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Pre-Service Middle School Mathematics Teachers' Considerations for Using Digital Games in Their Future Classrooms

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Abstract

The purpose of the study was to explore pre-service teachers' considerations for using digital mathematics games in their future classrooms. The participants of the study were eighteen pre-service middle school mathematics teachers who were enrolled in a teacher education program at a state university in Türkiye. Before collecting the data of the study, the participants took part in a fourteen-week elective course through which they gained some experience in designing digital mathematics games using the Scratch programming language. The data of the study were collected through a questionnaire with five open-ended questions. Follow-up interviews were conducted in relation to the questions in the questionnaire. The findings showed that all participants except for one expressed that they would use digital games in the last part of their mathematics lesson for the purpose of doing exercises, practicing, assessing learning, and identifying deficiencies in students' learning. Moreover, more than half of the participants expressed that they would use digital games in the main part of the lesson for teaching mathematics. About one-fifth of the participants expressed that they would use digital games in the introduction part of the lesson for the purpose of increasing students' curiosity about mathematics, attracting students' attention to the mathematical topics, motivating students to take mathematics lessons, and checking or recalling students' prior knowledge of different mathematical topics. On the other hand, roughly six-tenths of the participants thought that it is not possible to teach a mathematical topic entirely with digital mathematics games without the need to do any other activity other than digital mathematics games and a quarter of them thought that this depends on the digital game and the mathematical topic that is being taught. The common issues that participants considered when planning to use a digital mathematics game are compatibility with the mathematical topic, clarity of the game, appropriateness of the game to students' readiness and grade levels, and enjoyment of the game. Finally, the

participants foresaw the following potential problems when using digital games in their future classrooms: unclarity of the game, incompatibility of the game with the mathematical topic, inappropriateness of the game for students' readiness and grade levels, and technological problems.

Keywords

Designing digital mathematics games, pre-service middle school mathematics teachers, Scratch programming language

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Öğretmen Adaylarının Matematik Öğretiminde Dijital Oyun Kullanımına İlişkin Dikkate Aldıkları Hususlar

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Öz

Bu çalışmanın amacı, öğretmen adaylarının matematik öğretiminde dijital oyun kullanımına ilişkin dikkate aldıkları hususları araştırmaktır. Çalışmanın katılımcıları, Türkiye'deki bir devlet üniversitesinde öğretmen eğitimi programına kayıtlı olan on sekiz ortaokul matematik öğretmeni adayıdır. Araştırmanın katılımcıları ölçüt örnekleme yöntemi kullanılarak seçilmiştir. Dijital matematik oyunları tasarlama konusunda deneyim sahibi olmak katılımcı seçiminde kriter olarak kullanılmıştır. Bu nedenle, veri toplamadan önce, katılımcılar Scratch programlama dili aracılığıyla dijital matematik oyunları tasarlama konusunda deneyim kazandıkları on dört haftalık seçmeli bir derse katılmışlardır. Bu seçmeli ders kapsamında öğretmen adayları matematik içerikli dijital oyunlar tasarlamışlardır. Veriler beş açık uçlu sorudan oluşan bir test aracılığıyla toplanmıştır. Daha sonra katılımcılar ile bu sorulara ilişkin görüşmeler yapılmıştır. Katılımcıların biri dışında tamamı dijital oyunları matematik derslerinin son bölümünde alıştırma yapmak, pratik yapmak, öğrenmeyi değerlendirmek ve öğrencilerin öğrenmelerindeki eksiklikleri belirlemek amacıyla kullanacaklarını ifade etmiştir. Ayrıca, katılımcıların yarısından fazlası, dijital oyunları dersin ana bölümünde matematik öğretmek için kullanacaklarını ifade etmiştir. Katılımcıların yaklaşık beşte biri, dijital oyunları dersin giriş bölümünde öğrencilerin merakını artırmak, dikkatlerini matematik konularına çekmek, matematik konularına ilişkin ön bilgilerini kontrol etmek ve öğrencileri matematik öğrenmeye motive etmek amacıyla kullanacaklarını ifade etmiştir. Öte yandan, katılımcıların yaklaşık onda altısı, dijital matematik oyunları dışında başka bir etkinlik yapmaya gerek kalmadan bir matematik konusunu tamamen dijital matematik oyunlarıyla öğretmenin mümkün olmadığını, dörtte biri ise bunun dijital oyuna ve öğretilen matematik konusuna bağlı olduğunu düşünmektedir. Katılımcıların dijital matematik oyunlarını kullanmayı planlarken göz önünde bulundurdukları hususlar şunlardır: matematiksel konuya uygunluk, oyunun anlaşılırlığı, oyunun öğrencilerin hazırbulunuşluk ve sınıf seviyelerine uygunluğu ve oyunun eğlenceli olması. Son olarak, öğretmen adayları gelecekteki sınıflarında dijital oyunları kullanırken şu sorunların yaşanabileceğini öngörmüşlerdir: oyunun yeterince açık olmaması, oyunun öğretilecek matematik konusu ile uyumsuzluğu, oyunun öğrencilerin hazır bulunuşluk ve sınıf seviyelerine uygun

olmaması ve teknolojik sorunlar.

