 35 % English, and the methods were perceived as "new, different, good". All of the H-group lessons were rated "very easy" or "easy", with the average percentage of Mathematics 12%. The methods were mostly described as "fun" and "good". In both groups, the learners rated the experiment as enjoyable.

The experiment confirmed that Mathematics teacher trainees managed to create more balanced lessons at a level adequate for the learners. Their lesson plans and reflections also showed major development after each of the sessions. The non-Mathematics teacher trainees did not seek cooperation of their colleagues to adjust the level of Mathematics, and their lessons were perceived rather as an easy and enjoyable English lesson. Although both groups (M and H) employed the same variety of methods in their teaching experiments, in M group they were evaluated as innovative by the learners, which is probably due to the learners' perceiving the lesson more as a Mathematics one. On the other hand, in the lessons viewed by the learners as an English lesson, the methods were not perceived as exceptional.

Conclusions

We have analyzed the mutual influences and benefits of Mathematics and language in Content and Language Integrated Learning.

In teacher training, the Czech Republic can benefit from the dual qualification of the teachers, which allows them to exploit both language and content subject methodologies. The experiment further showed that hands-on experience with CLIL is challenging for the teacher trainees and facilitates deeper analysis of their general teaching approach.

One of the CLIL slogans is “Learn as you use, use as you learn.” Apparently, it is not only valid for language acquisition in CLIL, but also for teacher training.

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A comparative study of different strategies to overcome language barriers in the teaching and learning of mathematics in countries where English is the LoLT

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Abstract

Most African countries have many different indigenous languages. Some governments have introduced English as the *Lingua Franca* of education. The majority of learners and teachers are not English home language speakers. The situation differs from other countries where the LoLT is English, for example England, Australia and the USA. Here, English as additional language to learners applies mainly to immigrants, while especially the content teachers are mostly native English speakers. In Mathematics classrooms different solutions are pursued for different contexts. In South Africa and other African countries the resource of the home language of the learners has become an important scaffold to further learners' understanding. In other parts of the world the main trend is to upgrade the learners' language proficiency in English by means of different strategies. This paper investigates whether strategies that are pursued in these different situations can inform each other to benefit learners.

Introduction

Mathematics learners who have to study through medium English, but who are not native speakers of English, are situated in broadly two different contexts. The one context is where the learners are part of a minority group in an English speaking country, for example in England, America, Australia and New Zealand, etc. The other context is where English is an additional language of the majority of learners in the country, for example in many African countries, of which South Africa is one.

In both contexts the strategies that are followed to overcome language barriers that exist in multilingual mathematics classrooms consist of many variations. However, the language strategies can be divided into two main categories. The first strategy revolves mainly around upgrading the English of the learners to such an extent that they can cope adequately, and even with excellence, in the mainstream school system. In the second strategy code switching between the English as language of learning and teaching (LoLT) and the home language of the learners is used by both the teacher and the learners in the process to negotiate meaning in mathematical discourse.

This study proposes to investigate research literature on these two different strategies as it is followed in the two main contexts, and to investigate whether it is possible that the experience, knowledge and skills gained in research on these language strategies can inform each other. This is done from a mathematics education viewpoint and not from a linguistics viewpoint. The study is mainly done from a South African perspective and therefore the South African situation will receive some emphasis.

Theoretical perspective

Language is very important for conceptualisation and reasoning in general and for mathematics in particular (Vygotsky, 1962; Pimm, 1987, 1991). When new concepts are constructed "word sense" plays an important role. The "sense" of a word is the understanding of all the different nuances of the meaning of a word in different contexts (Vygotsky, 1962). Word sense is only mastered in a specific language when the proficiency of the learner has reached a certain level and can intuitively be used in the correct way.

The term *bilingual* usually applies to someone that is fluent in two languages and both languages are used extensively (Kearsey & Turner, 1999). The level of efficiency with which the bilingual person applies the two languages does not differ greatly. Setati and Adler (2000) support Grosjean's view that the language configuration of bilinguals differs from the language configuration of monolinguals. Bilingual persons must not be evaluated from the view of monolingualism. One integrated network is formed to negotiate meaning in the two languages. Cummins and Swain (1986) hold the theoretical view that certain skills developed in the main language will also be available in the second language and vice versa. They reported some contradictory research findings regarding the relationship between bilingualism and cognitive functioning. This can be explained by the *threshold hypothesis* that

> "proposes that there may be a threshold level of linguistic competence which bilingual children must attain in both their first and second languages, in order to avoid cognitive disadvantages and to allow the potential beneficial aspects of becoming bilingual to influence cognitive functioning".

This implies an additive approach in education. The main language of the learner should not regress in favour of the second language. A competence above the threshold level should be acquired in both languages. Furthermore, where learners come from socially deprived homes and the home language is not highly valued, they recommend that the initial instruction should be in the learners' home language.

In the process of learning mathematics, discourse about concepts and relationships, as well as discussing methods to solve problems, are very important. By articulating mathematical ideas and discussing it with peers, learners negotiate mathematical meaning for themselves (Costello, 1991; Pimm, 1987). Part of learning mathematics entails becoming proficient in the special language in the mathematics register. It poses problems even for first language learners because of the specific structure of the mathematics register (Pimm, 1991), and all the more so for learners who are not native speakers of English. Learners struggle with the specific and correct use of prepositions, the numerous synonyms in English, as well as with the fact that many words have different meanings in Standard English and the mathematics register (Pimm, 1987, Orton & Frobisher, 1996). The difference in the semantic structure of languages poses another problem, especially in cases where the semantic structure differs greatly from that of English, for example the indigenous African languages. According to Khisty (1995), the development of proficiency in the disciplinary register within the second language can take as long as seven years. In rural areas with an English foreign language environment it may take longer.

It is therefore clear that language strategies should be aimed at giving learners as much support as possible in becoming proficient in the LoLT, and specifically in mathematical language. The language strategies in the mathematics classrooms should provide enough support for learners to be able to conceptualise and understand relationships, procedures and problem solving strategies while they are still on their way to become proficient.

The strategy of code switching in the African environment

Contexts: Adler (2001) identified three different language situations in multilingual mathematics classes in South Africa, namely urban-suburban areas, the additional language situation of the urban or township contexts and a foreign language situation. This classification will also be applicable to the rest of the African countries with English as LoLT.

In the urban-suburban areas there is a strong English environment and many different home languages are found. This environment is also typical of many classrooms in English speaking countries. In this language situation the "English only" strategy is usually followed, most possibly because the variety of languages present renders the usage of learners' first languages difficult.

Secondly we find the additional language situation of the urban or township contexts, with less English in the environment, a strong regional language and different indigenous languages present. This environment can be compared to situations in English speaking countries where clusters of immigrants with a common first language are found, and they often communicate outside school in a "community language" with its own special features.

In the African context the choice of strategy would depend on two important features. If there is a strong regional language, many of the learners with other indigenous first languages are more fluent in the regional language that in English. This will make the choice of code switching as strategy more viable. However, the choice of strategy will also depend heavily on whether "the desire for social goods (jobs, higher education etc.) overrides teachers' and learners' concern for epistemological access" (Setati, 2008). Any of these strategies or variations may be found in these regions

Thirdly, a foreign language situation exists where the learners hear English mainly at school, and most of the learners have the same first language. This situation is found in the rural areas of Africa. In this context code switching nearly becomes a necessity, especially in the primary schools, although English is still seen as the key to success.

This situation may show some similarities to, for example, Spanish or Chinese communities in the U.S. where the first language is still strongly maintained and used in the community and English is reserved for schooling and communication with "outsiders". However, there are major differences of which not the least is the fact that such languages include a fully developed mathematics registers, while some of the indigenous languages in Africa lack terminology for many mathematical concepts.

The strategy of code switching

The term code switching will be used as a term to describe the use of dual languages, without going into the details about the distinction between code switching, code mixing or borrowing of words.

Code switching as sociolinguistic phenomenon is not new, but has previously been stigmatized as an unacceptable variety of language. This deficiency view of code switching still continues (Moschkovich, 2005) and is held by many mathematics teachers, parents and decision makers. In South Africa this is driven by the hegemony of English, as well as the deficiency view that some mathematics practitioners that are speakers of indigenous languages hold about their own language because their languages are lacking in mathematical terminology. What is more recent is the view that it is a valid and acceptable practice to use the learners' first language as a scaffold to understanding mathematics better in the situation where the LoLT is English, although it is the first language of a minority of learners. In many mathematics classrooms neither the teacher nor the learner speaks English as their first language.

In some countries, for example Botswana and Swaziland, there is one or at most two major indigenous languages, but many countries have multiple indigenous languages, for example 11 official languages in South Africa (including English), and 7 languages in Namibia (where English is a legacy from the times when it was a protectorate of South Africa) up to more than 30 languages and even so many as 120 languages in some other African countries. These indigenous languages are usually regionally based and "families" of languages exist that belongs to one group that have common language origins, which makes it easier for these language groups to understand each other. Therefore it is not uncommon to find people that can speak more than one language and are able to "hear" still more. This is consistent to the theory that Cummins & Swain (1986) underwrite that there is a common underlying proficiency that explains an interdependence between languages. Even languages that are not African languages such as English, Afrikaans, French and Portuguese will sometimes be included in the repertoire of languages of learners and teachers, depending on the region where the person lives. However, this often includes neither the written forms of these languages, nor the academic registers.

Webb, L. and Webb, B. (2008) reported that classroom observations in different countries in Africa revealed that the use of an unfamiliar language such as English often results in traditional and teacher-centred teaching methods. Less effective teaching strategies like the use of "safe talk" was reported by Heller and Martin-Jones (2001). "Safetalk" is established by means of "teacher dominated patterns of classroom talk, and the highly ritualized rhythmically teacher co-ordinated prompts and choral responses from the learners" or the so-called "*ritualization*". According to Hornberger and Chick (2001:42) the teacher in these hazardous situations often chooses for the social function over the academic function of language and so creates "safetime" in the classroom. Little learning takes place, but it seems that everybody is actively taking part. Another practice, namely circumvention of language by mostly using symbol language and avoiding words, forms part of the teaching culture in many multilingual mathematics classrooms. This practice contributed much to the over-emphasis on algorithmic procedures and less on conceptual development and solving problems where contexts are described in words.

Under-achievement of learners required teachers to look for new strategies. Gradually teachers started to use the first language of learners to promote understanding in an unstructured and intuitive manner. Gradually code switching became more acceptable and was practiced more openly. The work of Setati (2002, see also other articles referred to) and Adler (1997, 1999, 2001) and others on multilingual classrooms and code switching contributed much to de-stigmatize code switching and establish it as an acceptable language strategy in multilingual mathematics classrooms.

In the last ten years many studies of multilingual mathematics classrooms in the African context were published. Often case studies reporting code switching in multilingual mathematics classrooms and research describing features of code switching, for example the identification of "front stage" and "back stage" use of the indigenous language (Heller and Martin-Jones, 2001). For a time most studies in the African context were concerned with identifying the difficulties teachers and learners experienced in multilingual classrooms, the lack of learners' and teachers' proficiency in English and mathematics, and describing the practice of code switching. Little was done with regard to developing "best practices". In this regard Adler (1999) described the dilemma of how to balance visibility and invisibility of language teaching in order to exploit the language to serve conceptual development; modelling the correct language as well as revoicing learners' utterances in correct mathematical language without obscuring the mathematics. She (2001) also identified a lack of knowledge on how to plan the journey from informal language use in the learners' first language, to the end goal of formal mathematical English. Written work in the indigenous languages to supplement oral code switching was not on the table.

