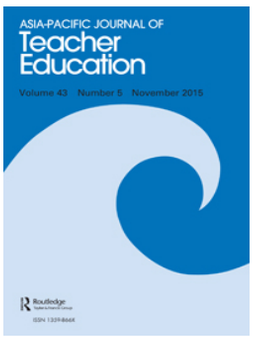

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Pre-service teachers' perceptions on TPACK development after designing educational games

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This qualitative case study aimed to investigate Early Childhood Education (ECE) pre-service teachers' perception of development in their technological, pedagogical, content knowledge (TPACK) after designing educational computer games for young children. Participants included 21 ECE pre-service teachers enrolled in the course Instructional Technology and Material Design. The data were collected through focus group interviews, observations, and journals. The results indicated a perceived improvement in TPACK. Moreover, participants described initial difficulty designing educational computer games since they had limited technological knowledge (TK), design knowledge (DK), or experience designing educational computer games (TPACK). However, during the game design, specific TPACK was disseminated, and participants reported increased abilities in using technology and designing computer games for educational purposes.

Keywords: case study; early childhood pre-service teachers; educational game design; TPACK

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Introduction

Modern educational policies expect that Early Childhood Education (ECE) pre-service teachers bring technology integration skills to today's technology-dominated classrooms. Haktanır (2008) has expressed that national policies should be changed and ECE programme educators should bear responsibility for pre-service teachers' competencies using information and communication technologies when teaching. Such skills are the main concern of TPACK – technological, pedagogical, content knowledge – which Mishra and Kohler (2006) have described as an emergent form of the three knowledge types, technological, pedagogical, and content knowledge, focused around teachers' technology integration skills.

Özgün-Koca, Meagher, and Edwards (2010) believe that teacher awareness of the intersection of technology, pedagogy, and content should be developed for effective teaching. One way to develop pre-service teachers' understanding of these concepts and the contexts in which they are used is by providing active involvement in creating hardware and software, also known as learning by design (Koehler & Mishra, 2005). In this study, learning by design means ECE pre-service teachers active involvement in designing educational computer games. Since playing computer games is very popular among young children (Cherney & London, 2006; Clements, 2004; Dwyer, 2007; Li & Atkins, 2004) and most researchers advocate their educational uses (Paraskeva, Mysirlaki, & Papagianni, 2010; Sancar Tokmak & Incikabi, 2013), this research study aimed to

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investigate ECE pre-service teachers' perceptions of TPACK development in the course Instructional Technology and Material Design, which required them to design educational computer games for ECE.

Theoretical background of the study: TPACK

Pierson (2000) and Mishra and Koehler (2006) have described teachers' technology integration knowledge and skills within the TPACK framework. TPACK is an extension of Shulman's Pedagogical Content Knowledge (PCK) framework (Angeli & Valanides, 2008; Mishra & Koehler, 2006). PCK is based on an understanding of both pedagogy and content (Shulman, 1986). However, as Leng (2008) states societies are surrounded by Information and Communications Technology (ICT) and schools are seen as a way to keep pace with ICT developments in the societies. For that reason, editing technological knowledge (TK) to the PCK is a necessity. Moreover, the history of educational technology is full of many failed examples of enhancing students' learning with technology (Mishra, Koehler, & Kereluik, 2009; Reiser, 1987) and the reason may be lack of a technology integration theory (Mishra & Koehler, 2006). Mishra and Koehler (2006) state that for that reason, they proposed TPACK.

Koehler, Mishra, and Yahya (2007) identified a transactional relationship between content, pedagogy, and technology knowledge in the core of TPACK. Graham (2011) further observed three main components – content knowledge (CK), pedagogical knowledge (PK), and TK – in addition to four combined aspects: technological- pedagogical knowledge (TPK), technological-content knowledge (TCK), pedagogical-content knowledge (PCK), and TPACK.

CK is defined as knowledge of the learned or taught subject matter, PK as knowledge about teaching practices and techniques, and TK as knowledge about both standard and digital technologies (Shin et al., 2009). Mishra and Koehler (2006) defined TCK as knowledge that is both technology and content related, TPK as knowledge about pedagogical strategies for using existing technological tools for teaching, and PCK as knowledge about teaching strategies for specific content. Moreover, Mishra and Koehler (2006) initially assigned the acronym TPCK to technological pedagogical content knowledge, explaining: "TPCK represents a class of knowledge that is central to teachers' work with technology" (p. 1029).

Later, Thompson and Mishra (2007–2008) began using TPACK instead of TPCK, noting how TPACK demonstrates how the three knowledge domains (TK, PK, and CK) are not isolated but integrated. According to them, TPACK means "TotalPACKage: the knowledge that lies at the intersection of knowledge of Content, Pedagogy and Technology i.e., TPACK" (Thompson & Mishra, 2007–2008, p. 38).

Computer game design and TPACK development

Computer game design is not new to education. Papert's constructionist philosophy is the core of designing computational learning environments (Bers, Ponte, Juelich, Viera, & Schenker, 2002; Kafai, 2006; Siko & Barbour, 2012). Piaget's student Papert emphasised the importance of more concrete thinking by building a meaningful artefact (Siko & Barbour, 2012). Bers et al. (2002) have further explained that while building or designing an artefact, people also construct knowledge, and, for that reason, it can be said that constructionism has its roots in Piaget's constructivism. According to Siko and Barbour

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(2012), computer games serve constructionist philosophy well since, in terms of TK, students need very little additional instruction while designing them.