Anahtar Kelimeler

Dijital matematik oyun tasarımı, ortaokul matematik öğretmen adayları, Scratch

Atıf Bilgisi

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Introduction

Digital games are widely used by children of different age groups (Karakuş et al., 2008; Lenhart et al., 2008). The widespread acceptance of digital games has attracted attention of researchers in the area of education and this popularity prompted the researchers to concentrate increasingly on integrating digital games into education (Boyle et al., 2016; Clark et al., 2016).

Digital games can be particularly used in the teaching and learning of mathematics (Divjak & Tomic, 2011; Kim & Ke, 2017; Plass et al., 2013). More importantly, digital games have the potential to enrich the quality of mathematics education (Giannakos, 2013; Plass et al., 2013). First, digital games aid in the development of pupils' affective domain skills such as developing positive attitudes towards mathematics (Mavridis et al., 2017), enjoying from mathematics (Chen et al., 2012), increasing motivation to learn mathematics (Divjak & Tomic, 2011), improving self-efficacy (Pan et al., 2022) and self-confidence (Ku et al., 2014) in mathematics, and increasing interest in attending mathematics lessons (Chen et al., 2012). Second, digital games contribute to students' cognitive domain skills including problem solving (Ke, 2019) and knowledge acquisition in mathematics (Giannakos, 2013; Kim & Ke, 2017; Plass et al., 2013). For instance, Plass et al. (2013) reported that digital games improved middle school students' flexibility in arithmetic operations. Similarly, Giannakos (2013) revealed that digital mathematics games fostered middle school students' performance on addition and substruction of integers. Moreover, he examined the relationship between students' mathematics performance and enjoyment of digital games and found that students who had more enjoyment while playing digital games were more likely to gain knowledge from the game.

However, there are several aspects that influence teachers' employment of digital games in their teaching practices. First of all, teachers do not take much formal training about digital games in pre- or in-service teacher education programs (Takeuchi & Vaala, 2014). Consequently, teachers might not have been subjected to the full spectrum of pedagogical techniques, tools, and game types that might improve and enable incorporation of digital games (Takeuchi & Vaala, 2014). Therefore, it is critical that pre-service teachers develop knowledge and expertise with digital games during their teacher education programs.

There are also several aspects that hamper teachers' use of digital games in the classrooms such as lack of curricular flexibility, detrimental impacts of gaming, pupils' lack of preparation, a lack of supporting resources, set class times, and restricted funds (Baek, 2008). Rice (2007) reviewed research on computer video game use in classrooms and similarly found several major

barriers to implementation, including a lack of suitable computing technology in classrooms to operate sophisticated video games and misalignment with state standards. Note that both Baek (2008) and Rice (2007) draw attention to the misalignment between digital games and the curriculum. Indeed, most of the game-using teachers in Takeuchi and Vaala's (2014) survey articulated that they had difficulty finding curriculum-aligned digital games.

In the mathematics education literature, most of the digital games were designed for teaching mathematical topics in the numbers and operations learning domain while fewer digital games were designed for teaching mathematical topics related to geometry, algebra, measurement, data analysis and probability (e.g., Byun & Joung, 2018; Joung & Byun, 2021; Pan et al., 2022). For example, Joung and Byun (2021) examined the alignment between the mathematical contents of digital games and content and process standards released by the National Council of Teachers of Mathematics and they found that most of the digital games focused on numbers and operations learning domain while none of the digital games were associated with the data analysis and probability content standards. The fact that most of the digital games designed for mathematics teaching are related to numbers and operations learning domain might be making it difficult for teachers to find digital games about other mathematical topics that they want to teach. Since it may not always be possible for teachers to find relevant digital games for the mathematical topics they wish to teach, it is of utmost importance for them to be equipped with sufficient digital game design skills.

However, having sufficient digital game design skills may not guarantee pre-service teachers' use of digital mathematics in their future classrooms. That is, their attitudes and beliefs towards digital games might play a crucial role in their intention to use these games in the teaching of mathematics (Yeo et al., 2022). If pre-service teachers do not believe that digital games should be used in mathematics teaching and if they do not appreciate the affordances of digital mathematics games, then they may not strive to incorporate digital mathematics games into their teaching practices. Therefore, it is significant to uncover whether pre-service teachers with sufficient digital game design skills intend to use digital mathematics games in their teaching practices or not.

Digital games can be integrated into lessons usually in the following three ways: before the non-game instruction, after the non-game instruction, and as a replacement for the non-game instruction (Hu & Sperling, 2022). Digital games may be utilized as a pre-lesson activity to expose pupils to new topics and help them become acquainted with them (Arena & Schwartz, 2014). Digital games can be used after a lesson as a review and application of the topics learned (Brom et al., 2011). Last, a whole lesson can be delivered directly and solely through digital games without any extra non-game activities (Pilegard &

Mayer, 2015). Hu and Sperling (2022) explained that this final method may provide the students with a sensory-rich atmosphere that would increase learning and motivation through high-quality gaming practices. However, they further cautioned that not all teachers can readily get access to digital games designed in this way and therefore that it may not be possible for them to replace their lessons with such digital games.

Simply put, every effort should be made to equip the pre-service teachers with the knowledge of digital game design such as the advantages of digital games, obstacles to using digital games, and different ways to incorporate digital games into mathematics lessons (e.g., sequencing of digital games in a lesson). Not only the knowledge of pre-service teachers but also their beliefs have a considerable influence on their teaching practices (Thompson, 1992). Moreover, teachers' attitudes and beliefs towards game use are critical predictors of their intentions to use digital games in their classrooms (Yeo et al., 2022). Therefore, it is of great importance to assist pre-service teachers in developing positive attitudes and beliefs about digital games before they start their teaching profession.