Only recently research on best practices in multilingual classes got more momentum. Gradually subject dictionaries for school level mathematics started to appear in different forms in the indigenous languages of South Africa (Department of Arts and Culture, 2003, Fricke & Meyer, 2005). Vorster (2008) did some research on using written work as a scaffold to oral code switching and using decoding in both English and the indigenous language to assist conceptualization. Setati, Molefe and Langa (2008) investigated pedagogy where the "invisible" use of the learners' first language combined with a problem centred approach is used to try and promote better understanding. This also included written text. Webb and Webb (2008) did some research on developing exploratory talk. They differentiated between disputational talk that is characterized by disagreements and individualized decision-making, cumulative talk that takes place when learners build positively but uncritically on statements and assertions made by others, and exploratory talk that takes place when learners engage critically, but constructively with others' ideas. Exploratory talk was not reached when learners were restricted to English, but only where code-switching was allowed. When using only English, learners at most reached cumulative talk. Webb and Webb (2008) concluded that teachers participating in the research realised that if they provided guidance and practise using language in order to express mathematical reasoning, learners could express themselves more effectively, and that it aided problem solving in mathematics. However, it is a slow process that requires guidance.

The English speaking countries

A quite different situation exists in countries where the majority of the learners and teachers are English first language speakers. The enormity of the challenge to teach the diverse population in major cities is only understood when it is realized that, for example, the immigrant population in Greater London, includes about 350 different languages and that 75% of the school aged population in the inner city of London belongs to ethnic and linguistic minority groups (Harris & Leung, 2007). In Australia the percentage of the population's whose first language is not English is rising and Clarkson (2007) reports that in some parts of Sydney and Melbourne classes with learners representing five or six countries are common. The task of teaching learners of minority language and ethnic groups has grown to a field of major importance in education.

Many different strategies are followed, not only in different countries, but also in different regions of the same country. It is not possible to describe all these strategies in the scope of this paper. However, the common denominator between these strategies is a goal to prepare the learners of the minority groups to become part of the main stream of learners. In the early years an assimilationist approach was followed in England. According to Harris & Leung (2007), this was based on the view that languages and cultural practices of new immigrants should be erased as precondition for their educational success. Later a more positive approach to the learners' mother tongue was advocated. Harris & Leung (2007) quote the Swann report (1985) as reaffirming a positive attitude to the first and community languages of the learners but that they cannot support programmes of bilingual education in main stream schools. According to the report maintenance of the mother tongue is best achieved within the minority community itself. Furthermore, the report insisted that the ethnic minority learners must at all times be educated in the mainstream to ensure equal access to the curriculum.

A system of English Additional Language teachers is in place. However, there is no EAL curriculum. All learners are assessed according to the criteria for the English as subject in the main curriculum. This applies to both mother tongue speakers and those who are still in the process of learning English. The EAL teachers work in partnership with subject teachers as classroom teacher, curriculum adviser and adviser to other colleagues on EAL matters. In consequence of a shortage of EAL teachers, not all teachers needing EAL specialist assistance have this privilege (Harris & Leung, 2007).

Harris & Leung (2007) distinguish between three broad groups of EAL learners:

> *New arrivals*: …possessing limited acquaintance with and low level of expertise in English, together with little familiarity with British cultural and educational practices.

(compare to Adler's foreign language situation in the African context)

> *Low key British bilinguals:* Pupils born and brought up in multilingual homes in British urban areas. They have regular routine interaction with family and community languages but without claiming a high degree of expertise in these languages. They are entirely comfortable with the

discourse of everyday English particular local vernacular Englishes and with contemporary British cultural and educational practices.

(compare to Adler's urban/suburban situation in the African context)

Pupils born and brought up in British urban areas, with dominant spoken proficiency in 'community'/'home' language originating from outside the UK, but not in English.

(compare to Adler's additional language situation in the African context)

Pupils born in other countries starting schooling in English between 5 an 16 years of age and appear to gradually move from the 'new' arrival to the low key British bilingual category.

High achieving multilinguals: These pupils have a good level of expertise or an untapped potential to rapidly acquire expertise in home/community language(s) other than English. At the same time they also have a high degree of proficiency in the kind of written standard English required for school success.

Each one of these groups has to be catered for and may be present in the same class, including learners from different ethnic origins and language backgrounds.

Mohan (2001) emphasised the need for content teachers to become involved in this situation, because it takes a long time to master the second language skills and the learner's academic instruction cannot be delayed until these skills are developed. Even first language speakers need assistance to develop the skills to understand, read and write academic language, and for this paper's focus specifically to develop the English mathematical register. Language teachers are not equipped to teach the register of mathematics because language in mathematics is irrevocably entangled with subject specific conceptual understanding. On the other hand the mathematics specialists are usually not well enough versed in language teaching methodology to identify the specific problems of the EAL learners and to identify the impersonal, abstract and often context reduced language of mathematics as a specific discourse genre. Collaboration between language teachers (in this case the EAL teachers) and mathematics content teachers is therefore of great importance, especially when teaching EAL learners whose English discourse skills are still developing. This is also true for countries like Canada and Australia where full time EAL/ESL teachers are allowed. (The term English Second Language (ESL) learners is still used in some countries, while in other countries EAL is preferred.)

To meet the goal of "*explicit and systematic* integration of language" Mohan (2001) sees systemic functional linguistics as providing a functional theory of language and discourse, while the 'Knowledge Framework' "provides a theoretical basis for aspects of language as medium of learning". He describes the 'Knowledge Framework' as "a view of language as discourse in the context of social practice" and identify six core knowledge structures namely, description, sequence, choice, classification, principles and values. Knowledge structures can be represented in both visual and verbal mode. One mode can be changed to another, and graphics can be used to represent knowledge structures that provide a basis to construct written discourse.

A task based approach to language learning in the content classroom is propagated by Mohan (2001), Leung (2001), as well as Lucas, et al. (2002). Much can be written on planning mathematical tasks for EAL learners, but only a few aspects will be highlighted. Teachers have to be familiar with the learners' linguistic, academic and ethnic backgrounds to be able to select and prepare tasks. Furthermore, they have to analyse the language inherent in the learning tasks for mathematical words, syntax, logical connectors, and semantic structures that can be difficult especially for EAL learners. The teachers need to determine the mathematical skills as well as language skills needed and then plan for using appropriate scaffolding so that EALs will be able to complete the tasks (Lucas, et al, 2002; Dale & Cuevas, 1992)

A task can be planned collaboratively between a language teacher (or EAL teacher) and a content teacher for content and language outcomes respectively. However, a long term common working agenda is often difficult to achieve because of the different focuses of the content and language teachers (Leung, 2001). It could be of great help to EAL learners if the mathematics content teacher and a language teacher could discuss ways to organise content classes in such a way that the necessary scaffolds are built into the tasks so that the learner will understand the language and at the same time systematically learn to use language more efficiently in their own outputs. Although it is primarily the task of the mathematics teacher to initiate learners into using the mathematics register, the English Language teachers will understand more specific language problems of learners such as for example difficulties to use and interpret prepositions. Furthermore, language teachers will understand better and which problems learners from different language origins will experience with specific features of English as related to how to syntax in their own language differ from English.

Although the first language of learners was previously used in California to teach mathematics science and social sciences to some EAL/ESL learners while they also were instructed in English in ESL classes (Richard-Amato & Snow, 1992), the use of bilingual education was banished in some states in the USA, for example in California where it may only be used if a school applies for a waiver of proposition 227 (Barwell et al, 2007; Téllez, 2008). This seems to be a step in the opposite direction as that of the growing use of the learner's first language in the African context and research results that reveals evidence that bilingual learners benefit from the use of their first language (Clarkson, 2007).

Discussion

While the "pro's and con's" of bilingualism were being discussed in the UK, USA, Australia and other countries, learners and teachers in Africa silently cast their vote in the discussion and expressed the need for their first language by informally starting to use it as a scaffold to English as LoLT in the mathematics classrooms. This happened in spite of the hegemony of English and quest for English as key to "social goods" (Setati 2008). The research describing the phenomenon in a sense "legitimised" the practice of code switching and teachers started to use it more openly.

Work done in other contexts can enhance the understanding of code switching. The findings of Kern (1994) as quoted by Clarkson (2007) on the language of thought explain some benefits for learners when they translate to their first language when thinking. Benefits included: the first language facilitates semantic processing; learners can hold long and complex chunks of information in their first language better in their short term memory; meaning can be assimilated and integrated better; the network of concepts is richer in the first language and it enhances the learners' confidence in their ability to understand. However, Kern also warned that there may be problems with the accuracy of the learners' translation and that the learner may focus too much on transformed first language representations rather than on the original forms of the second language. With regard to the possible inaccuracy of the learners' own translation while processing information, it may be worthwhile to investigate whether the availability of notes in both English and the learners' first language would help to reduce the inaccuracy that may occur in the learner's own internal translation, especially when the learner is still not very proficient in English.

The most important contribution from the research done in the African context is that it is done from a truly plurilingualistic viewpoint, that is, from the viewpoint of people that not only live and work in a multilingual society, but also speak more than one language fluently themselves. This often includes three or four languages. If this is pursued, insight from this viewpoint may prove valuable in a world changing to a multilingual society. Furthermore, the code switching practice that sprung up in an informal way, highlights the learners' need for the scaffold of their own language when struggling to cope with mathematics taught in an additional language, understood by teachers who are teaching in a language that is not their first language.

Mathematics teachers in Africa have to take cognisance of the practice of EAL teachers that give assistance to content teachers on language issues. Much more could be made of cooperation between mathematics teachers and English language teachers to plan more structured teaching of mathematical language, especially the task based approach as described above. Although the need for the learners' first language as scaffold was highlighted by code switching, the importance of Cummin's findings must also be taken into account and the learners' first language should also be enhanced by excellent instruction.

Furthermore, the mathematics community at large have to take their task to teach the mathematics register seriously, and through this enhancing second language learner's language proficiency. In order to achieve this they also have to take cognisance of the large body of research done by sociolinguists regarding teaching in multilingual classrooms.

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Conceptualization of Nature of Science, socioscientific issues among science majors and nonscience majors

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Abstract

The aim of the study is to explore conceptualization of science majors (SM) and nonscience majors' (NSM) views on Nature of Science (NOS) and Socioscientific Issues (SSI) related with global warming. A science brief about SSI were distributed to SM and NSM classes. Students were asked to answer questions related with the story of global warming related NOS. According to responses, 8 SM and 9 NSM were semi structurally interviewed. The sample was selected purposeful from the data obtained from students' responses. The study utilized phenomenological qualitative research design. Even if the sample may not be representative of all SM and NSM it provided insight into how these students conceptualize NOS and SSI. Some of the results suggested that SM generally understood certain NOS concepts whereas some results indicated deficiency in connecting science to society. Data obtained from NSM indicated that a highlighted need for instructional attention both for NOS and SSI.

Introduction

Learners in the field of science education are generally directed to have an overview on science and society together in a meaningful context so that growth occurs in all three educational domains: cognitive, psychomotor and affective. Recognition of the importance of connecting science to both nonscience majors and science majors' careers should be mission of state and universities. Not only for science majors but also for nonscience the goal should be to help nonscience majors become scientifically literate citizens who are able to understand the scientific issues.

Development and assessment of students' conceptions of nature of science (NOS) have been concerns of science educators for many years. More recently, emphasis has been placed on providing an expanded view of an individual's beliefs regarding NOS. Pajare, (1992) states that students' and teachers' beliefs may influence their educational practices especially their beliefs about scientific epistemology. Conceptualizations of NOS then serve as a necessary condition for helping students' understandings of scientific way of thinking (Hanuscin, Akerson & Mower, 2005, p.913).