When using computer games for educational purposes, Kafai (2006) used two terms to define how to integrate them, instructionist and constructionist. The instructionist approach requires teachers to select a commercial game and use it during instruction, while constructionist approaches require students to construct their own games (Kafai, 2006). Similarly, Van Eck (2006) proposed three approaches to computer game integration: (a) instructors have students' build games, (b) instructors build and use their own games for instruction, and (c) instructors select and integrate commercial games. However, another method has been discussed in the literature that combines the first and second approaches when the target audience is teachers or pre-service teachers and the objective is to improve TPACK. Koehler et al. (2011) categorised this approach, learning technology by design (LT/D), as deep play and described it as an instructional technique for understanding TPACK.

In a research study in line with the learning by design approach, Bers et al. (2002) made pre-service early childhood teachers develop robotics and integrate them into instruction in a real classroom environment. Findings showed that participants mastered the robotic content and technology, as well as supported young children learning. Barbour, Rieber, Thomas, and Rauscher (2009) conducted a research study in which children designed educational computer games using PowerPoint templates. Similarly, Sweedyk, Delaet, Slattery, and Kuffner (2005) integrated computers games into instruction by making computer science students' build games in groups. According to the results, the students learned the programming language, solved game design issues, and worked collaboratively. Another TPACK study was conducted by Sancar Tokmak and Özgelen (2013). The study had two phases: pre-service teachers first selected and integrated an educational game into instruction to teach a subject matter from the national early childhood curriculum in Turkey; then they redesigned the games using PowerPoint (Sancar Tokmak & Özgelen, 2013). The results showed that most of the participants shifted integration decisions from behaviourist to constructivist mindsets. Similarly, Siko and Barbour (2012) have supported the idea of having teachers/pre-service teachers design educational computer games with PowerPoint to improve their TPACK and believed that researchers should continue to investigate TPACK development through the learning by design approach.

In this study, the researcher investigated ECE pre-service teachers' perceptions about TPACK development during instruction based on learning by design. In a college course, the ECE pre-service teachers designed PowerPoint computer games on subject matters from the national early childhood curriculum in Turkey. The following research question was asked in this study: How do ECE pre-service teachers perceive their TPACK development during and after an educational computer game design activity?

Methodology

This single case study design sought the answer to a "how" question. According to Yin (2003), "The case study is the method of choice when the phenomenon under study is not distinguishable from its context" (p. 4). In this research method, the context is significant, and richness of data collection methods is needed (Patton, 1990; Yin, 2003). For this study, ECE pre-service teachers' perceptions of their TPACK development were investigated in a single case through multiple data sources as demographic questionnaires, focus group interviews, and journals. Moreover, during the study, the data were collected from a

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single case to deeply understand how the participants perceive their TPACK development during educational computer game design activities.

Sampling

The participants were selected by applying convenience sampling strategies, and were considered to be both "captive" and "volunteers," according to Teddlie and Yu's (2007) description of the two forms of convenience sampling. All participants attended the Play in Early Childhood course; requirements for the course included investigating educational computer games for young children, selecting one, and conducting micro-teaching with it. Participants were familiar with the national early childhood curriculum in Turkey, educational computer games, and integrating technology into instruction. Participants were in their second year with the Early Childhood Department at a university. Two participants were male; the others (n = 19) were female, which is common distribution for ECE departments. The pre-service teachers' ages ranged from 19 to 22, with an average of 20. The mean of their GPA was 3.09. The ECE pre-service teachers' computer use ranged from 1 to 7 hours with an average of 4 hours a week. Moreover, their computer game playing time was about 2 hours a week. The pre-service teachers were also asked what types of computer games they played. They mentioned strategy and puzzle games, such as *Age of Empires* or *Tetris*, plus sports games, such as football, basketball, and car racing games.

Instruments

The data sources of the study were interviews, game designs, journals, and observations. Three instruments were applied during the study: (a) a demographic questionnaire, (b) a focus group interview form, and (c) journals. All instruments were prepared by the researcher and checked by an expert whose background included 9 years in the Instructional Technology field. The expert's research interests are design and integration of educational games, learning by design, human–computer interaction, and internet security for children.

Demographic questionnaire

There were nine questions in the demographic questionnaire developed by the researcher. It was checked by an external expert before being administered at the beginning of the course. The questions asked about age, gender, department, class level, GPA, hourly home computer usage in a week, hourly computer game play in a week, types of computer games they played, and activities requiring computer use.

Focus group interview form

The semi-structured focus group interview was conducted with eight pre-service teachers about their perceptions of TPACK after the activity. Three questions were asked: (a) What did you learn during the game design activity? (b) What were your motivating factors in the design of the game? (c) What difficulties did you face during the game design activity?

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Journals

During the game design activity, the pre-service teachers were asked to write about the process in response to five questions related to (a) the thing they took account during educational computer game design, (b) the adjective they could use to describe their educational computer games, (c and d) the strengths and weaknesses of the educational computer game, and (e) the difficulties they encountered during the educational computer game design, and how they tackled them?