1. Aim and the Significance of the Study

Although mathematics education researchers emphasize the importance of using digital games in mathematics classrooms (e.g., Divjak & Tomic, 2011; Kim & Ke, 2017; Pan et al., 2022; Plass et al., 2013), they also caution that there are some barriers that negatively influence teachers' employment of digital games in their teaching practices (e.g., Baek, 2008; Can & Cagiltay, 2006; Pastore & Falvo, 2010). One of these barriers is that teachers do not take sufficient formal training about digital games in pre- or in-service teacher education programs (Takeuchi & Vaala, 2014). For this reason, training pre-service teachers on using digital games in mathematics education and on designing these games through relevant digital game development tools such as Scratch plays an important role in overcoming this barrier.

Apart from insufficient formal training, there are also other factors that hamper teachers' use of digital games in the classrooms such as lack of curricular flexibility, detrimental impacts of gaming, pupils' lack of preparation, a lack of supporting resources, set class times, and restricted funds (Baek, 2008). Pre-service teachers' recognition and knowledge of these factors may aid them in preventing possible issues before these issues actually occur in mathematics classrooms. Thus, it is significant to inform mathematics teacher educators about the potential problems that pre-service teachers consider they will face when using digital mathematics games in the future.

Mathematics teachers' attitudes and beliefs towards digital games have a considerable influence on their intention to use these games in their classrooms

(Yeo et al., 2022). That is, gaining expertise in digital game design during teacher education programs does not ensure that pre-service teachers would employ these games in their future classrooms. Therefore, it is significant to uncover whether pre-service teachers with sufficient digital game design skills intend to use digital mathematics games in their teaching practices or not. Additionally, pre-service teachers' sequencing of digital mathematics games, and purposes for using them in their mathematics classrooms would make a great contribution to the literature on digital mathematics games as these aspects have been largely underresearched in the literature.

Furthermore, the mathematics education literature shows that digital games with mathematics content are mostly related to numbers and operations learning domain (e.g., Byun & Joung, 2018). Mathematics teachers who wish to integrate digital games into their lessons may have difficulty finding digital games related to other learning domains. Developing appropriate digital games related to the topics mathematics teachers are required to teach in their lessons would be a great contribution to them.

In previous studies on digital games with pre-service teachers, the participants were either exposed to different examples of digital games via essential gameplay videos, as was the case in Hu and Sperling's (2022) study, or they had no experience with digital games. In the literature on digital mathematics games, there are very few studies in which participants are pre-service teachers who have experience in designing digital games (e.g., Yıldız Durak & Karaoğlan Yılmaz, 2019). Therefore, the present study fills this gap in the literature by focusing on experienced pre-service teachers' considerations for employing digital mathematics games in their future classrooms.

For all the reasons mentioned above, it is very important to involve pre-service teachers in a digital game design process during teacher education. Bearing this in mind, in the current study, the pre-service teachers were exposed to a game development process within the scope of an elective course. In this course, the pre-service teachers learned about coding with the Scratch programming language and had experience of designing a digital mathematics game with this programming language. At the end of this course, the pre-service teachers' considerations for using digital games in their future classrooms were analyzed. Briefly, the purpose of this study was to explore pre-service teachers' considerations for using digital mathematics games in their future classrooms and, therefore, the research question I sought to answer was "What are the pre-service teachers' considerations for using digital mathematics games in their future classrooms?"

In this study, the term "consideration" refers to "something that must be thought about when you are planning, deciding or studying something", as defined in the Oxford Learner's Dictionary of Academic English (2023). The

participants attended a fourteen-week elective course on digital mathematics games. During and after this course, they are expected to think carefully and reflect on the sequencing of digital games in mathematics lessons, replacing non-game instruction entirely with digital mathematics games, and on the potential problems about digital mathematics games in their future classrooms. All of the actions that pre-service teachers need to take before using digital mathematics games in the classroom correspond to their considerations about these games.

Methods

1. Participants, Context, and Research Design

This phenomenological study focuses on pre-service teachers' considerations for using digital games in their mathematics classrooms. Phenomenological research aims to uncover similarities in the perceptions of several people about a certain phenomenon (Fraenkel et al., 2023). The criterion sampling method, which is one of the purposeful sampling methods, was employed when choosing the participants of the current study (Mills & Gay, 2019). In the current study, the criterion is having experience in developing digital mathematics games. The participants of the study were eighteen pre-service middle school mathematics teachers registered in a teacher education program at a less populated state university in Türkiye. Fifteen junior and three senior pre-service teachers were enrolled in a two-hour elective Teaching Mathematics through Digital Games course. The pre-service teachers were informed about the current research before they were enrolled in this course. Thus, only the pre-service teachers who volunteered to take part in the current study were enrolled in the course.

During the elective course, the participants took fourteen weeks of training on coding with Scratch programming language and designing digital mathematics games. By this way, they gained considerable experience in the Scratch programming language and in designing digital mathematical games. During the first eight weeks of the training, the participants were introduced to the content of the Scratch coding cards and the activity guides on the website of Scratch (Scratch Ideas, 2023). In the remaining six weeks, the participants first designed animations and then they designed Exercise games and Teaching games. An overview of the Teaching Mathematics through Digital Games course is presented in Table 1.