Socioscientific issues involves understanding the content of an issue, processing information regarding the issue, attending to moral and ethical branches of the issue, and adopting a position on the issue (Sadler & Zeidler; 2004). Both NOS understanding and the ability to negotiate socioscientific issues contribute to scientific literacy that, for many, is the ultimate goal of science education. If a person is able to use 'scientific ways of thinking' then he/she necessarily understands at least some aspects of the nature of science; and if he/she is applying scientific ways of thinking to 'individual and social purposes', then he/she is considering socioscientific issues. In other words, the nature of science informs debate surrounding socioscientific issues. These two themes, which are integral to modern science education, are implicitly associated with one another. Therefore this study aims to explore conceptualization of science majors and nonscience majors' views on NOS and socioscientific concepts related with global warming. Additionally the study aimed to compare how they interpret and evaluate conflicting evidence regarding socioscientific issues.

The Problems

How science majors and nonscience majors conceptualize NOS and socioscientific concepts related with global warming?

How do they interpret and evaluate conflicting evidence regarding socioscientific issues?

Method

Since the study aimed to elicit students views of NOS and SSI, phenomenological qualitative research design was utilized. This design seeks for meaning of the lived experiences for several individuals about a concept or the phenomenon (C. Marshall, G. Rossman, 2006). A science brief about global warming were distributed to a science class and a nonscience class. Students were asked to answer five questions related with the story of global warming. According to responses, 5 science and 5 nonscience majors were semi structurally interviewed. Then the some questions were asked again in order to acquire deeper information about students' perception of socioscientific issues and NOS. The sample was selected purposeful from the data obtained from students' responses. Science major (SM) students were from Faculty of Chemistry and nonscience major (NSM) students were from Administration department. Students were generally in their first years of department.

Results

Data obtained from the interviews were coded thematically. Codes of interviews indicated that, there are some common terms that science majors use in conceptualization of NOS. Although the investigation examined only three of many aspects of NOS, Students exhibited diverse ideas. Three interviewees from science major and one nonscience major commonly mentioned that science account for Explanation of Universe and one SM stated that it does in manner of cause effect relationship. According to five SM interviewees science has some certain things for everyone and these are obtained throughout the experiments and observations. One SM stated that "There are some realities for chemistry, physics and mathematics, if molecular formula of water is composed of two hydrogen atoms and one oxygen atom this same for all". Additionally another SM stated that science is constructed on definite framework like prior knowledge whereas generally NSM interviewees emphasized science is less interpretive. When the difference of science with other disciplines is asked, the common answer given by all SM and NSM was like "other disciplines are not same for anyone"

When question related with conflicting evidence data was asked to both group of students. Three of the NSM interviewee stated that the type of data affects the conclusions of any study. They stated that sometimes data can be interpretive. According to one SM scientists should perform experiment and they should control variables and consider covariates so they may not make mistakes, also she states like "Correct use of data and meaningful use of data is not maintained so same data have different conclusions".

When compared to NSM, SM students have more emphasized the tentative nature of science. One student stated that as "When additions of new knowledge on literature integrate with existing knowledge, this tentaviness will strengthen the science".

Responses related with whether scientists discover or invent scientific knowledge indicated that. Generally SM interviewee responded as place of existing knowledge. According to one of SM "fundamental frameworks are discovered earlier, scientists take them as reference and new product explored". On parallel to what his friend statement another SM mentioned as follow "Shortly, sometimes they discover from existing things, sometimes by changing some variables on experiments they explore a new thing which is not in nature already".

Students' responses related with effects of cultures on development of scientific knowledge were not diverse for this theme. They all explained the different type of science in different cultures. Also They all stated needs of society, trends in society determine preferences of society on science. One SM stated that "Needs of society determines development of science, there are some culture directed choices, for example; trade, raw material, science of processing, development of social sciences are some of them". One NSM said that "When we consider two different societies, we see that level of development of these countries is not equal". One SM interviewee mentioned even in same type of science, rate of development in the changes from society to society. One NSM talked about some poor societies may not supporting development of some fields of science, which is also role of culture on society and thus on science.

Conclusion

Even if the present sample may not be representative of all science majors and nonscience majors it provided insight into how these students conceptualize NOS and socioscientific issues. Some of the results suggested that science majors generally understood certain NOS concepts whereas some results indicated deficiency connecting science to society. Science major students generally have more contemporary views on question related with hypothesis, theories and laws. As expected nonscience major students showed naïve views regarding with these items. Both science and nonscience students held has-merit views about the social construction of scientific knowledge. One possible reason for that might be students could find easily examples to how different cultural groups have different development levels in the same science

Data obtained from nonscience majors indicated that a highlighted need for instructional attention both for NOS conceptualization and socioscientific issues. Especially responses of nonscience majors related with knowledge of the substantive content of science that is related specifically to understanding the interrelationships among people and activities influencing the world were seriously inadequate. Results suggest that some basic courses designed especially for nonscience majors should be offered for them as elective courses in order to improve their scientific literacy. The content can be simple but including popular science terms and concepts to increase students' motivation to learn science. The study reveals the range of views concerning the nature of science teachers must work with in the classroom especially at primary and high school levels.

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An investigation of pre-service teachers' alternative conceptions of global warming

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Abstract

Global warming is an average increase in the temperature of the atmosphere near the Earth's surface and in the troposphere, contributing to changes in global climate patterns. In this paper, the term 'global warming' is used to refer to the exacerbation of the natural greenhouse effect by human activities. Due to representing one of the greatest environmental, social and economic threats facing our planet, global warming is receiving considerable attention by scientists, policy makers, and educators. However; little is known about pre-service teachers' conceptions regarding the scope and nature of this phenomenon. This study aims to present alternative conceptions of 85 pre-service teachers about the consequences, causes and cures of 'global warming. The most prevalent misconceptions were that more people will get skin cancer with increasing global warming and radioactive waste from nuclear power stations and holes in the ozone layer cause global warming.

Introduction

One of the major subjects that should concern all the people living on Earth can be considered as Global Warming. On the website of National Aeronautics and Space Administration (NASA); global warming is defined as an increase in the average temperature of Earth's surface. Since the late 1800's, the global average temperature has increased about 0.7 to 1.4 degrees F (0.4 to 0.8 degrees C). Many experts estimate that the average temperature will rise an additional 2.5 to 10.4 degrees F (1.4 to 5.8 degrees C) by 2100 (NRDC, 2005). Although it is difficult to ascribe any specific climatic change or environmental event to global warming, it is becoming clear that we are now beginning to see some of its consequences (IPCC, 2007). Thus, we observe changes in weather patterns and melting of the polar ice caps. In addition, it is anticipated that thermal expansion will result in a rise in sea levels and, as a result, coastal flooding in some areas. Global warming will cause geographical redistribution of some organisms whose ecological range is limited by temperature, and such organisms may include crop pests and disease-carrying insects. Furthermore, it is likely that some of these changes will continue even if greenhouse gas concentrations could be stabilized (IPCC, 2007).

It seems obvious that students must be made aware of the issue of global warming, its possible causes, and the effects both recorded and predicted. It would seem equally important that students must know of the debate and uncertainty surrounding the issue. It is likely that they will be called upon, in the near future, to take action on this issue, either through direct activity effecting their lifestyle, or by indirect action. Preparing students to take effective action on this issue involves providing them with an understanding of the issue. While discussion of possible causes and effects, the nature of the evidence, and the controversy surrounding the issue must be considered, educators must be equally aware of the possible misconceptions that students bring to the discussion. Consequently, the extent to which teachers are environmentally educated themselves will undoubtedly affect the kind of environmental knowledge transmitted to their students. For instance, if teachers have a poor understanding of some environmental concepts, they will possibly perpetuate this misinformation in their classrooms (Khalid, 2003).

In the last decade a lot of research has been conducted concerning pupils' and adults' understanding of global warming and other global environmental problems, which uncovered the misconceptions and misunderstandings people, of all ages, hold of many aspects of these issues in terms of causality, possible consequences, and possible cures. (e.g., Dimitriou, 2005; Dove, 1996; Boyes & Stanisstreet, 1993, 1994; Boyes et al., 1999; Francis, Boyes, Qualter & Stanisstreet, 1993; Khalid, 2003; Koulaidis&Christidou, 1999; Summers, Kruger,Childs,&Mant, 2000).. However; studies investigating alternative conceptions of pre-service teachers about global warming is limited. Dove (1996) used a questionnaire survey to investigate the understanding of 60 trainees in three areas: the greenhouse effect, ozone layer depletion and acid rain. In the case of the greenhouse effect, Dove found that the trainees were generally familiar with the term itself but had little awareness of the concepts involved. They were aware, for example, of carbon dioxide as an important greenhouse gas but had little awareness of other greenhouse gases and were largely unaware of the natural greenhouse effect. They also held the common misconception that 'holes' in the ozone layer are a direct cause of global warming.

Khalid (2003) showed that among American pre-service high school teachers many misconceptions concerning the greenhouse effect, the depletion of the ozone layer and acidification are present. Most students knew that carbon dioxide is the most abundant gas responsible for the enhanced greenhouse effect and that the temperature in the USA will rise if the greenhouse effect increases. But a majority also indicated that holes in the ozone layer would enhance global warming and that an enhanced greenhouse effect will result in more people getting skin cancer.

Furthermore, in the present study, we aim at contributing to relevant research in general, by exploring the alternative conceptions of pre-service teachers about consequences, causes and cures of global warming for whom research is quite limited.

Methods

The sample for this study was a sample of convenience. The subjects were 85 pre-service teachers majoring in secondary science education at Middle East Technical University. Most of the subjects were 4th and 5th year students in physics or chemistry education (46% 5th year, 41% 4th year). There were two reasons for choosing this sample for data collection. First, by the time these students completed the questionnaire, they have finished taking all the required science courses. Second, they will begin their professional career as secondary science teachers in about 1 to 1,5 years. The sample was also homogenous in terms of gender and undergraduate programs. There were 54 females and 31 males and 55% of the subjects enrolled in physics education whereas 45% of them are chemistry education students.

The instrument used in this study was a closed-response type which was derived from the questionnaire devised by Boyes and Stanisstreet (1993) and contained a series of statements about Global Warming. The questionnaire contained 36 statements in three sections; the sections concerned real and possible consequences of an exacerbation of the Global Warming, real and possible causes of the Global Warming and real and possible actions to reduce the Global Warming. Each section contained six scientifically acceptable statements and six erroneous statements and these were in random order. For each statement students were asked to respond by ticking one of five boxes labeled 'I am sure this is right', 'I think this is right', 'I don't know about this', 'I think this is wrong' and 'I am sure this is wrong'. The inclusion of an answer with the statement "I don't know" was used in order to diminish the disadvantage of closed-form questions, namely, the selection of the right answer by chance.

In addition, the questionnaire included items which asked students to report how much knowledge about global warming they felt they had gained from television, the Internet, school, newspapers and the radio. One of the questionnaire items consisted of a free-response question; students were asked to explain their understanding of global warming with a few sentences.

Results

Cell responses were collapsed when analyzing the answers of students, "I am sure this is right" grouped with "I think this is right," and "I am sure this is wrong" grouped with "I think this is wrong."

Consequences of Global Warming. Ideas of pre-service teachers about consequences of global warming are summarized in Figure 1. Almost entire group of the respondents correctly recognized that if the greenhouse effect increases, the earth will get hotter (90%), and changes in the world's weather would be a result (94%). In addition to these; 98% of the students have the scientific belief that an increase in the greenhouse effect will result in melting of some of the polar ice. 95% of the students are aware that desertification will increase with the increased greenhouse effect. In general, it can be said that pre-service teachers are mostly well-informed about observable consequences of global warming. However; %45 of the students do not know whether flooding will increase and 48% of them lack knowledge of there will be more 'bugs' and 'pests' on crops with the increased greenhouse effect.