Procedure

The study lasted one semester, 14 weeks. The procedure included three steps: (a) pre-service teachers chose a topic from the ECE curriculum, (b) participants were instructed about the theory behind instructional material/technology design, and (c) participants created educational computer games for young children to teach the topic they selected. See Table 1 for a timeline of activities and implementation of instruments.

During the game design, the instructor took the role of advisor, while the ECE pre-service teachers considered the topic and its goals (CK) in the curriculum. They also assessed the interests, development level, and preparation of their target audience, young children (PK). They also used PowerPoint or Word to design the interface of their educational computer games, searched the Internet for images to use, and drew or reshaped images in Paint (TK). All known issues were taken into account concurrently during design (TPACK). The activity and its relation to the TPACK framework can be seen in Figure 1.

Data analysis

The demographic questionnaire was analysed by applying descriptive statistics. The data collected through journals were analysed by applying conventional content analysis; codes and themes emerged based on the text (Hsieh & Shannon, 2005). As Ayres, Kavanaugh, and Knafl (2003) have suggested, categories of significant statements were organised through themes. The focus interviews were transcribed, analysed, and coded into common themes through an open coding method. Similarly, open coding analysis was applied to observation notes. The educational computer games designed by the ECE pre-service teachers were analysed using pre-defined categories, and frequencies were measured.

Table 1. Main parts of the procedure and the instruments conducted.

The parts of the procedure	Data collection
	Demographic questionnaire
Choosing topic from National Early Childhood Education curriculum	Journal, Observations
Attending instruction about the theoretical part of the instructional material/technology design	Journal, Observations
Designing educational computer games for young children	Journal, Observations Focus group interviews Computer games designed

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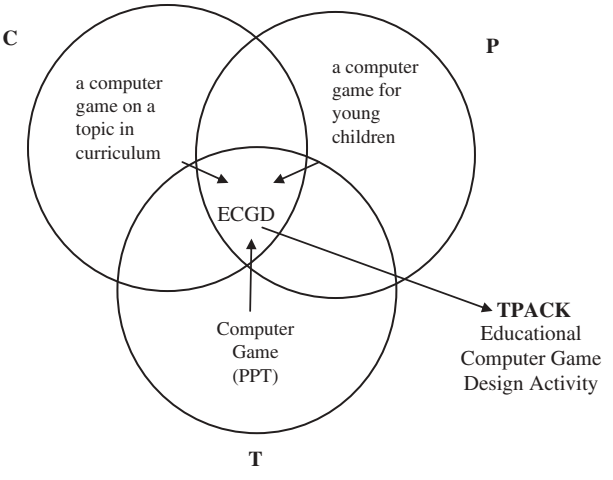

Figure 1. The game design activity and relation with TPACK.

Validity issues

In the study, four validity-reliability strategies were used: first, data were triangulated across observations and journals, and focus group interviews were conducted. Next, through peer debriefing, the process of the study was discussed with a colleague who had been studying educational computer game development and integration for 10 years. Third, external audits were conducted by experts on the process of the study and its data collection instruments. Finally, a thick description of the context was developed and is provided.

Ethical issues

It was taken great care to obtain all data in this article in accordance with guidelines of ethical conduct. Since the researcher was also the lecturer of the course, participants were assigned pseudonyms during the study to maintain confidentiality, as they were also students enrolled in the course for credit. All the students were interviewed after they had received their course grades. Moreover, all pre-service teachers participated in the study voluntarily.

Results

The ECE pre-service teachers' perceptions on their TPACK development were investigated through focus group interviews, journals, observations, and the educational computer games they designed. Codes that emerged from the journal question about the planning stage were: (a) design principles, with sub-categories of colour use in design, screen design, rhythm of elements, size of interface elements, and appropriateness to curriculum goals; (b) appropriateness for children with sub-categories of attractiveness for young children, colour selection, and drawing; (c) providing motivation with sub-categories of scoring, levels, and characters; and (d) usability with sub-categories of easily understood and easily used. The focus group interview results supported the journals. The themes that emerged about participants' focal points can be seen in Table 2.

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Table 2. The focus group interviews on "what they paid attention."

Themes
➢ Design principles
• Colour use
• Sizes of elements
• Places of elements
➢ Appropriateness to young children development
• Complexity of game
• Attractiveness of design for young children
• Paying attention to details
➢ Appropriateness to curriculum goals
➢ Designing attractive games
• Game characteristics
• Levels
• Time limitation
• Scoring
• Character use

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The results showed that the ECE pre-service teachers took into account design principles, curriculum objectives, children's development levels, and motivation. Moreover, journal data showed that they also thought about the usability of the games while designing. The ECE pre-service teachers stated that they tried to apply design principles by paying attention to interface design related to colour use and object placement, size, and distribution. Under the scope of colour use, participants mentioned tonal harmony, contrast between backgrounds and figures, and even hot/cold shades. As far as objects in the game are concerned, participants stated that they were placed on the interface in a balanced way and their sizes were selected according to real life relationships. For example, pre-service teacher S3, whose game appears in Figure 2, said:

> In my game, there are houses and characters. The houses are big, and the characters were small in size. I tried to distribute all components as houses, trees, characters, buttons, etc. on the screen. I tried to use live colours that the young children like such as red, green, blue, pink.