Table 1.

Overview of The Teaching Mathematics through Digital Games Course

Weeks	Requirements	Content
1 – 8	Completing the content of the Scratch coding cards and activity guides	- Understanding and using different types of blocks (motion, events, control, sensing, etc.), sprites, costumes, operators, and variables. -Animating characters, creating stories, and making music. -Designing a pong game, catch game, jumping game, and chase game. -Using the coding skills and Scratch knowledge gained in the first eight weeks.
9 – 10	Designing animations by using Scratch	-The participants' animation projects had to fulfill the following criteria: ● Reflect an understanding of blocks and how they work together. ● Involve an organization, logic, and creativity. ● Use loops, conditional statements, broadcasts, operators, variables, and random numbers (Note that not all of them are mandatory in a single project).
11 – 12	Designing an Exercise game by using Scratch	-Designing an Exercise Game about the learning objective involved in the Turkish middle school mathematics curriculum. -Having a student play the initial version of the Exercise Game, identifying the difficulties experienced by the student, and doing necessary revisions to remedy difficulties. -Exercise game refers to a digital mathematics game that helps players do exercises about the previously learned mathematics topic. -The aim of the Exercise game is not to teach a new mathematics topic with which the player is not familiar. - The Exercise game mentioned here corresponds to prior knowledge activation explained by Ke (2016).
13 – 14	Designing a Teaching game by using Scratch	-Designing a Teaching Game about the learning objective involved in the Turkish middle school mathematics curriculum.

	-Having a student play the initial version of the Teaching Game, identifying the difficulties experienced by the student related to the game, and doing necessary revisions to remedy these difficulties. -Teaching game refers to a digital mathematics game that helps the player learn a new mathematics topic. -The aim of the Teaching game is to teach a mathematics topic with which the player is not familiar. -The Teaching game mentioned here corresponds to the acquisition of new knowledge explained by Ke (2016).

2. Data Collection and Analysis Process

The main data of the current study is comprised of the written responses given by the pre-service teachers to the Digital Mathematics Games Questionnaire. Follow-up interviews regarding the questions in this questionnaire were also conducted with participants. These interviews, which were taped with a voice recorder, were also used as the data of the current study.

There are 5 open-ended questions in the questionnaire (see Appendix for the Digital Mathematics Games Questionnaire). Questions 1 and 2 are related to participants' intention to design and use digital games in their future mathematics lessons and were developed by the researcher. Questions 3 and 4 were adapted from Hu and Sperling's (2022) study. Hu and Sperling (2022) used the following multiple-choice question to examine how prospective teachers integrate a digital game with non-game elements of a lesson:

> "If you must use a digital game in the future, how would you prefer to use it in your teaching practices? (1) I would lecture first, then I would ask students to play a digital game tied to that content as a review. (2) I would let students play a digital game tied to the content first, then I will provide my lecture. (3) I would let students play the digital game to learn about the entire lesson, and I would answer any questions that they have throughout the gameplay" (p. 6).

I modified this question and turned it into two open-ended questions (Questions 3 and 4). In this way, I aimed to provide more detailed insights into pre-service teachers' integration of digital games into their mathematics

lessons. Question 3 uncovers for which purposes and in which parts of the mathematics lesson participants plan to use digital mathematics games. Question 4 asks the participants to state whether it is possible to teach a mathematics topic completely with a digital game without doing any non-game activity.

Question 5 was developed by the researcher and aims at identifying which considerations participants would employ and with which problems they expect to encounter when designing and using digital mathematics games. Overall, the five open-ended questions in the Digital Mathematics Games Questionnaire were designed to gain a comprehensive picture of the participants' considerations about digital games and their use of these games in mathematics education.

In this study, the digital mathematics games designed by pre-service teachers were not analyzed as the data of the study. In this study, the content analysis method was used to reveal the pre-service middle school mathematics teachers' considerations about designing and using digital mathematics games. Content analysis involves the exploration of codes, categories, and themes within the data (Fraenkel et al., 2023). The researcher first transcribed the interviews recorded with the voice recorder verbatim. The interview transcripts and the participants' written responses to the questions in the questionnaire were read several times by the researcher. The researcher read the data line by line, identified important dimensions, categorized the data into meaningful sections, and named these sections, which formed a meaningful whole in themselves. After coding all the data, a code list was created. This list played a key role in analyzing and organizing the data. Thus, the data in different sections that were related in terms of meaning were brought together by repeatedly working on the relevant codes. Then, categories and themes were formed by finding commonalities among the codes.

After developing the coding scheme, I and another researcher with a Ph.D. in mathematics education carried out the coding. We coded the data independently using the constant comparison strategy (Corbin & Strauss, 2015). In the current study, inter-rater reliability was calculated to provide evidence for reliability. Inter-rater reliability is the degree of agreement between raters and provides a measure of how much agreement is reached by the raters, which is called scoring agreement (Fraenkel & Wallen, 2023). I calculated the reliability using Miles and Huberman's (1994) formula, which involves dividing the number of agreements by the sum of agreements and disagreements. The inter-rater reliability between me and the second coder was found as 84%. In a number of meetings, we resolved the discrepancies among us. Then, we reached an almost complete agreement and completed the data coding.