The questionnaire also explored the prevalence of certain misconceptions mentioned in the literature. About half of the students (51%) did not know whether global warming will result with increased incidence of earthquakes and food poisoning (45%). Greater proportions of the respondents, between about half and two thirds, associated global warming with diseases such as heart attacks (53%) and fish poisoning in rivers (64%). However, the most common two misconceptions, held by more than three quarters of the students, were that some of our tap water will become unsafe to drink (78%) and more people will get skin cancer with increasing global warming (86%).

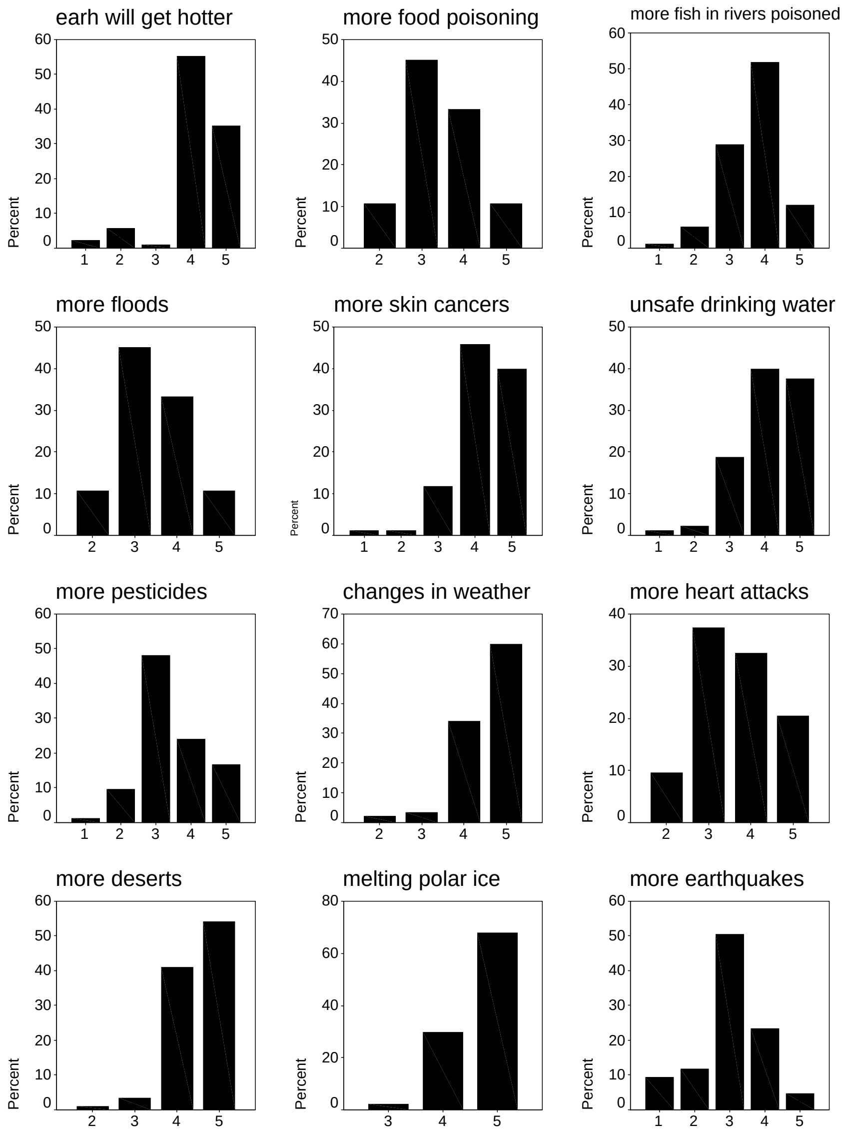

Figure 1. Ideas about consequences of Global Warming

Causes of Global Warming. Ideas of pre-service teachers about causes of global warming are summarized in Figure 2. When statements about causes of Global Warming were analyzed; it was found that most of the respondents were aware of the contributions of carbon dioxide emissions (95%) and CFCs from spray cans (82%) to global warming. Over half of the students recognized that gases from rotting waste (76%) and artificial fertilizers (67%) could exacerbate global warming, although it is not possible to know from this questionnaire whether students knew what these gases were (methane, and nitrogen oxides, respectively).

%61 of the students think that Global warming is made worse since the Sun's rays cannot escape from the Earth. Fewer of the students, less than half (37%) realized that ozone near the ground in the atmosphere could act as a greenhouse gas.

More than half of the students (58%) thought incorrectly that rubbish dumped in rivers and streams have an effect on global warming while fewer than half of the students thought that litter in the streets (40%) could exacerbate global warming. 58% of the students also thought that global warming is made worse because too many sun's rays get to Earth. More than one thirds of the students (%41) relate acid rains with global warming. A higher proportion of students (64%) have the misconception that radioactive waste from nuclear power stations is a cause of global warming. However; the most prevalent misconception held by 82% of the students was that the greenhouse effect is made worse by holes in the ozone layer.

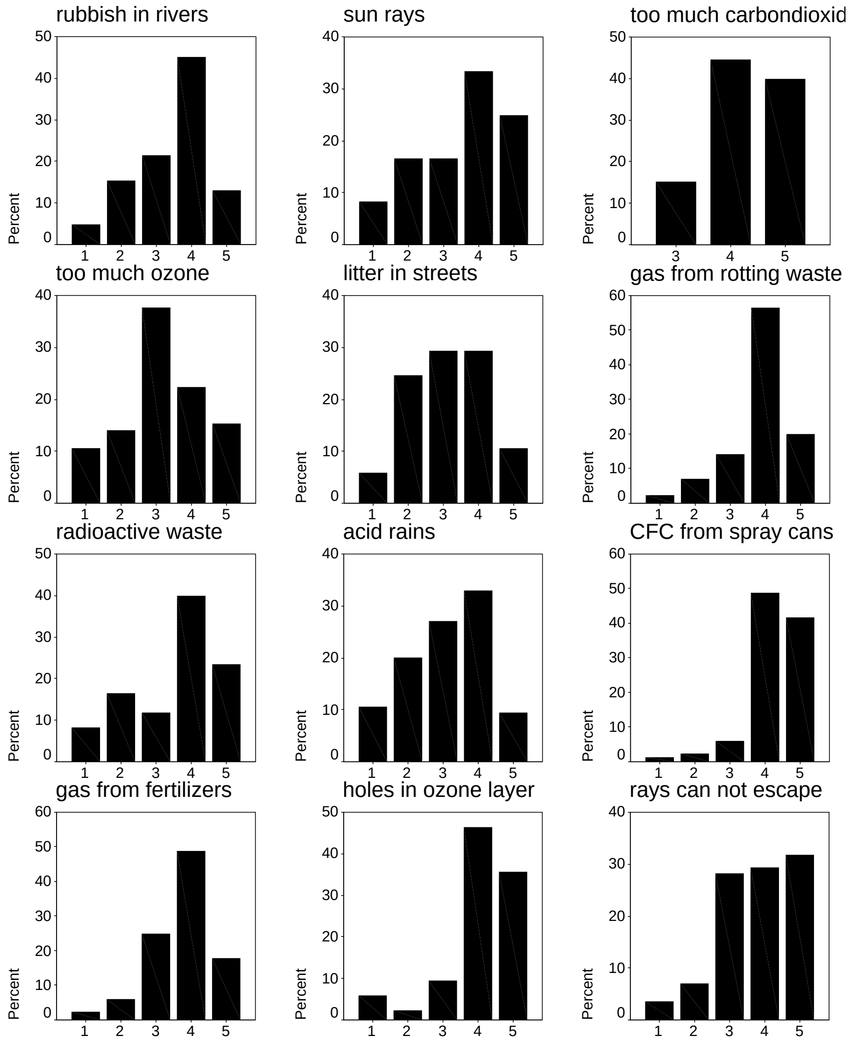

Figure 2. Ideas about causes of Global Warming

Cures for Global Warming. In the third section of the questionnaire; students' ideas about the ways of reducing global warming were identified and they are summarized in Figure 3. Almost the entire group realized correctly that planting more trees (93%), recycling paper (95%), reduction in car use (93%), producing electricity from wind, waves and tides (95%), and saving electricity (87%) would reduce global warming. However, the advantages of having more nuclear power stations instead of coal power stations were appreciated by only half of the respondents (51%).

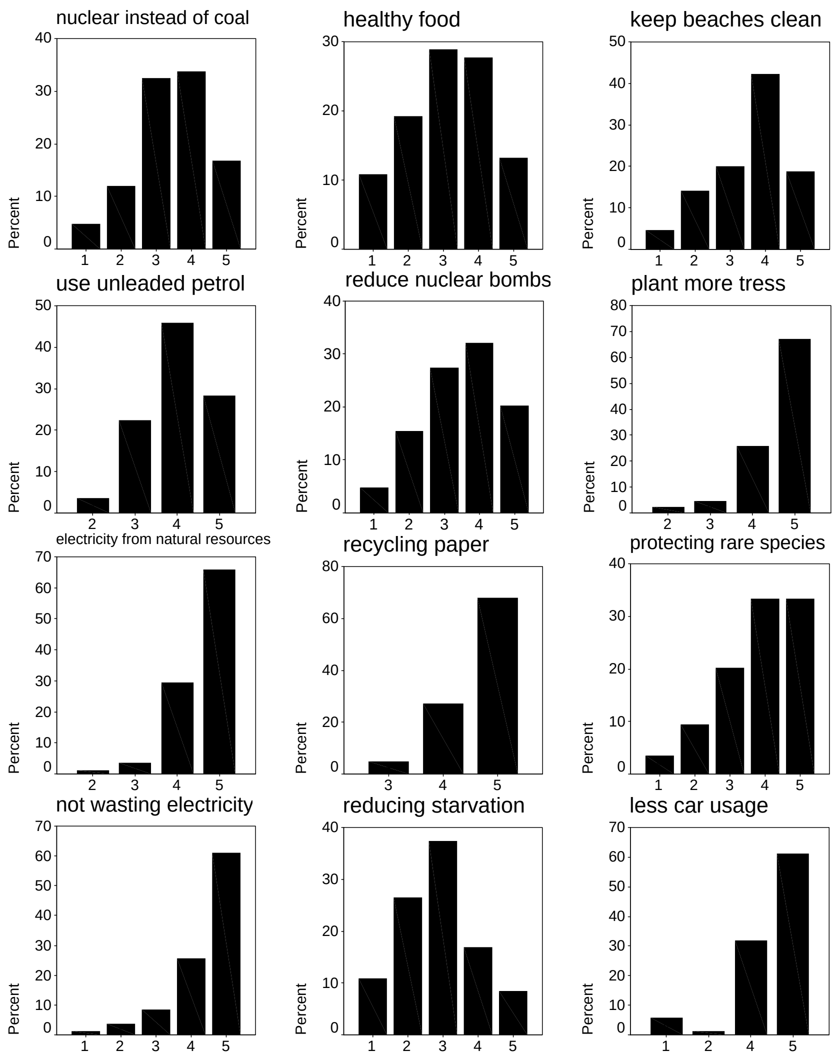

Figure 3. Ideas about cures of Global Warming

When the point comes to erroneous statements about global warming; it is seen that only a quarter of the students (25%) made an incorrect connection between global warming and reducing starvation in certain parts of the world.