The main character of the game designed by S3 is Pepee™, who is trying to rescue his sister, mother, and friend by completing in-game tasks. On Screen I, Pepee™ faces three gates: selecting the red gate saves his mother; blue saves his sister; and yellow saves his friend. Behind the red gate are five coloured pencils. The user selects a pencil and guesses which colours compose its shade (Screen II). Behind the blue gate, Pepee™ must collect balls of intermediate colours such as green, purple, and orange, depositing them in front of the prison where his sister is held. If he collects enough balls, the prison gate opens (Screen III). The yellow gate leads to a forest where Pepee™ must collect the primary coloured balls of red, yellow, and blue. However, the balls are hidden under rocks, in the grass, and on the trees. Pepee™ must find and collect 20 balls in five minutes. If he fails, the game restarts and his requirement drops to 15 balls in five minutes (Screen IV).

According to the ECE pre-service teachers, designing games according to objectives and goals of the national ECE curriculum was important since they were created for the purpose to make children gain curriculum objectives. For that reason, they stated that while designing, they thought about whether the games would help them reach goals/

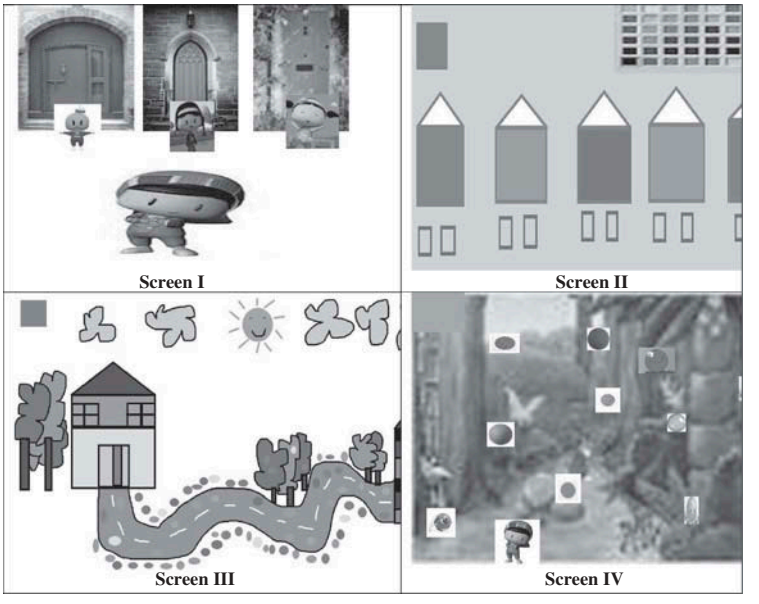

Figure 2. The screenshots of the educational game designed by S3.

objectives of the curriculum. They also said that they paid attention whether the games are suitable for young children development. During focus group interviews, ECE pre-service teacher S16 stated:

> Whether it can provide young children a learning experience parallel to the curriculum goals is the thing I paid attention to. I asked my neighbour's son's (he is six years old) opinions about my game. He loves puzzle games. My game is also a puzzle type. I wondered whether the game was complex for him or whether it was attractive for him.

The goal for content in the educational computer games was appropriately simple and appealing. For that reason, participants tried to motivate and attract young children by using characters such as Pepee™, Dora™, Caillou™, and the Smurfs™ as Smurfette™ and Hefty Smurf™; by using vibrant colours; by including scorekeeping and competition; and by using game levels to record progress. Another issue pointed out by the ECE pre-service teachers was that the educational games should be easy to use by young children. Therefore, they planned to provide directions using sound. Figure 3 shows the educational computer game designed by ECE pre-service teacher S12.

S12's computer game consisted of four levels about part–whole relation. In each level, the user selects a photo from a menu to the right of the screen. The selected object appears in the centre but is missing parts. The user clicks on photos at the bottom to complete it. In each level, the number of missing parts increases. On Screen I, the introduction to game was presented. On Screen II, the butterfly is only missing one part. After completing it, Garfield™ congratulates the user (Screen III). In the second level, the user selected a flower; both the stem and leaves are missing (Screen IV). Each completed level awards the user enough points to progress in difficulty.

The themes that emerged from analysis of the journals about difficulties faced during design were technology use, creating a design, reflecting the ideas in one's mind in the

