

Evaluation of scratch-based educational digital games from the perspectives of prospective teachers

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ABSTRACT

This study evaluates educational digital games developed in Scratch from the perspective of prospective primary school teachers. This research investigated participants' perceptions of educational digital games (EDGs), their experiences with these games, and their views on EDGs' contribution to mathematics instruction. The study used a phenomenological design, which is a qualitative research approach, and involved 16 final-year prospective teachers from the primary education department of a state university's faculty of education during the 2023–2024 academic year. Data were collected through semi-structured interviews and analyzed using content analysis. Five themes emerged from the findings: the concept of educational digital games, their use in mathematics teaching, game design, challenges encountered in the games, and feedback on design. Participants defined EDGs as effective instructional tools that capture students' attention, make learning enjoyable and lasting, and help to concretize abstract concepts. Overall, the findings suggest that educational digital games can enhance student motivation and conceptual understanding in mathematics education and serve as a valuable tool for developing pre-service teachers' digital pedagogical competencies.

KEYWORDS: Educational Digital Games; Scratch Program; Mathematics Education

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1. Introduction

The rapid growth of portable devices and digital technologies has directly impacted educational processes. New technologies are integrated into educational environments to facilitate and reinforce learning and provide more interactive learning experiences. The concept of play has also become digitized, and children's and students' play habits have become significant variables shaping learning processes as they integrate with technology use practices (Gee, 2003; Prensky, 2001). Furthermore, game-based learning approaches are gaining importance, and it has been emphasised that digital games can support the learning process, particularly in mathematics teaching (Gök, 2020). In this context, digital games have significant potential, especially in mathematics teaching, to reduce learning difficulties and help students understand abstract concepts. Mathematics instruction has a structure that demands varying levels of conceptual understanding, depending on students' individual differences. Consequently, although students learn mathematical concepts more easily, learning difficulties become more evident in certain subjects, especially those with high levels of abstraction. One of the main reasons for this is that certain mathematical concepts are more readily

integrated into mental processes, whereas others have more complex cognitive structures. For instance, fractions are among the most challenging topics for students to conceptually understand (Dehaene, 2020). Thus, there is a need for innovative teaching tools that can increase students' engagement in the learning process and facilitate the comprehension of abstract concepts. The increasing digitalization of educational environments has diversified teaching materials in parallel with this transformation. Game-based learning approaches enhance student motivation, make learning enjoyable, and offer a powerful alternative to traditional instructional methods (Çetin, 2013). Recent research also shows that interest in the use of digital games in mathematics education is rapidly increasing and that research in this field has grown considerably (Poçan, 2023; Engin, 2023).

It is believed that developing effective digital tool design skills is essential for teachers before graduating from teacher training programs (Özdemir, Basır, Balbay, Meredova, et al., 2021). Being competent in designing and utilizing digital tools not only strengthens the professional qualifications of prospective teachers but also affects teaching quality across disciplines. Mathematics as a discipline and mathematics teaching are areas where the impact of digital pedagogical competencies is evident. Teachers who integrate digitalisation into their mathematics instruction can more effectively engage students. Computer games provide alternative solutions and perspectives for addressing difficulties and motivational challenges in subjects such as multiplication tables, vocabulary acquisition, language learning, pronunciation, writing, formulas, and rules (Çetin, 2013). Consequently, it has become critical for prospective teachers to develop these competencies and master technology-supported teaching processes to increase student engagement.

Mathematics is considered a compulsory subject globally, at all levels from primary school onward, as it was in ancient times (Demir, 2019). Indeed, fostering students' enjoyment of mathematics from the outset of primary school is an essential concern for classroom teachers. Schools are entirely different worlds for students who begin their education. To help students who leave their family environment for the first time adapt more easily to school, greater emphasis should be placed on play-based activities in the learning process (Baltayeva, 2021). Using games to teach mathematics in primary school has proven highly effective, and the use of mathematical games is particularly important, especially for students in the early grades (Doğan, 2019). As emphasised in Boz's (2018) study, concretizing abstract mathematical concepts by relating them to students' experiences and through play significantly supports conceptual understanding. Intelligence games, especially those implemented at the primary school level, are among the effective tools that contribute to this concretisation process in mathematics teaching. In addition, developing digital versions of these educational games enables mathematical concepts to be conveyed in a more comprehensible, enduring, and structured manner.