41% of the students thought that greenhouse effect can by made smaller by eating healthy foods. About half of the students (52%) thought that reducing nuclear bombs in the world could help to reduce global warming. Two thirds of the students (66%) thought that protecting rare species might help to reduce global warming. More than half of the group (61%) apparently made some sort of erroneous link between marine pollution and global warming, thinking that cleaning up beaches would reduce global warming. The most prevalent misconception, however, was that most of the respondents (74%) imagined that using unleaded petrol would reduce global warming.

Discussion

When answers of pre-service teachers were analyzed; it was seen that there are some prevalent misconceptions regarding Global warming. The most prevalent misconception held by 86% of the students was that more people will get skin cancer with increasing global warming. These explanations provide evidence of pre-service teachers incorrect ideas regarding the two phenomena, ozone depletion and greenhouse effects. Students think that ozone depletion is either caused by the increase in the greenhouse effect or the greenhouse effect is the product of ozone depletion. The fact is that the two phenomena are independent of each other. Skin cancer is caused by the ozone depletion and not by the increased greenhouse effect. Similar findings reported by other researchers support the findings of this study. Boyes and Stanisstreet (1993) reported that their secondary school subjects had the misconception that an increased greenhouse effect will increase the incidence of skin cancer. The same misconceptions were reported by Boyes *et al.*(1993) with high school students and by Boyes and Stanisstreet (1992) and Khalid (2001) with the college students.

Almost same proportion of students (82%) thought that the greenhouse effect is made worse by holes in the ozone layer. This result was also evident in previous studies that the majority of students thought that “holes” in the ozone layer contributes to global warming by allowing great penetration of sun rays resulting in raising the earth’s temperature (i.e. Boyes and Stanisstreet, 1993; Francis *et al*., 1993; Groves and Pugh, 1999; Koulaidis and Christidou, 1999; Pruneau *et al*., 2001; Rye *et al*., 1997). This misconception is strongly held and persists even after instruction (Groves and Pugh, 2002).

It was also seen that more than two thirds of pre-service teachers thought incorrectly that rubbish dumped in rivers and streams have an effect on global warming. They also think that some of our tap water will become unsafe to drink and more fish will be poisoned in rivers with increasing global warming. According to their beliefs; that cleaning up beaches and using unleaded petrol would reduce global warming. A great proportion of pre-service teachers also have the misconception that radioactive waste from nuclear power stations is a cause of global warming. We can say that pre-service teachers make an erroneous link between pollution and global warming. In general, they connect global warming to all environmental harms and match their cures with the cures of global warming. The connection of pollution to global warming also seem to be a commonly held misconception by people.

For instance Groves and Pugh (1999) found that participants in their research consider radioactive waste and acid rain to be the causal factors of global warming. Bord *et al.* (2000) and Bulkeley (2000), also found that public understands global warming from the perspective of pollution.

There are also some points that pre-service teachers lack comprehension of scientific concepts related with global warming. Almost half of the students lack knowledge of there will be more 'bugs' and 'pests' on crops with the increased greenhouse effect and ozone near the ground in the atmosphere could act as a greenhouse gas. It can be inferred from these results that teachers are being environmentally educated in lay and not in scientific terms.

When pre-service teachers are asked to report how much knowledge about global warming they felt they had gained from television, the Internet, school, newspapers and the radio; results show that the most frequent source of information about global warming was television; on average, 32% of the students reported that they obtained information about global warming from this source. Internet was the next most popular source, with 25% of students reporting that they obtained of their information from Internet. School (19%) and newspapers (17%) played relatively less role in providing information about this issue, and radio apparently played only a minor role (3%). This can be another evident that teachers are being environmentally educated in lay and not in scientific terms.

In conclusion, it seems that pre-service teachers confuse greenhouse effect with ozone layer depletion and with pollution. The presence of misconceptions regarding these environmental issues raises several concerns because these pre-service teachers will be teaching in their classrooms very soon. The question is whether these pre-service teachers are fully prepared to discuss these abstract concepts in their classrooms. In order to improve pre-service teachers understanding of global warming, the pre-service teachers need to be engaged in class discussions on these abstract environmental issues in their science teaching methods courses. Exchange of ideas during discussions helps students to not only evaluate but also correct their pre-existing conceptions (Wals & Alblas, 1997). In science teaching methods classes, students can also be assigned to prepare lesson plans on misconceptions about various environmental issues to teach. Students are encouraged to do the extensive research on the assigned topic before they are ready to teach the topic (Dove, 1996) or present the lesson to their peers. The exercises of doing extensive research on one topic will help pre-service teachers eliminate their misconceptions about a particular issue (Khalid, 2003). Presentation of various topics in class will also serve the same purpose of enhancing students' understanding of these abstract concepts. By adopting these teaching practices, we will be able to provide more in-depth knowledge to our pre-service teachers and eliminate their misconceptions. In other words, they will be better prepared to teach environmental issues in their classrooms.

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Cognitive architecture of misconceptions

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Abstract

The triangular model of concept modeling the cognitive architecture of the concept structure and four developmental levels of physical concepts are presented: primitive, empirical, symbolical, and formal. The basic components of the model are: core, meaning, sense, and the relationships between them. Based on the model, a method of concept mapping is presented. Concept maps as models of the cognitive architecture of an Aristotelian preconception at the empirical level and a Newtonian conception at the symbolical level of the concept of "force" are designed.

Introduction

Many studies were conducted to explore the physics misconceptions of pupils and students over the last three decades (Fenclová-Brockmeyer, 1980, Nachtigall, 1981, Hejnová, 1984, Renström at al, 1990, Hestenes at al, 1992, 1995, Sharma at al, 2007, Tarábek, 1985, 1989, 2007). The authors' studies were focusing on the understanding of mental representations of misconceptions and formal knowledge in the minds of students and have resulted in the creation of a model of concept, which has described a structure of common and scientific concepts. The model, called the triangular model of concept structure (Tarábek, 2005, 2007), is built upon Vygotsky's concept theory (Vygotsky, 1986), the conception of the "semantic frame" (Fillmore, 1976, 1982, Hestenes, 2006), the semantic/semiotic triangle, and on widespread ideas of the structuring of conceptual systems (Guilford, 1967, 1988, Linhart, 1976, Hestenes, 1987, 2006, 2007, Lakoff, 1980, 1987, Bergeron, 1999, Merrill, 2002, Novak, 1998, 2004, Sternberg, 1999). The model captures the structure of *concept* and its semantic frame, where the term *concept* is taken in the sense as it is used in cognitive psychology (Sternberg, 1999). In this paper, the term "concept" is used in a wider sense: *concept* and its semantic frame. Besides the description of concept formation (Tuomi, 1998) through the Vygotian phases (Tarábek, 2007), the model distinguishes four phases in the development of common/scientific concepts: primitive, empirical, symbolical, and formal. The model also distinguishes the concept's meaning and sense as two disjunctive sets following Frege's idea of reference/meaning and sense (Frege, 1892). The idea of different kinds of meaning is also used in Double R Grammar concerning language comprehension (Ball, 2004), where the relational and referential meanings are distinguished – the relational meaning corresponds to the sense and the referential meaning to the meaning in the triangular model of concept. The triangular model describes the cognitive architecture of the concept as part of the conceptual knowledge system, which may be external (mental) or internal.

The triangular model was used to solve problems concerning the mental structure of misconceptions and scientifically correct knowledge. Differentiation between the empirical and symbolical (scientific) levels of concept development has shown that many misconceptions in mechanics are developmental states of human cognition at the empirical level (Tarábek, 2007, 2008), i.e. preconceptions or "CS misconceptions" (CS – common sense), which "were clearly articulated by great intellectuals – Aristotle, Buridan, Galileo, and even Newton himself before writing Principia" (Hestenes, 2006). These preconceptions have a large resistance to instruction (Hestenes, 2006) and also a significant influence in the formation of new knowledge (Atkinson et al, 2000). If students learn Newton's laws of motion, the CS-concepts remain "wrapped up in Newtonian words" (Hestenes, 2006) in their memory. For instance, the empirical level of the concept "force" (so-called Aristotelian) in the thinking of students tends to increase with age together with the Newtonian level (Tarábek, 2007). To overcome misconceptions and solve problems in the understanding of Newtonian conception, we have also to know exactly how the cognitive architecture as a specific structure of the related concepts looks at both levels. Concept maps created from the triangular model show the cognitive architecture of the concept "force" at the empirical (Aristotelian) and symbolical (Newtonian) level.

Conceptual Knowledge Systems (CKS)

According to the Modeling Theory (Hestenes, 2006, 2007), a system is a set of related objects. The structure of a system is defined as the set of relations among objects in the system. Common and scientific concepts and knowledge comprise a system with a structure. We can distinguish two types of conceptual knowledge systems: the internal (mental) and the external (Tarábek, 2007).

The internal (mental) conceptual knowledge system (ICKS) is a result of the individual cognitive process of a human. It is a system of concepts and knowledge which humans acquire and form through the process of education, learning, observation, and empirical experience, as well as in the process of scientific cognition through goal-oriented experimentation and through their own thinking. The internal conceptual knowledge system comprises the elements and relations between them. The basic elements of the ICKS are concepts at various levels of abstraction and formation. The concepts are also systems and involve words, mathematical, physical, chemical, and other symbols, features of denotata (objects, events, phenomena in reality to which the given concept refers), and images at various levels of abstraction. The ICKS also contains experiences and perceptions stored in the memory. Relations between the elements of the ICKS are of various types – connections between components of concepts and among the concepts, declarative knowledge as specific (cognitive) connections between the concepts, intrinsic rules of several types of human reasoning: abductive, deductive, inductive, analogical, metaphorical, analytical, and synthetic (Hestenes, 2006) and specific procedural knowledge. The term ICKS partially corresponds to the term "mental model" of Hestenes (2006, 2007).

The external conceptual knowledge system (ECKS) is a result of the social cognitive process, i.e. the cognitive processes of human society as a system of cognitive agents, while it is necessary to distinguish which system is being discussed. The scientific conceptual knowledge system (SCKS) is the result of the cognitive process of a scientific community in a given science. It consists of the scientific concepts, terms, empirical facts, laws, principles, theories, their applications and interpretations, and cognitive, modeling, application, and interpretation methods and procedures that the given science makes use of. The term ECKS partially corresponds to the term of the "conceptual model" in the Modeling Theory of Hestenes (2006, 2007).

Triangular model of concept

The triangular model describes a cognitive architecture as a specific structure of the *concept* and its semantic frame. The basic components of the model are: **core** C, **meaning** M and **sense** S, their mutual connections and also the **hierarchical layers** M1, M2, and M3 of the meaning (see Figure 1). The usual meaning of the term *concept* in cognitive linguistics corresponds roughly to the core C (see the paragraph below for a description of the C). In this paper, the term "concept" is used in a wider sense: *concept* and its semantic frame. Thus the semantic frame consisting of the meaning and the sense is a part of the complete concept, which comprises the structure depicted in a simplified way in Figure 1. In this paper, the term "concept" and associated terms mean the components in both of the forms of CKS – external and internal. In specific cases, where a distinction is needed, the word "internal" (mental) or "external" is added. If the term *concept* is used, it means the core of a concept. After a comparison of the term "*concept*" as defined by Hestenes (2006) with the term "concept" we have come to the careful conclusion that "*concept*" represents a substructure of the cognitive architecture of the "concept" composed of the core, the attributes and the attributive links.