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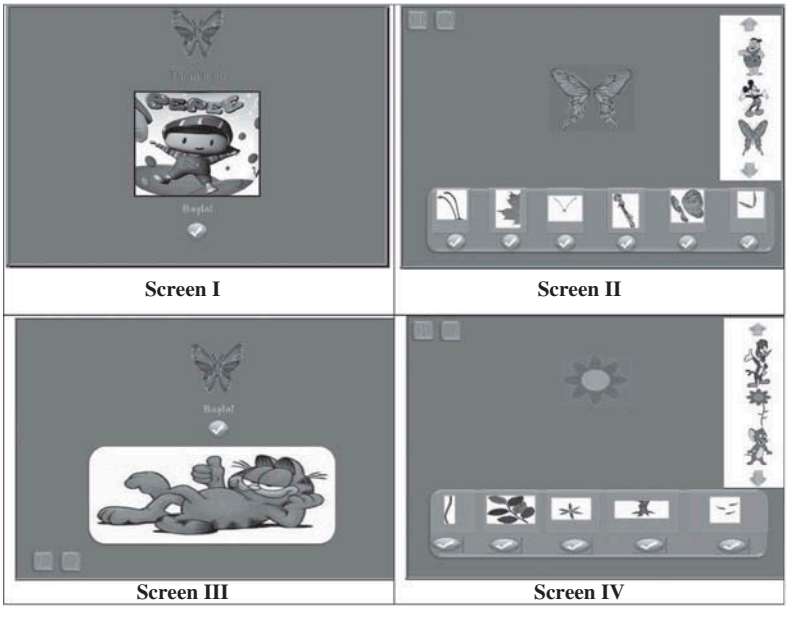

Figure 3. The screenshots of the educational game designed by S12.

design, and deciding design issues. The themes that emerged according to interview analysis can be seen in Table 3.

According to the results, the ECE pre-service teachers again called attention to difficulties with technology use. S18 stated, "I struggled too much because I had to draw or recompose the pictures... but I learned how to use Photoshop." They also had difficulty using PowerPoint, Paint, and the Internet. Most participants used images found on the Internet, but they also drew or manipulated some objects, changing colours, sizes, or shapes using Paint. They then merged all the visual components in PowerPoint. Moreover, ECE pre-service teachers struggled with creating a design, because young children's developmental levels require creativity. S16 explained, "I realised that it was very difficult to design a game on a specific subject matter."

Table 3. The focus group interview results on "the difficulties the ECE pre-service teachers met."

Themes
➢ Technology use
• PPT
• Paint
• Photoshop
➢ Designing a computer game
• Interface design
• Creating a scenario
➢ Designing a game on a subject matters
• Curriculum goals
• Subject matters limiting the used elements in the game

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The ECE pre-service teachers also struggled to reflect the design in mind into their design since they had limited TK (drawing/shaping objects, finding pictures, etc.). According to the results, they had difficulty in creatively defining objects, colours, scenarios, buttons, and characters. They pointed out attempting different combinations of these issues again and again to decide the best fit. In the focus group interview, S7 indicated:

> This game design activity requires creativity. I always think, "What colour should I use for that part? What should I place in that part? How could I do this computer game attractive for young children?" All these questions are in my mind during the design.

Figure 4 represents S10's computer game, which teaches four geometrical shapes: circle, triangle, rectangle, and square. In the game, Smurfette™ is put in prison by Gargamel™ (Screen I). Dreamy Smurf™ must earn points to save her. In Screen II, the user is expected to match the shape in the upper left corner to score and climb the stairs. Incorrect answers move Dreamy Smurf™ backwards. With enough points, Dreamy Smurf™ saves Smurfette™ (Screen III).

Observation notes supported focus group and journal findings: ECE pre-service teachers had difficulty with and sought instructor and peer assistance in choosing and identifying objects, colours, scenarios, children levels, and subject matter objectives. Further, without sufficient TK, instead of drawing objects, they preferred to find and combine images from the Internet. During this process, they acquired help from instructors, friends, and the Internet.

S1 added in her journal:

> It was very difficult to design a creative game. I tackled the problem during game design with the help of the friends and, also, I was inspired by computer games on the Internet.

The journals showed that participants used strategies to overcome obstacles like getting help from instructors, getting help from friends, researching commercial games, reading books, conducting image searches on the Internet, attempting trial and error, and learning to use Paint and PowerPoint. Similarly, focus group interview themes were help of friends, help of instructors, internet searches, learning to use technology, and gaining the competency to design an educational game, which included subcategories of learning design principles, student level, content, and searching for information.

The ECE pre-service teachers indicated that while designing the educational computer games, the instructor gave regular feedback and constantly encouraged them to reflect on their designs. They discussed their designs with friends, who also provided technology assistance. To realise which colours, objects, and characters would make their designs better, they investigated commercial computer games and applied the trial/error method. Moreover, they read material design books and books for young children to help select design components. The pre-service teachers also pointed out that they tackled problems related to technology use (Paint, PowerPoint, Internet) by learning to use the technologies needed. S2 stated during the focus group interview, "I really became an expert on using PowerPoint and Paint." The ECE pre-service teachers were also requested to describe their computer games using five adjectives (see Table 4).