I used the credibility, dependability, transferability, and confirmability criteria provided by Lincoln and Guba (1985) to determine the trustworthiness of this study. To ensure credibility, the following strategies were employed: triangulation, member checking, and using thick descriptions (Lincoln & Guba, 1985). In this study, there were eighteen prospective teachers as the data source (data triangulation), a second coder (investigator triangulation), and different kinds of data as follow-up interviews and written responses to the questionnaire (methodological triangulation). Moreover, member checking was employed in the follow-up interviews with the pre-service teachers. This enabled me to determine whether there were any discrepancies between myself and the pre-service teachers on their considerations of digital mathematics games. I provided detailed explanations (thick descriptions) of the data collection and analysis techniques. Besides, the participants' statements were quoted to reflect their considerations about digital mathematics games.

Transferability corresponds to the generalizability of research findings. According to Lincoln and Guba (1985), researchers should offer enough contextual information about the research so that readers may apply the findings to their own context. I thoroughly explained all aspects of the present study so that the researchers may determine whether the findings of this study can be used in other settings.

To ensure dependability, I tried to maintain consistency throughout all steps of the study. I explained each phase of the study transparently. Besides, I described the data analysis process with as much clarity and reported the findings in tables to help the readers evaluate the whole data coding process. Finally, in order to achieve confirmability, I tried to control my biases as much as possible and was careful to ensure that my findings were only shaped by the data collected in the study.

Results

In this section, findings related to the pre-service middle school mathematics teachers' considerations about designing and using digital mathematics games are presented.

1. Participants' Intention to Use Digital Games in Their Mathematics Classrooms

All participants expressed that they would like to use digital mathematics games, designed by them or by others, in their lessons when they start their teaching profession. They also indicated that they would like to design digital mathematics games when they start their teaching profession. For instance, PT6 indicated, "I will definitely use Scratch and develop digital games because

mathematics should not be taught directly with formulas. It should be taught with educational digital games that are fun. This way memorization is avoided". Similarly, PT18 expressed, "As a student, I was very bored with the traditional teaching methods. I want to design digital games that my students can learn while having fun, using the opportunities existing in the developing world". More importantly, the pre-service teachers emphasized that it is still worth designing digital games although they know that designing these games is a time-consuming task. For example, PT4 stated, "Yes, I want to design digital games, but I know it will take time" and PT7 stated, "It enhances the enjoyment and retention of learning. However, I may not be able to design digital games for all topics because it's time-consuming".

2. Participants' Sequencing of Digital Mathematics Games and Purposes for Using Them in Their Mathematics Classrooms

Participants' explanations showed that they thought of mathematics lessons with three parts (i.e., introduction, main part, and the last part). They indicated that the introduction part of a mathematics lesson involves drawing students' attention to the mathematical topic and checking or recalling students' prior knowledge, the main part of a mathematics lesson involves teaching a mathematical topic, and the last part of a mathematics lesson involves doing exercises or measuring students' learning. More importantly, they sequenced their digital mathematics games differently by incorporating these games into different parts of their mathematics lessons. The breakdown of participants' sequencing of their digital mathematics games in different parts of mathematics lessons and examples of their sequencing and purposes for using digital mathematics games are provided in Table 2.

Table 2.

The Breakdown of Participants' Sequencing of Their Digital Mathematics Games in Different Parts of Mathematics Lessons and Some Examples

Sequencing digital games in	Examples of sequencing and purposes	*f*
a. Introduction part and the last part of a mathematics lesson	To attract students' attention and to motivate students at the beginning of the lesson; to do exercises and to assess learning at the end of the lesson (PT5)	2
b. Main part of a mathematics lesson	To teach mathematics during the main part of the lesson (PT15)	1
c. Main part and the last part of a mathematics lesson	To teach mathematics during the main part of the lesson and to do exercises about previously learned topics at the end of the lesson (PT3)	7

d. The last part of a mathematics lesson	To do exercises about previously learned topics at the end of the lesson (PT17)	6
e. Introduction part, main part, and the last part of a mathematics lesson	To attract attention, to recall the subject, and to check previous learning at the beginning of the lesson; to teach mathematics during the main part of the lesson; and to assess learning at the end of the lesson (PT6)	2

Note: The statements in the "Examples of sequencing and purposes" column are not direct quotations of the participants. Therefore, participants' IDs are given in parentheses.

Overall, four participants expressed that they would use their digital games in the introduction part of their mathematics lesson (the sum of participants in Part a and e of Table 2), 10 participants expressed that they would use their digital games in the main part of their mathematics lesson (the sum of participants in Part b, c, and e of Table 2), and finally 17 participants expressed that they would use their digital games in the last part of their mathematics lesson (the sum of participants in Part a, c, and e of Table 2).

As seen in Table 2, four pre-service teachers considered that digital mathematics games can be used in the introduction part of the mathematics lesson. For instance, PT9 stated, "Digital games can be used at the beginning of the lesson to draw students' attention to the subject" and, PT7 stated, "It can be used to increase students' curiosity at the beginning of the lesson". Similarly, PT5 indicated, "It can be used to make students have an idea about the topic before teaching and it can be used to attract students' attention and motivate them to the lesson". Furthermore, PT6 expressed that "Digital games can be used to attract attention at the beginning of the lesson. If the subject of the lesson is related to previous years, it can be used both to recall the subject and to check previous learning".