Core C of a concept is composed of three mutually linked elements: a **word**, a **symbol** (in scientific concepts – mainly quantities), and a **representative semantic image –** RSI. The mental RSI is the dominant image that emerges in the mind after saying a given word and may appear in the mind as a dominant image during a thought operation with the word or symbol. The RSI contains a list of features (the RSI as prototype) or attributes (the RSI as core of category) that the denotatum in the extension of the related concept tends to possess. It is applied by judging the similarity between the RSI and the mental representation produced by the concrete denotatum (object, phenomenon or event) as it is experienced. Thus the RSI corresponds either to the prototype (Rosch, 1978) or to the category core (Armstrong at al, 1983) where its structure is the concept sub-structure given by attributes and attributive links (see below).

Meaning M of concept is composed of the set of all cores of subordinate concepts and sets of images referring to the given concept core and of the set of meaning links. In the meaning of the concept, we can differentiate the following hierarchical **meaning layers**: M1, M2, and M3. **The meaning layer M1** is a **referential set** – a set of **referentes**, e.g. subordinate referential *concepts*, which refer to the given concept core. The referents are coordinate *concepts* and divide the whole class of denotata into disjoint subclasses. For instance, the class of referential *concepts* of the concept "force" is composed of the *concepts* "gravitational force", "electromagnetic force", "nuclear force", and "weak interaction". However, it is necessary to emphasize that other classes of referential *concepts* may exist in the scientific system of physics. Forces are divided, for instance, into real and fictitious in classical mechanics. **The meaning layer M2** is a **set of designata** – a set of concrete subordinate *concepts* and mental semantic images which may be subordinate to the referential *concepts* of M1 or to core C. Layer M2 may consist of more sub-layers – the *concepts* of the lower sub-layer are subordinated to the *concepts* of the higher one. **The meaning layer M3** is a set of concrete mental semantic images of denotata which refer to the core C or to the referential *concepts* or to the elements of M2. **Extension** E of the given concept is the class of **denotata** – objects, phenomena, events, and entities to which the word or symbol of the given concept points. The extension is not a part of the concept structure. **Meaning links** are, firstly, the links between the concept core and subordinate *concepts* or mental images, and, secondly, all other links between the elements of the meaning layers.

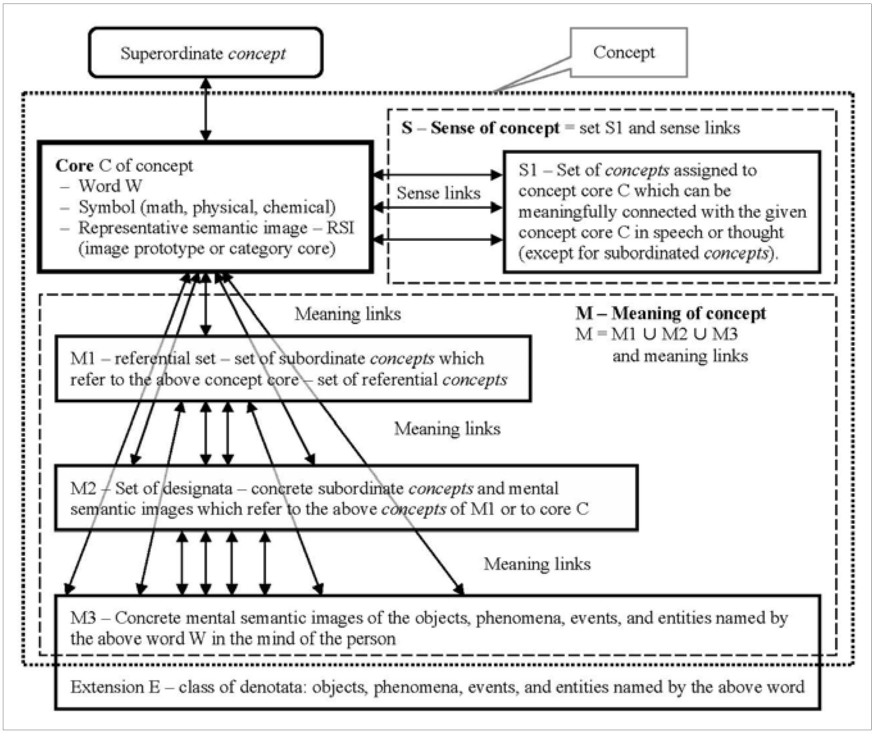

Figure 1: Triangular model of concept structure – cognitive architecture of the concept

The rectangular boxes represent the components of the concept structure (core C, S1, M1, M2, M3), the dashed boxes represent subsystems (meaning M and sense S – semantic frame), the dotted box represents a complete concept, and the arrows represent links between the components of the concept structure.

The sense of concept consists of the set S1 of assigned *concepts* which can be meaningfully connected with the given concept core C in speech or thought (except for subordinated *concepts*) and **sense links** from the core to the assigned *concepts* (see figure 1). We can divide **sense links** into qualitative, attributive, cognitive, operational, and contextual types.

Qualitative sense links are the links to *concepts* which express **potential qualities**. **Potential qualities** are properties characterizing denotata of subordinate *concepts* – referential *concepts* or designata. The connection of potential qualities to a given *concept* results in its division into subordinate *concepts*. For example, potential qualities connected to the *concept* "force" are "gravitational", "electromagnetic", "nuclear" and the quality expressed by the term "weak interactions." Thus the general *concept* of force is differentiated into referential *concepts*: "gravitational force", "electromagnetic force", "nuclear force", and "weak interaction".

Attributive sense links are the links to *concepts* which express **attributes** of a given concept. **Attributes** of a given concept are the relevant properties characterizing the denotata class (objects, phenomena, events, and entities denoted by the name of the concept). According to these properties, we are able to categorize an observed object, phenomenon, or entity into a denotata class (an extension of the given concept). For instance, the concept "body" has its mass as an attribute. The concept "force" has as an attribute the fact that the term "force" expresses the mutual interaction of physical bodies or bodies and fields. The **attributes** are used in definitions together with superordinate *concepts*. For instance, in the definition "Body is a mass object", "object" is a superordinate *concept* while "mass" is an attribute. In the definitions "Solid body is a mass object with constant volume and shape" or "Liquid is a mass object with constant volume and variable shape", "mass object" is a superordinate *concept* and "constant volume" and "constant/ variable shape" are attributes. In the definition: "In mechanics, a force is an interaction that causes acceleration of a body" (Glenn, 2008), "interaction" is an attribute whereas "cause" is a superordinate *concept*.

Cognitive sense links are links between the core of the given concept and *concepts* that are related to physical and natural law (rule, principle) together with this *concept*. For instance, if we consider Newton's second law in the form: $\boldsymbol{F} = m \cdot \boldsymbol{a}$, students have a mental cognitive link "$\boldsymbol{F} \Rightarrow \boldsymbol{a}$" from the *concept* "force" to the *concept* "acceleration" if they understand that force causes the acceleration of a body's motion or the curving of its trajectory. Another cognitive link is "$a \propto F$ ", i.e. acceleration is directly proportional to net force (when mass is constant), or "$\boldsymbol{a} \uparrow\uparrow \boldsymbol{F}$ ", i.e. acceleration has the same direction as the force.

The set of *concepts* linked by the cognitive links and a symbolic form of these links (expressed by a mathematical formula) comprises the structure of **declarative knowledge** in the mind of an intelligent agent. The meaning of knowledge consists of subordinated *concepts* of all main *concepts* related to the knowledge (described by symbols in a mathematical formula), their mental semantic images, semantic images of cognitive links, and corresponding facts. **Formal knowledge** means knowledge of the formula without the appropriate cognitive links and without the meaning of the knowledge (or these components are not completely built in the mind).

Developmental levels of concept formation

The analysis of the historical development of external physical conceptual knowledge systems led to the distinguishing of five **levels of conceptual knowledge systems** in physics (Tarábek 1989, 2005) and four **developmental levels of physical concepts**: primitive, empirical, symbolical, and formal, which are depicted in Figure 2 (Tarábek, 2007, 2008). Two developmental levels were indicated during the study of students' concepts (Tarábek, 2007). The empirical level of the concept "force" called the **Aristotelian level** or the **Aristotelian preconception**, was identified in the students' formulation of "force is needed to keep a body in motion", and similar expressions (see Figure 3). The symbolical level called the **Newtonian level** was identified in the students' formulation of "force causes a change of motion – acceleration or deceleration of a body or curving of its trajectory" and similar expressions (see Figure 4).

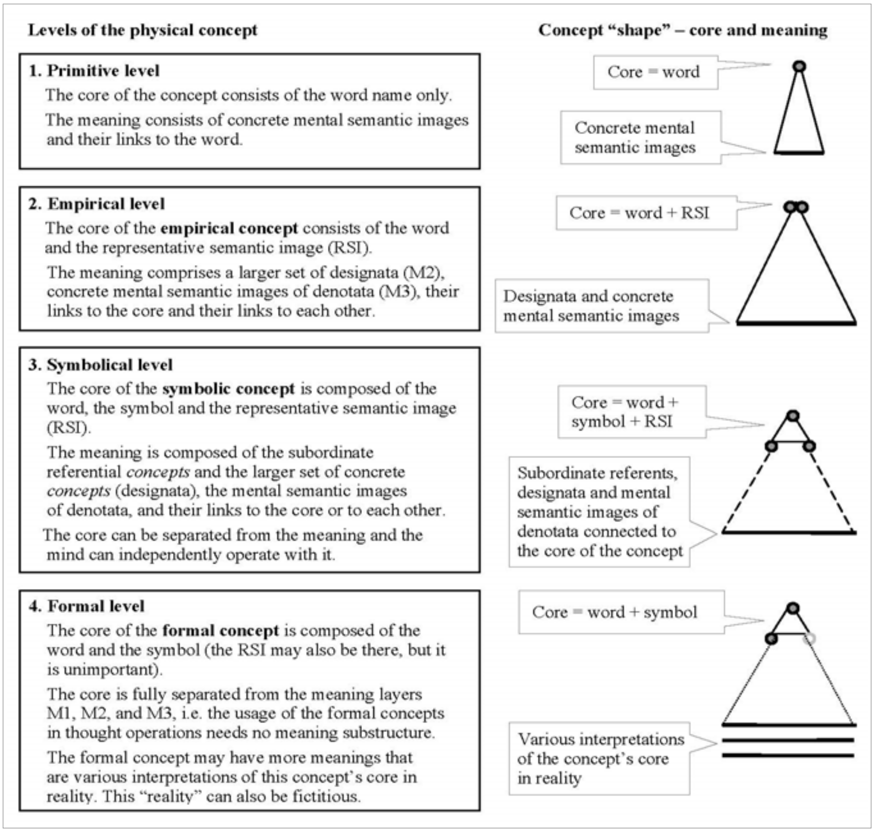

Figure 2: Levels of physical concepts in the process of their formation.
The oblique lines represent links between the core and elements of the meaning. The dashed lines represent a possible core's separation from the meaning of the symbol concept. The dotted lines represent the full core's separation from the meaning of the formal concept. The formal concept is fully determined by the sense links – see also the description of the formal concept in Hestenes (2007).

Concept mapping

Concept mapping searches for components of a structure of concept and arranges them into a system following the structure of triangular model. Thus the created concept map depicts the cognitive architecture as a specific structure of the given concept.