The journal analysis showed that the ECE pre-service teachers most frequently used the adjectives instructional, entertaining, colourful, attractive, specific to content, creative, original, easy to use, and specific for young children. In her journal, S4 described her

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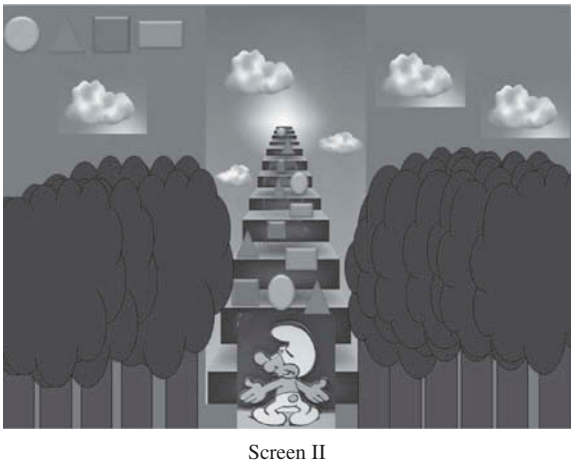
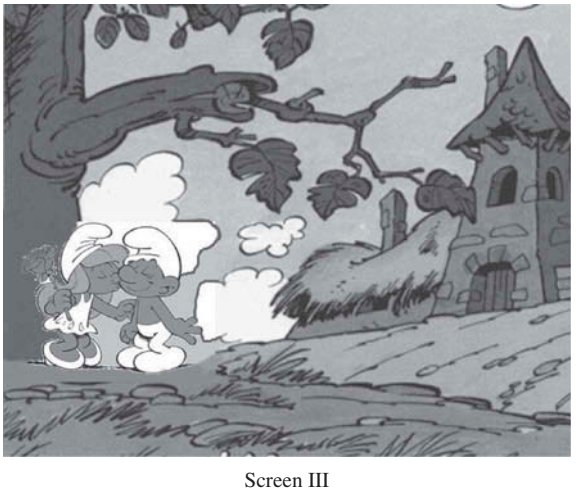
Screen I



Screen II



Screen III

Figure 4. The screenshots of the educational game designed by S10.

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Table 4. The journal results on the adjectives the ECE pre-service teachers used to describe their games.

Adjectives	
Entertaining	Original
Instructional	Specific for content
Colourful	Lovely
Creative	Attractive
Easy to use	Motivated
Task based	Supporting creativity
Beautiful	Specific for young children
Thought-provoking	Exciting to play

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game as "Entertaining, instructional, attractive, colourful, and original." According to analysis, participants emphasised technological components and design properties. Moreover, they emphasised PCK (specific to young children), TCK (specific to content, appropriate to aim, and supporting creativity), and TPACK (instructional).

According to the focus group interviews, creativity emerged as a different theme with subcategories as listed in Table 5.

According to the results, creativity requires combining too many elements. These things were related to TPACK in that the ECE pre-service teachers thought about how to design their instructional games by taking into account student level, subject matters, game characteristics, and design issues. All the described points relate to TPACK. S7 stated:

> I designed my educational computer game by thinking, for example, what the game gives as an award when the young children do the right action in the game. I decided the children can get stars, and the number of stars would increase while they are doing the right action. ... Really, this project was very beneficial to increasing creativity.

The ECE pre-service teachers were also asked in their journals to discuss the strength of the computer games they designed. Most participants described their games as attractive

Table 5. Codes emerged under "creativity" themes during focus group interviews.

- ➢ Creativity
  - Thinking too many things together
- ➢ instructional game
  - student level
    - designing attractive games
  - subject matters
  - planning how to integrate into instruction
- ➢ game characteristics
  - awarding in the game
  - character use
  - levels, scoring, time limitation
- ➢ design issues
  - colour use
  - place of elements in the game
  - function of elements in the game

Table 6. The strengths of the educational computer games pointed by ECE pre-service teachers.

Strength
➢ Attractive
• Colourful
• Having a scenario
• Having level
• Having characters
➢ Motivated
• Characters
• Levels
• Time limitation
➢ Appropriate the target audience
• Interface design
• Content presentation
• Having audio directions
➢ Appropriate to the content
• Cover all sides of the content
➢ Enhancing children thinking
➢ Usable for different instructional purposes
• Assessment tools
• Practice tool
• Making children aware of the content
➢ Appropriate for both boys and girls
➢ Easy to use
• Free to choose among options
➢ Easy to understand content
• Real life objects
➢ Appropriate the design principles
➢ entertaining

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and motivating. According to them, character use, levels, time limitations, visual design, colourfulness, and scenarios contributed to appeal and may help motivate young children to play their games. Some ECE pre-service teachers indicated the strength of their game stemmed from its ease of use. Some of the games were designed for both girls and boys, eliminating gender bias. The categories that emerged according to the results of data analysis appear in Table 6.

ECE pre-service teachers found their games entertaining and instructional. They felt teachers could teach with their educational computer games while amusing students. Participants also found their games appropriate to the curriculum and target audience. Their games had pictures and content presentations that young children easily understand. Moreover, their games could be used for different instructional purposes, such as assessment or practice tools, making children aware of the subjects. In the journals, participants were also asked about the weaknesses of their games, yet very few responded (see Table 7).

A few ECE pre-service teachers found their games weak in terms of game characteristics, interface design, giving direction with text in the game, and monotony. Only four participants indicated that their games lacked characteristics such as scoring and characters. According to one ECE pre-service teacher, single player games did not maintain children's motivation to play as much as multiplayer games. Another pre-service teacher complained that her game only included text directions, rather than audio, which were featured in her friends' projects. The identified reasons for these weaknesses were limited

Table 7. Weaknesses of the educational computer games according to ECE pre-service teachers.