To sum up, some pre-service teachers considered that, in the introduction part of a mathematics lesson, digital games can be used for the following purposes: increasing students' curiosity about mathematics, attracting students' attention to the mathematical topics, motivating students to mathematics lessons, and checking or recalling students' prior knowledge of different mathematical topics.

Ten pre-service teachers explained that digital mathematics games can be used in the main part of the mathematics lessons for the purpose of teaching mathematics. For instance, PT12 indicated, "It can be used to teach the subject in the main part of the lesson". Similarly, PT8 stated, "Digital games can be used in the teaching phase of the lesson. Students can learn by having fun". Besides, PT18 expressed, "It can be used in the teaching phase of the lesson so that students can add new ideas to their previous knowledge. However, two of the

ten pre-service teachers conditionally said that digital games can be used in the main part of the lesson. More clearly, PT4 explained, "When the class size is suitable for playing digital games, games can be used in the teaching part of the lesson". Furthermore, PT13 indicated, "Digital games can be used in the teaching part if the time spent playing games can be properly managed". Thus, according to some of the pre-service teachers, the amount of time to be spent on the digital game and the class size play a decisive role in the use of digital games in the main part of the lesson.

All but one of the pre-service teachers indicated that digital games can be used in the last part of the mathematics lessons for the following purposes: doing exercises, practicing, assessing learning, and identifying deficiencies in students' learning. For example, PT1 indicated, "Digital games can be used for doing exercises related to the previously learned topics and for assessing learning". Similarly, PT2 stated, "It can be used for practicing at the end of the lesson and it can be used to see whether the student can apply what has been taught". Furthermore, PT10 explained, "Digital games can be used for practicing and assessing learning after mathematics instruction. With the help of students' answers to the questions in the digital games, it can be determined whether the students understand the subject or not". Similarly, PT11 indicated, "It can be used at the end of the lesson to see if students learned the subject and if there are still any gaps in their learning after teaching". It is worth noting that, as seen in Table 2, 6 out of 18 pre-service teachers expressed that digital games should preferably be used in the last part of mathematics lessons. That is, they argued that digital games can be more effective for practicing mathematical topics rather than for teaching mathematical topics. For example, PT14 explained, "I think it would be effective to use digital games in the practice phase rather than the teaching phase. Some games can mislead students. If the student progresses incorrectly in the game or cannot progress at all, his/her interest in the subject may decrease and learning may not take place. In other words, after learning the subject with the teacher through non-game activities, it would be much better if the students do exercises related to the subject by playing digital games".

3. Participants' Considerations About the Possibility of Teaching a Mathematical Topic Entirely with Digital Mathematics Games

When the participants were asked to state whether it is possible to teach a mathematical topic entirely with digital mathematics games (i.e., without the need to do any other activity other than digital mathematics games), only two pre-service teachers responded "Yes". For example, PT6 explained, "Absolutely, yes because when teaching mathematical topics, digital games can be used to attract students' attention to the mathematical topic and by having students play these digital games, the mathematical topics can be taught to the

students clearly, intelligibly, and enjoyably. Digital mathematics games can also be used for doing exercises and this may provide the students with a competitive environment in which they are motivated to attend mathematics lessons.

On the other hand, eleven out of eighteen (61%) pre-service teachers indicated that it is not possible to teach a mathematical topic entirely with digital mathematics games. For instance, PT8 explained, "I do not think it is possible because after the game is played, the teacher should go over important points and guide his/her students. Also, misunderstandings and mislearned concepts should be corrected immediately". Similarly, PT15 stated, "I think that we cannot teach because the students will always have some questions in their minds, and I think that another supporting activity has to be done to answer their questions". Moreover, PT13 indicated, "I think no. Teaching and practicing the subject can be supported by using digital games, but other materials may also be needed.

The remaining five pre-service teachers attributed the possibility of teaching a mathematical topic entirely with digital mathematics games to certain conditions. They thought that this possibility depends on the digital game, the mathematical topic, and the students being taught. For instance, PT7 stated, "I think we can teach, but not every topic" and PT18 stated, "This may not be the right choice for every learning objective". Similarly, PT3 stated, "There is a chance to teach a topic with a digital game. But this depends on the content and the nature of the topic. It also depends on the students. So, we cannot get the same result with every student. Furthermore, PT10 stated, "We can teach. But we cannot teach the topic with all kinds of digital games. Some games are only suitable for practicing".

4. The Considerations Employed by The Participants When Planning to Use Digital Mathematics Games and The Potential Problems Foreseen by Them When Using These Games

The considerations employed by the participants when planning to use digital mathematics games in their future classrooms, the frequencies of these considerations, and some sample statements regarding each consideration are presented in Table 3.

Table 3.