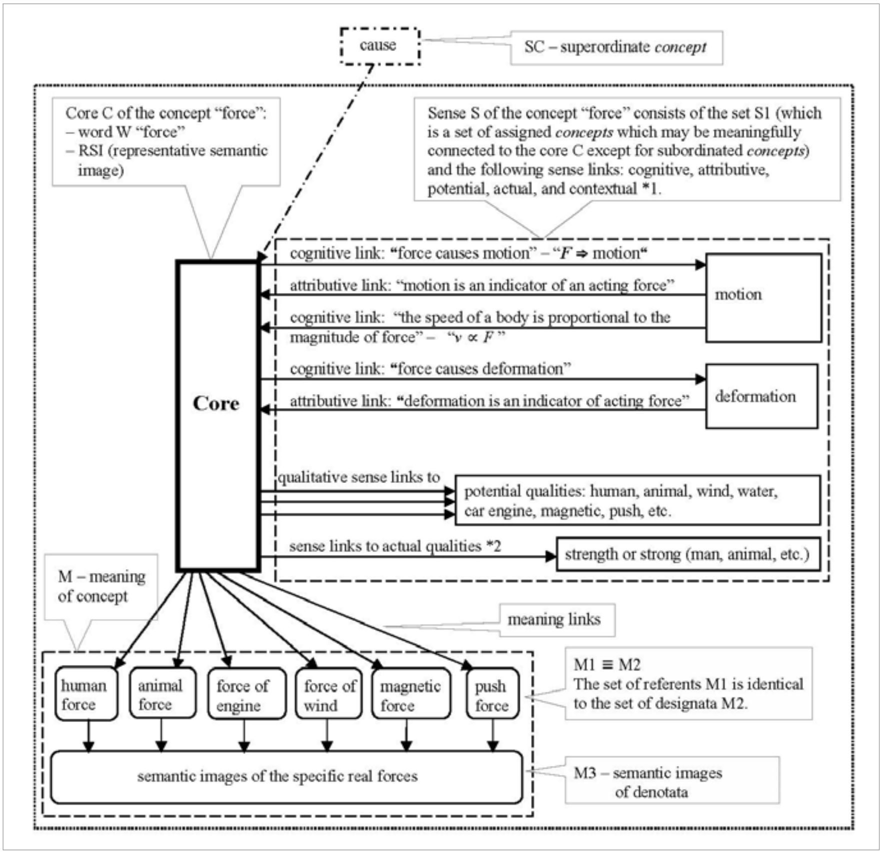

Figure 3: Concept map showing the cognitive architecture of the concept “force” of 6 – 8th grade students at the Aristotelian level. Concepts at this level correspond to the CS (common sense) concepts of Hestenes (2006).

The group of respondents answered questions regarding components and links of the structure of the concept “force” (Tarábek, 2007). The concept map was designed with the answers of students from 6th to 8th grade as they reached the Aristotelian level of “force”. Cognitive links were detected from answers such as: “A force is something that keeps a body in motion” or “A speed of body is higher when a force is stronger”. To the cognitive link “$v \propto F$ ”, some students attached the link expressed as “the speed of a body is indirectly proportional to the friction or resistance of an environment”, e.g. “if the friction is bigger, the speed is lower”. The “cause” as a superordinate *concept* of “force” was shown in statements such as, “A force is a certain pressure on an object, which causes its motion”.

Secondly, the structure of concepts depends on the level of their development. We especially have to take into consideration significant differences between the symbolical and empirical level of the concepts and corresponding conceptual knowledge systems. Many concepts at the empirical level change their structure during the transformation to the symbolical level (especially the quantities).

Thirdly, the structure of the concept maps has two dimensions: vertical, which represents a concept's meaning – it is the direction from the concept core C to reality and horizontal, which represents a concept's sense – it is the direction from the concept core C to other *concepts* except for subordinate ones.

To construct concept maps of external scientific concepts, we may use scientific texts, papers, textbooks, written explanations, diagrams, etc.

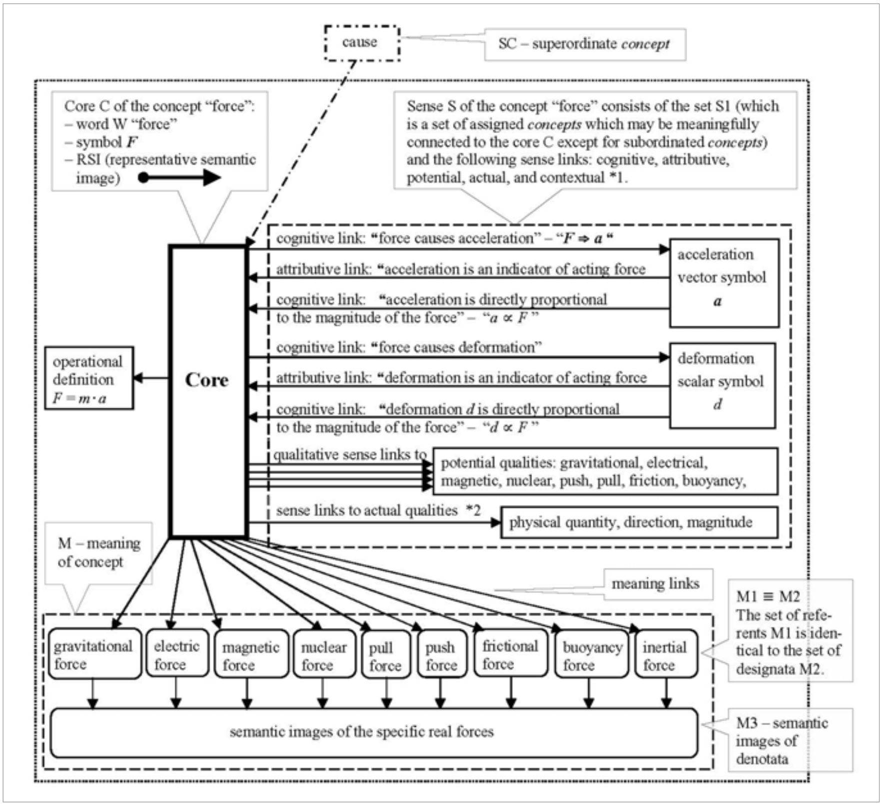

Figure 4: The concept map shows the cognitive architecture of the conception of force by 12 grade students at the Newtonian level.

The group of respondents answered questions regarding components and links of the structure of the concept "force" (Tarábek, 2007). The concept map was designed with the answers of the best students whose cognitive links reached the symbolical level of concept "force" because their meaning structure does not correspond to this level.

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*1 In both cases (figure 3 and 4), the contextual sense links are not designated.

*2 The actual qualities are actual properties characterizing the denotatum of the concept and belong to the attributes.

The concept maps of internal (mental) concepts may be constructed from the answers of students. The researcher or teacher poses questions and tasks to students to investigate concrete components: RSI, symbol, subordinate *concepts* and mental semantic images of the meaning, *concepts* and sense links of the sense, etc. At the end he/she arranges the discovered components into a system according to the structure of the triangular model. Many FCI questions and tasks (Hestenes et al, 1992) may be used for this purpose. Examples of questions are presented also in Tarábek (ICSENS, 2008). The concept maps constructed in this way are depicted in Figures 3 and 4.

Discussion and conclusions

The triangular model of concept as a theoretical construct based on knowledge of cognitive psychology and the cognitive sciences is the model of the cognitive architecture of a concept. Cognitive architecture is a specific structure consisting of the concept core (*concept* in the context of the cognitive linguistic), the semantic frame as the meaning and the sense of the concept, and the relations among all components of the conceptual structure. This theoretical conception was partially revised during the last year due to critical comments at the conferences PERC 2008, GIREP 2008, ICSENS 2008, DIDFYZ 2008, Innovations in School 2008 and thanks to the Modeling Theory of Hestenes (2006, 2007). Secondly, this theoretical conception is needed in educational research because of substantial differences between the empirical (pre-scientific) and symbolical (scientific) levels of the concepts. The need of such a conception is shown, for instance, in the Force-as-Action Metaphor and Ohm’s p-prim (Hestenes, 2006) which represents a considerable part of the cognitive architecture of the Aristotelian preconception.

The triangular model may be used for the mapping of the cognitive architecture of external and mental concepts. The concept map of the concept “force” at the empirical (pre-scientific) level designed in this paper represents a model of the cognitive architecture of the Aristotelian preconception. The notion that such knowledge means a first level of human cognition flowing from a common experience confirms the results of the research in the cognitive linguistic as are analyzed e.g. in Hestenes (2006) or in the conception of the Force Dynamics (Talmy, 2000). These preconceptions are resistant to traditional instruction and can be overcome only if students really understand why such beliefs are mistaken. This understanding may be supported by the creation of concept maps which show the apparent difference between both the cognitive architectures of the Aristotelian preconception and the Newtonian conception.

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Consistency of students' conceptions about superposition and reflection of waves: findings from the development of a conceptual survey in mechanical waves

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Abstract

A multiple choice conceptual survey in mechanical waves was developed and evaluated with over 900 students (Tongchai et al., 2008). The survey consists of four subtopics: propagation, superposition, reflection and standing waves. In this study, we explored students' responses to the questions on the subtopics of superposition and reflection only. The objectives of this study were (1) to explore the consistency of students' conceptions, and (2) to explore the usefulness of the correlation coefficient for dichotomous data (Φ). The samples were five different groups of students with a total number of 509. Our findings support studies found in the literature in which students often use their conceptions inconsistently. Moreover, we found that the correlation coefficient for dichotomous data is useful for measuring the strength of the association between question pairs, however it has some issues which researchers need to be aware of when using it for a particular purpose.

Introduction

During the last three decades studies in science education have revealed that many students have difficulty with conceptual understanding which is important for understanding advanced topics. Moreover, many research studies have reported that students' responses to a series of questions testing the same idea are not consistent (e.g. Clough & Driver, 1986; Finegold & Gorsky, 1991; Palmer, 1992; Warnakulasooriya & Bao, 2003; Saglam & Millar, 2006). Thus suggesting that students' understanding of a particular concept is not consistent − it may depend on the context of the questions.

In our study, we have investigated the consistency of students' responses when trying to solve question pairs testing the same idea by using a statistical analysis technique, the correlation coefficient for dichotomous data (Φ).

Purpose of the study

- To investigate consistency of students' conceptions when trying to solve question pairs testing the same idea on the subtopics of superposition and reflection.
- To explore the usefulness of a statistical analysis technique, the correlation coefficient for dichotomous data (Φ).

Method

Instrument. The instrument was the Mechanical Waves Conceptual Survey (MWCS) (Tongchai, et al., 2008) which we developed recently. The survey has been trialled with over 900 students from high school to second year university. Development procedures and evaluation of the survey can be found in Tongchai et al. (2008). The survey consists of four subtopics: propagation, superposition, reflection and standing waves. Each subtopic has several questions. The full survey can be viewed at http://www.physics.usyd.edu.au/super/mwcs/mwcs.pdf. In this study, we explored students' responses to the subtopics of superposition (questions 9, 10, 11 and 12) and reflection (questions 13, 14, 15 and 16).

Participants. The participants were five different groups of students from the state of New South Wales, Australia as listed below.

1. Sydney-High school students (SydHigh): These were senior high school physics students in Sydney.
2. First year university regular physics students (1stReg): These students had studied senior high school physics, and in terms of overall high school academic achievement were ranked in the top 5% to 16% in the state of New South Wales.
3. Second year university regular physics students (2ndReg): These students had completed first year physics courses at the University of Sydney and majority of them had completed regular physics courses in 2007.
4. First year university advanced physics students (1stAdv): These students had studied senior high school physics, and in terms of overall high school academic achievement were ranked in the top 4% in the state of New South Wales.
5. Second year university advanced physics students (2ndAdv): These students had completed first year advanced physics courses at the University of Sydney in 2007.

Students groups were sorted according to the quantity of formal instruction in physics they have had. However, even with the same quantity of formal instruction, the advanced groups have had a better quality of learning experience – advanced students have considerably more mathematics background, inherent interest in the sciences and many will have participated in Physics Olympiads and similar extra-curricular experiences. Hence we have chosen to use the phrase 'previous engagement with physics learning' to refer to the mix of quantity and quality of experiences with physics. Therefore, the groups of students are ranked as above.