Weakness
➢ Game characteristics • Single player (S2) • Lack of time limitation (S20) • Lack of scoring (S4) • Limited Variety of character use (S13)
➢ Interface design • Not good interface design (S19) • Lack of some navigation buttons in the design (S3) • Disconnection between interfaces of levels (S15) • Different background colour use for each level (S11)
➢ Directions with text (S11)
➢ Monotony (S14, S16)

knowledge about technology used and inexperience designing educational computer games. S19 explained the shortcomings of her work (see Figure 5):

> My educational computer game is very amateurish. I think it is very weak in terms of interface design. If I had known how to use a computer well, I could have drawn a much better design. Although it had weaknesses, it was instructional.

Another theme and relevant sub categories emerged as a result of the focus group interview with regard to what the ECE pre-service teachers learned after taking the role of an educational computer game designer (see Table 8).

Participants stated that they learned how to plan and design a game by taking into account subject matters, curriculum goals, student levels, and design principles. Moreover, they stated that they focused on teaching the content to young children with the game. They frequently emphasised newly acquired skills in Paint, PowerPoint, and Photoshop, as well as the Internet. During focus group interviews, S7 stated:

> I really learned how to design an educational game. Today, if someone says me to design an educational game, I can do it. I learned what I should think while designing an educational game. Also, I learned design principles and how to search for information.

Moreover, participants pointed out that during the process, they learned how to criticise and contribute to their friends' projects. As they learned about design principles, computer games, the curriculum, subject matter presentations with games, and identifying student levels, they could make constructive comments about the missing parts of their friends' projects. They stated that they could now criticise also their own efforts. Increased knowledge provided the ability to see from a new perspective.

Discussion and conclusion

This research aimed to investigate ECE pre-service teachers' perceptions on their TPACK development during an educational game design activity using PowerPoint. A total of 21 ECE pre-service teachers participated in the study and designed educational computer

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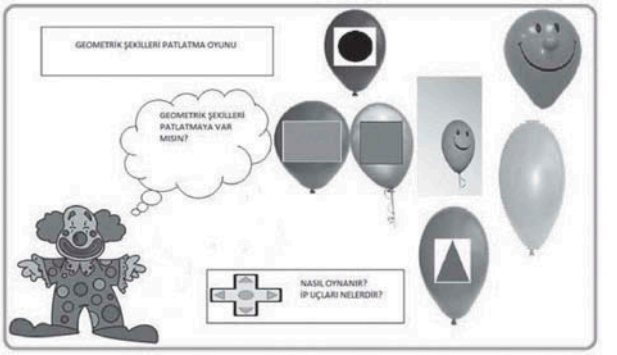
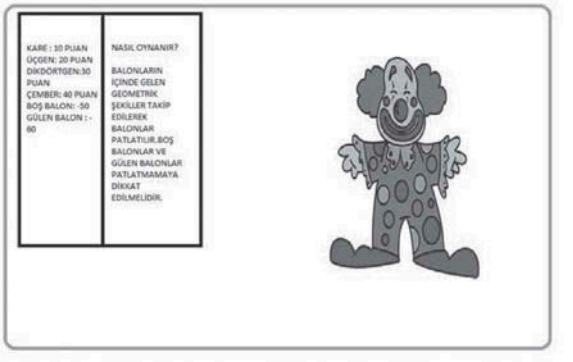
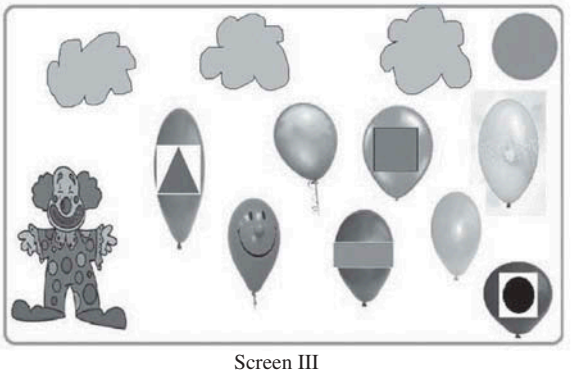


Screen I



Screen II



Screen III

Figure 5. The screenshots of the educational game designed by S19.

games over 14 weeks. The data were collected through educational computer games designed by participants, focus group interviews, observations, and participant journals.

The data confirmed that educational game design prompts ECE pre-service teachers to use TPACK together. During the planning phase, pre-service teachers paid attention to young children's development (PK), curriculum goals (CK), design principles (DK), usability (TK), and characteristics of computer games (TK) together (TPACK). Both Siko and Barbour (2012) and Sancar Tokmak and Özgelen (2013) have also advocated that designing an educational game using PowerPoint requires teachers' and pre-service teachers' use of TPACK.

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Table 8. The codes emerged under "Learned" themes during focus group interviews.