The Considerations Employed by The Participants When Planning to Use Digital Mathematics Games in Their Future Classrooms

Considerations	Sample statements
Compatibility with the mathematical topic (*n* = 16)	PT12: Does the game cover the entire learning objective?
	PT15: I pay attention to whether the game goes beyond the scope of the topic or not.
	PT2: The first thing I will pay attention to is whether the game is appropriate for the topic, will the students be able to learn the topic with this game?
Clarity of the game (*n* = 9)	PT4: The game should be easy to understand.
	PT8: The game should be explanatory, clear, and easy to follow.
	PT11: Is the game sufficiently clear, simple, and concise?
Appropriateness of the game to students' readiness and grade levels (*n* = 7)	PT5: I will pay attention to whether the game is too difficult or too easy for the students.
	PT18: I will make sure it is appropriate for students' grade levels.
Enjoyment of the game (*n* = 7)	PT9: I pay attention to whether it is a game that the student might enjoy.
	PT16: I make sure that the game is engaging and fun.
Ensuring the absence of errors and misconceptions in the mathematical content (*n* = 3)	PT10: I pay attention to whether it will cause any misconceptions. I will check whether it contains wrong mathematical information.
	PT14: Is the mathematical content of the game correct?
Connections with daily life (*n* = 1)	PT11: I make sure that it includes a situation from students' daily lives.

Table 3 shows that all but two of the pre-service teachers emphasized the compatibility of the digital game with the mathematical topic and half of them emphasized the clarity of the game. Seven pre-service teachers emphasized the significance of the appropriateness of the digital game to students' readiness

and grade levels. Similarly, seven pre-service teachers indicated the importance of enjoyment of the digital game. Finally, ensuring the absence of errors and misconceptions in the mathematical content and connections with daily life were other considerations employed by the participants when planning to use digital mathematics games.

The potential problems foreseen by the participants when using digital mathematics games, the frequencies of these problems, and some sample statements regarding each problem are presented in Table 4.

Table 4.

The Potential Problems Foreseen by The Participants When Using Digital Mathematics Games

Potential problems	Sample statements
Unclarity of the game (*n* = 7)	PT16: The game may be difficult to understand.
	PT11: If the game does not clearly explain what to do and how to do it, there will be confusion.
	PT13: If the game is not understood, the student may get bad results. If he/she knows the mathematical topic but cannot get the expected result at the end of the game, his/her motivation may decrease.
Incompatibility of the game with the mathematical topic (*n* = 6)	PT12: If the game does not cover the whole topic, there may be missing parts that are not covered in the lesson.
	PT14: The game may include concepts that are irrelevant. That is, it may include unrelated concepts.
Inappropriateness of the game for students' readiness and grade levels (*n* = 5)	PT5: The game may not be appropriate for students' grade levels.
	PT9: The game may be too simple or too difficult for students. If the game is too easy, they may be bored. If the questions in the game are too difficult, they may think that they have not learned the topic.
Technological problems (*n* = 5)	PT4: Technological problems may arise.
	PT1: There may not be enough computers in the classroom or school to play games for every student.
Time-related problems (*n* = 2)	PT17: It can take a lot of time. We may not be able to complete the whole topic.
Classroom management (*n* = 2)	PT7: If students give their full attention to the game, it can be difficult to draw their attention back to the lesson after the game.
Students' lack of	PT17: Students may not like the game and may not be

motivation (*n* = 2)	interested in it.
Boringness of the game (*n* = 2)	PT16: The game may not be interesting.
Playing blindly (*n* = 1)	PT6: The learner can play a game by giving random answers without relating them to the mathematical topic.

Table 4 shows that the unclarity of the game and incompatibility of the game with the mathematical topic were the problems that were mostly emphasized by the pre-service teachers. In addition, for five of the pre-service teachers, the inappropriateness of the game for students' readiness and grade levels and technological problems were potential problems that might be encountered when using digital mathematics games. Time management, classroom management, students' lack of motivation, boringness of the game, and playing digital games blindly were problems that were less frequently emphasized by the participants when using digital mathematics games.

Discussion and Conclusion

The purpose of the study was to explore pre-service teachers' considerations for using digital mathematics games in their future classrooms. The present study focused on pre-service teachers' intention to use digital games in their mathematics classrooms, their purposes for using digital mathematics games in classrooms, their sequencing of digital mathematics games in lessons, their considerations about the possibility of teaching a mathematical topic entirely with digital mathematics games, their considerations about digital mathematics games when planning to use them in their classrooms, and the potential problems foreseen by them when using these games in their classrooms. Below, the findings are discussed in line with the literature on digital games.

The findings showed that all pre-service teachers intended to design and use digital mathematics games in their classrooms when they start their teaching profession. This is promising because they were aware of the potential benefits of digital mathematics games and were willing to use digital mathematics games in their future classrooms despite the fact that designing digital mathematics games requires considerable time and effort from the participants. This finding is in line with the findings of previous research focusing on teachers' digital game use (e.g., Fishman et al., 2014; Takeuchi & Vaala, 2014). For instance, 513 out of 694 teachers (74%) in Takeuchi and Vaala's (2014) survey expressed that they used digital games for instructional purposes with their students and 55% of game-using teachers indicated that they used digital games at least once a week. Similarly, 83% of the teachers in

Fishmen et al.'s (2014) survey expressed that they used digital games for teaching at least monthly (i.e., 18% daily, 38% weekly, and 27% monthly).