Data analysis. The correlation coefficient for dichotomous data (Φ) was used to investigate the consistency of students' responses to question pairs. The correlation coefficient Φ has been widely used in the social science (e.g., Heller & Huffman, 1995; McCartney & Rosenthal, 2000; Saglam & Millar, 2006; Howell, 2006). A brief description of Φ is provided below (for more detail, see Howell, 2006).

Consider a study where students' responses to two multiple–choice questions testing the same idea are recorded. Table 1 shows the resulting contingency table.

Table 1. Contingency table of students' responses to Q1 and Q2

		Q1		
		Correct	Wrong	Total
Q2	Correct	cc	wc	*cc+wc*
	Wrong	cw	ww	*cw+ww*
	Total	*cc+cw*	*wc+ww*	n

Note: cc = correct both Q1 and Q2, ww = wrong both Q1and Q2, cw = Q1 correct and Q2 wrong, wc = Q1 wrong and Q2 correct, n = sample size

According to the data shown in Table 1, the correlation coefficient of dichotomous data (Φ) is calculated using equation 1 (Guildford, 1965).

$$\Phi = \frac{(cc \times ww) - (wc \times cw)}{\sqrt{(cc+cw)\cdot(wc+ww)\cdot(cw+ww)\cdot(cc+wc)}} \qquad \text{Equation (1)}$$

The quantity Φ indicates the strength of the association between the two questions. In general, Φ ranges from -1 to +1. A positive or negative Φ denotes whether the product of the number of students who have either both correct or wrong is larger or smaller than that for having one correct and one wrong. This is counterintuitive as one is tempted to simply consider sums. A value of Φ close to zero indicates that responses to the two questions are less correlated. A value of Φ close to +1 indicates that responses to the two questions are highly correlated.

For two questions testing the same idea, we would expect a student's responses to both questions to be consistent; i.e., if a student understands the concept, he or she would answer both questions correctly, and if a student does not understand the concept, he or she would answer both questions incorrectly. If a student has an inconsistent concept, he or she may answer the two questions using different ideas, thus resulting as correct on the first question and wrong on the other. If a student has inconsistent responses, it suggests that the student does not view both situations as similar, or suggests that the student's responses might depend on the context of the questions. According to Table 1, "cc" and "ww" are considered as consistent responses, while "cw" and "wc" are considered as inconsistent responses.

Results and discussion

Results of Superposition. Table 2 shows patterns of students' responses to the question pairs on the concept of superposition. Questions 9 and 11 are testing students' understanding of wave superposition while two pulses are overlapping. The percentage of correct responses to both questions (cc) increases as the previous engagement with physics learning increases, while the percentage of wrong responses to both questions (ww) decreases. This might suggest that students with high previous engagement with physics learning have more consistent correct concept than students with less previous engagement with physics learning. When looking at the trend of the quantity Φ, the trend is not readily identifiable; i.e., the trend seems to increase as the previous engagement increases, except for second year regular students whose responses spread out over the available cells, resulting in a small Φ value. The Φ values of all groups for this question pair suggest that students sometimes answer one question differently to the other, indicating that these two situations are, sometimes, differently understood by the students.

For questions 10 and 12, which are about the situation where two pulses have passed through one another, the trend of patterns of students' responses is similar to the previous pairs, questions 9 and 11, however these questions are seemingly easier for many students. Furthermore, the Φ values are increasing as the previous engagement with physics learning increases. Most of the Φ values are significantly high, indicating that the two questions are highly correlated. Students' responses to these questions are likely to be consistent as shown by high values in column "cc" and "ww" in Table 2.

Table 2. Patterns of students' responses to question pairs on the subtopic of superposition

Q9-11: while two pulses are overlapping						
Sample	**n**	**cc (%)**	**cw (%)**	**wc (%)**	**ww (%)**	**Φ**
SydHigh	54	19	15	26	41	0.16
1stReg	287	25	14	19	41	0.32**
2ndReg	48	27	21	21	31	0.17
1stAdv	69	49	16	14	20	0.34**
2ndAdv	51	57	16	12	16	0.34*
Q10-12: while two pulses have passed through one another						
SydHigh	54	50	9	6	35	0.70**
1stReg	287	48	22	4	26	0.52**
2ndReg	48	79	8	2	10	0.63**
1stAdv	69	77	9	0	14	0.75**
2ndAdv	51	94	6	0	0	#DIV/0!

Note: c = correct, w = wrong. $*p < 0.05$, $**p < 0.01$, and shading highlights the trend of percentage responses

Results of Reflection. Table 3 shows the results of the reflection subtopic. For this particular subtopic, it is apparently clear that the trends of correct and wrong responses to both questions depend on students' previous engagement with physics learning. However, the quantity Φ of both question pairs changes unevenly, in fact it seems to change irrespective of students' previous engagement.

When looking at the patterns of students' responses to both question pairs, we can see that students' responses spread out over available patterns, suggesting that students mostly view the two questions different from one another. This might also suggest that students' understanding of these two questions depends on the context of the questions.

Table 3. Results of students' responses to questions pairs on the reflection subtopic

Q13-14: Reflection after the pulse has finished bouncing the pole						
Sample	**n**	**cc (%)**	**cw (%)**	**wc (%)**	**ww (%)**	**Φ**
SydHigh	54	2	28	9	61	-0.10
1stReg	287	9	23	6	62	0.26**
2ndReg	48	19	21	10	50	0.32*
1stAdv	69	22	19	4	55	0.52**
2ndAdv	51	55	18	10	18	0.37**
Q15-16: Reflection while the pulse is bouncing the pulse						
SydHigh	54	4	17	22	57	-0.09
1stReg	287	9	11	19	61	0.18**
2ndReg	48	21	19	17	44	0.25
1stAdv	69	17	29	12	42	0.17
2ndAdv	51	31	24	4	41	0.50**

Note: c = correct, w = wrong. *$p < 0.05$, **$p < 0.01$, and shading highlights the trend of percentage responses

The trend of Φ values is not clear, it seems to change unevenly. Furthermore, it does not provide insight into how consistent students' responses are. To see whether students' responses are consistent, we still need to look at the patterns of students' responses in the table. In fact, this issue has been controversial, see for example, Heller and Huffman (1995), Halloun and Hestenes (n.d.). Moreover, Guilford (1965) has reported that the size of the Φ value also has limitations; i.e., Φ can vary over a range within the limits -1 to +1, but only under certain condition can Φ be as large as either of these extremes. Therefore, researchers need to be aware of such matters when using this kind of statistical method for a particular purpose.

Conclusion

We have investigated students' consistency of their answers when trying to solve question pairs testing the same idea on the subtopics of superposition and reflection. We used the correlation coefficient for dichotomous data (Φ) to measure the consistency of students' responses. Our findings show that students often use their conceptions inconsistently. This might suggest that students' answers depend on the context of the questions, however we still need to explore this in the future. This finding supports many research studies found in literature, e.g. Clough and Driver (1986), Saglam and Millar (2006), Palmer (1992).

Further, we found that the Φ values change unevenly; i.e., they change irrespective of students' previous engagement with physics learning. It is clear that the quantity Φ tells us about the association of students' responses, but it does not tell us about the consistency of students' responses. Perhaps, exploring consistency of students' responses to a multiple-choice survey could be done by some other methods, for instant, Model Analysis (Bao, 1999).

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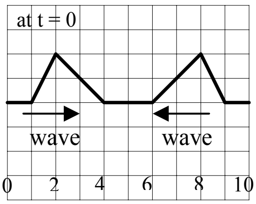
Appendix: Examples of the questions used in this study

Superposition:

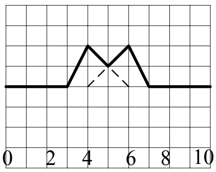
Consider the following description and answer questions 9-10.

Two pulses are moving towards each other. Each pulse has a speed of 1 cm/s. The figure on the right shows the pulses at time t = 0 s. Each square width corresponds to 1 cm x 1cm. The dashed lines indicate the correct positions of the individual pulses after 2 s.

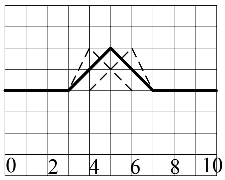


9) Select the drawing that corresponds to the shape of the resultant pulse after **2 s**.

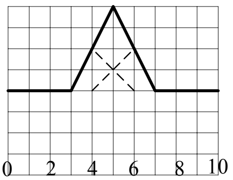
A.



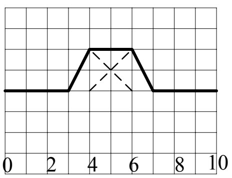
B.



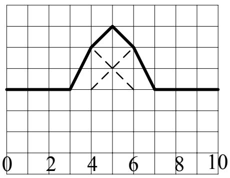
C.



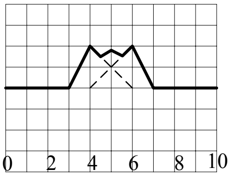
D.



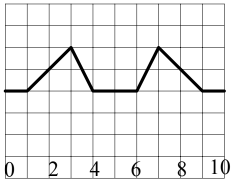
E.



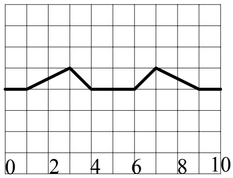
F.



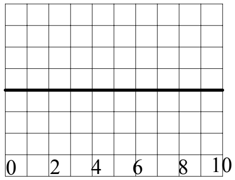
10) Select the drawing and explanation that corresponds to the shape of the resultant pulse after **5** s.



A. Waves have passed through one another and retained their shapes.



B. Waves have become smaller because they have collided and so lost energy.

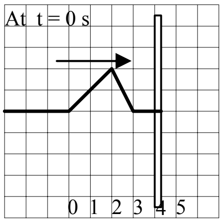


C. Waves have cancelled each other.

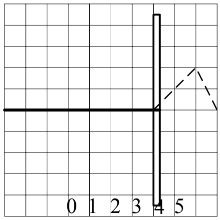
Reflection:

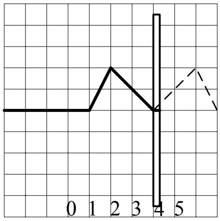
Consider the following description and answer questions 13-14.

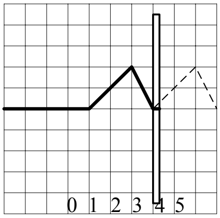
A girl is demonstrating wave motion on a string attached to a pole. The string can be either ***firmly*** attached so that the end cannot move or tied to a ring that can move ***loosely*** up and down on the pole. The girl flicks the string creating an ***asymmetric*** pulse moving towards the pole. The pulse has a speed of 1 cm/s. Each square in the figure corresponds to 1 cm x 1 cm. The

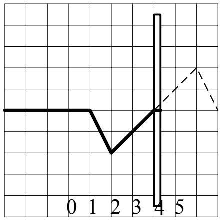


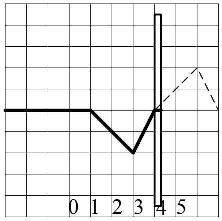
For questions 13 and 14, choose the drawing from **A** through **E** which best answers each question.

A


B


C


D


E


___ **13)** Select the drawing that corresponds to the shape of the resultant pulse after **4 s**, assuming the string is ***firmly*** attached to the pole.

___ **14)** Select the drawing that corresponds to the shape of the resultant pulse after **4 s**, assuming the string is tied to a ring that can move ***loosely*** up and down on the pole.