- ➢ Learned
  - Planning and designing a game
    - Subject matters
    - Curriculum goals
    - Student level
    - Design principles
  - Learning to teach a subject matters with a game
  - Learning to use technology
  - Learning design principles
  - Learning to search information from Internet
  - Learning to look from another perspective
  - Learning to criticise a work

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Identified difficulties and coping strategies showed that participants emphasised TK, DK, and TPACK. They had difficulty using PowerPoint and Paint (TK), plus reflecting their ideas into their games (DK; TPACK). With help from friends and instructors, they learned to use the technology (TK). These results show that during the process, the inadequacies of TK and DK caused ECE pre-service teachers difficulty in designing educational computer games. These findings are consistent with Thompson and Mishra's (2007–2008) claims that the three knowledge domains (TK, PK, and CK) are integrated. In other words, the competence level of each knowledge domain affects the overall process and TPACK. However, the results also showed that participants compensated for inadequacy in a knowledge domain with help from friends, instructors, or the Internet, in addition to personal efforts to increase knowledge. In this case, most of the participants learned PowerPoint, Paint, computer game characteristics, and how to apply design principles.

Bers et al. (2002) emphasised the role of collaboration and self-reflection in a study in which ECE pre-service teachers independently designed robotic artefacts. Although the ECE pre-service teachers in the current study designed educational computer games individually, they did have help from friends. Moreover, most participants stated that while they controlled their designs, they got friends' or the instructor's opinions about designs during each step. With that feedback, their designs became more instructional and appropriate in terms of design principles. The adjectives participants used to describe their final games showed a positive response: colourful (DK), entertaining (TK), creative (TPACK), original (TPACK), instructional (TPACK), specific for content (CK), thought provoking (CK), supporting creativity (TPACK), and specific for young children (PK). Moreover, their game designs, which included characters Pepee, Dora, Caillou, smurfs, Gardfield (see Table 9), stories, colours, supported the preservice teachers' statements about creativity. These results demonstrate how their games reflected TPACK. Another important finding in the study related to the ECE pre-service teachers' knowledge about design. In interview results, ECE pre-service teachers expressed how the process required significant creativity, since they had to bring together TK-PK-CK in addition to DK (design knowledge). Koehler et al. (2011) have further emphasised the role of creativity in designing educational technology.

Another important result of the current study is that ECE pre-service teachers thought about the environments in which the educational computer games would be used. The

Table 9. Trade marks of characters used game designs.

Characters	Trade marks
Pepee	Düşyeri Çizgi Film Stüdyosu
Dora	Viacom International Inc. Corporation Delaware
Caillou	Chouette Publishing (1987) Inc. Corporation
Smurfs (Smurfette, Hefty Smurf, Dreamy Smurf, Gargamel)	Studio Peyo S.A. Company by Assignment
Garfield	Paws, Incorporated Corporation Assignee of Indiana

ECE pre-service teachers' knowledge development and its relationship with TPACK are shown Figure 6.

The results showed that most participants were satisfied with the educational computer games they designed. They felt their games were attractive, followed design principles, and were appropriate for the target audience and curriculum. Very few pre-service teachers reported weaknesses in their games in terms of game characteristics or interface design. These results were parallel with the ECE pre-service teachers' statements about creating the best designs they could by getting help from friends, instructors, and the Internet, plus conducting trial and error. Moreover, this result is consistent with their acknowledgement that they learned DK and TK in addition to considering all relevant issues and using all knowledge domains related to designing educational technology.

Finally, the results of the study showed that designing educational technology requires all knowledge domains of TPACK in addition to DK. Moreover, creativity was highly emphasised by the ECE pre-service teachers. This study was an example of designing by

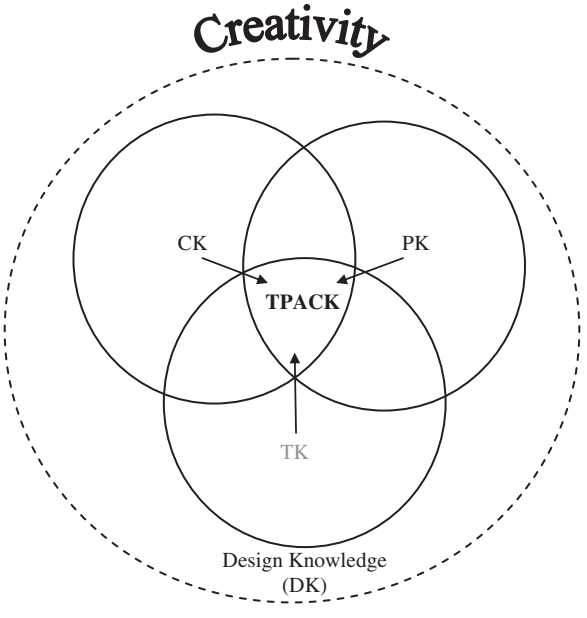

Figure 6. ECE pre-service teachers' knowledge development and relation with TPACK during game design activity.

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learning a constructionism approach to research, and it was designed as a case study. The current case study was limited to a group of volunteer pre-service teachers' opinions of their TPACK development through game design activity. The convenience sampling applied was one of the limitations. Other limitation of the study stemmed from the nature of single case studies, the generalisability. The generalisability of single case studies has been the concern of qualitative research theorists and researchers (Schofield, 2002). Schofield (2002) presents different points of view about this issue and focuses on the thick and clear description. The thick description of the study was presented to eliminate this limitation and generalize the study results. In the future, this study could be conducted with design-based research to investigate how the three knowledge domains plus DK merge.

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