The findings also revealed that roughly one-fifth of the pre-service teachers considered that digital mathematics games can be used for the following purposes in the introduction part of the lesson: attracting students' attention, increasing their curiosity, motivating them to the lesson, checking their prior knowledge or recalling their prior knowledge. This finding is interesting because although the participants attended a fourteen-week elective course on digital game design and consequently had gained enough experience about digital games only a small portion of them referred to the aforementioned purposes of using digital games in mathematics classrooms. Additionally, this finding is in contrast with past research that reported on the perceived values of digital mathematics games (e.g., Divjak & Tomic, 2011; Hu & Sperling, 2022). For instance, in Hu and Sperling's (2022) study, exactly half of the pre-service teachers with "extremely and very useful ratings" indicated that digital games make learning motivating. What is more, one of the most important characteristics of digital games is that they should be engaging, entertaining, and thrilling to play so students will be driven to keep playing and learning (Hu & Sperling, 2022). Many researchers also paid attention to the fact that digital games are principally designed for the purpose of improving students' academic achievement and motivation to learn (e.g., Baek, 2008; Divjak & Tomic, 2011). Therefore, it is regrettable to report that the majority of the participating pre-service teachers overlooked the basic rationale for using digital games in mathematics classrooms.

Additionally, more than half of the pre-service teachers considered that digital mathematics games can be used for the purpose of teaching mathematics in the main part of the lesson. More strikingly, all but one of the pre-service teachers indicated digital games can be used for the purpose of doing exercises, practicing, assessing learning, and identifying deficiencies in students learning in the last part of the lesson. It is worth noting that although, all but one of the pre-service teachers considered that digital games can be used for doing exercises, only a little more than half of them considered that digital games can be used for teaching mathematics. This finding is in line with the findings of Hu and Sperling (2022) who also found that 89% of the pre-service teachers indicated that they would lecture before administering a digital game. The literature review studies also reported that most of the researchers chose digital mathematics games as supplemental tools for instruction rather than for the purpose of constructing new knowledge (e.g., Ke, 2016; Pan et al., 2022).

Another finding of the current study is that eleven pre-service teachers thought that it is not possible to complete a mathematics lesson and teach a

mathematics topic without the need to do any other activity other than the digital game. Five pre-service teachers thought that this depends on the digital game and the mathematical topic that is being taught. Two pre-service teachers considered that it is possible to teach a mathematics topic without the need to do any other activity. Hu and Sperling (2022) emphasized that digital games that can be used to teach the entire lesson without the need for non-game activity are often designed with more sophisticated technological elements with regard to duration, narration, visual, and gaming mechanics. Therefore, the pre-service teachers in the current study might have perceived that it would be difficult for them to create or get access to well-designed digital games that can replace the entire lesson due to lacking knowledge about the aforementioned advanced technological skills used in designing digital games. For all these reasons, it is important to strengthen pre-service teachers' programming knowledge and skills to design these kinds of digital games or to provide easy access to such well-designed digital games to improve the functionality of digital games in mathematics education.

In the current study, the pre-service teachers were asked to state to which points they would pay attention when planning to use a digital mathematics game. Pre-service teachers' considerations were related to compatibility with the mathematical topic, clarity of the game, appropriateness of the game to students' readiness and grade levels, enjoyment of the game, ensuring the absence of errors and misconceptions in the mathematical content, and connections with daily life. All these considerations were mentioned in the previous studies as the issues that should be taken into account when using digital games (e.g., Baek, 2008; Hu & Sperling; 2022; Joung & Byun, 2021; Pan et al., 2022). The pre-service teachers' meaningful and diverse considerations on this issue can be attributed to the fact that they became experienced in the Scratch program and designing mathematical games with Scratch during the course of this study. Pre-service teachers' considerations, which are also supported by the literature, may be useful in choosing appropriate digital games for their future students.

Finally, the findings showed that the pre-service teachers foresaw the following potential problems when using digital games in their future classrooms: unclarity of the game, incompatibility of the game with the mathematical topic, inappropriateness of the game to students' readiness and grade levels, technological problems, time-related problems, classroom management, students' lack of motivation, boringness of the game, and playing blindly. The pre-service teachers' considerations about the potential problems regarding digital mathematics games may be associated with the experiences they gained during the course of this study. All of the potential problems expressed by the pre-service teachers were also identified in the related

literature on digital games (e.g., Avraamidou et al., 2015; Baek, 2008; Can & Cagiltay, 2006; Hu & Sperling; 2022; Jensen & Skott, 2022; Rice, 2007). Having various ideas about the potential problems that might be encountered when using digital mathematics games may help pre-service teachers prevent these problems without encountering them in their future classrooms.

This study was carried out with pre-service mathematics teachers. Further study with in-service mathematics teachers might be conducted to see the current status of digital game use in mathematics classrooms. In this way, their considerations related to the use of digital mathematics games, their preferences related to digital mathematics game types and digital mathematics game content, their purposes for using digital mathematics games, and finally their sequencing of digital mathematics games in their lessons might be uncovered.

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Appendix

Digital Mathematics Games Questionnaire

1) When you start your teaching profession, would you like to use digital mathematics games, designed by you or by others, in your lessons? Yes or No. Explain your answer.

2) Would you like to design digital mathematics games when you start your teaching profession? Yes or No. Explain your answer.

3) In which part of the mathematics lesson should a digital mathematics game be used? For which purposes should it be used?

4) Is it possible to complete a mathematics lesson and teach a mathematics topic without the need to do any other activity other than the digital game? Explain your answer with reasons.

5) Suppose that you are planning to use a digital game, developed by yourself or someone else, in your mathematics lesson.

a) To which points would you pay attention?

b) With which problems would you possibly encounter?