Fractions, one of the more complex forms of the number concept, help students understand the relationships between numbers by illustrating the whole-part relationship. There is a growing demand for innovative teaching tools that can engage students and support conceptual understanding in teaching conceptually abstract and challenging topics such as fractions. With the digitalization of educational environments today, teaching materials are diversifying in parallel. Notably, game-based digital learning applications both capture the attention of primary school students and provide interactive environments that enhance conceptual understanding.

The primary objective of this research was to evaluate the contribution of two educational digital games developed using the Scratch program to the teaching process, aligned with the requirements of the digital age, to enhance primary school students' conceptual understanding of fractions. This research also seeks to identify prospective primary school teachers' perspectives on the design of

educational digital games for mathematics instruction. Accordingly, the impact of prospective teachers' experiences with the digital game design process on their creative thinking, problem-solving abilities, and technology-based teaching skills is also a focal point of research. The study not only assesses the contributions of digital game-based teaching to mathematics learning but also highlights the need to incorporate innovative practices, such as educational game design, into teacher training programs.

Game-based approaches are regarded as essential alternatives for overcoming the difficulties encountered in mathematics instruction. Recent research indicates that interest in using digital games in mathematics education is rapidly increasing, and the number of studies in this field has grown considerably (Poçan, 2023). Educational digital games not only foster positive attitudes towards learning but also help concretize concepts. In this respect, the use of digital games to teach abstract concepts is an effective method for enhancing learning retention (Boz, 2018; Doğan, 2019). In this context, the use of digital games in teaching fractions offers a significant opportunity to improve students' conceptual understanding. Game-based learning approaches capture students' attention and make learning more enjoyable, particularly at the primary school level (Baltayeva, 2021). However, for effective integration of digital games into mathematics teaching, teachers must possess adequate knowledge and skills in this area. Teacher candidates' experiences in digital game design both facilitate the integration of technology in the instructional process and foster their creative thinking and problem-solving skills (Özdemir, Basır, Balbay, Meredova et al., 2021).

Existing research demonstrates that studies on the use of game-based digital tools in mathematics education primarily focus on middle and high school levels (Gök & İnan, 2021; Taş et al., 2023; Demir & Bilgin, 2021); however, research on fractions at the primary school level remains limited. This study addresses a significant gap in the literature. Additionally, research examining pre-service teachers' experiences with the digital game design process is quite scarce. Therefore, this study offers original data regarding the development of digital pedagogical skills in teacher training programs.

Furthermore, while most studies on the use of block-based programs such as Scratch in education focus on student achievement (Permatasari, Yuana & Maryono, 2018; Çilengir & İzmirlı, 2023; Çakıroğlu & Muştuoğlu, 2025), this research offers a different, application-oriented perspective by examining prospective teachers' experiences. Additionally, this study is expected to contribute to the literature by highlighting the significance of innovative teaching practices in teacher training programs. Digital game-based instruction not only supports student learning but also enhances prospective teachers' technology integration skills. Within this framework, the research aims to examine how educational digital games developed through Scratch contribute to the teaching process in developing primary school students' conceptual understanding of fractions. In this regard, the following research questions were addressed:

1. What are the prospective primary school teachers' perspectives on the concept of educational digital games?
2. What are the prospective primary school teachers' perspectives on the use of educational digital games in mathematics instruction?
3. What are the prospective primary school teachers' perspectives on educational digital games designed for mathematics instruction?

2. Theoretical Background

When we discuss block-based game design, Scratch is one of the first programs that comes to mind and is favored by teachers and teacher candidates for its ease of use and simplicity. Studies on Scratch have been conducted across the fields of science, mathematics, and visual arts, primarily focusing on middle school students. When adequate resources are available, educational digital games developed using Scratch can support teaching and learning. Both domestic and international research (Fang, 2012; Korkmaz, 2012; Korkmaz & Altun, 2014; Lau & Yuen, 2011; Maloney et al., 2010) confirms the effectiveness of digital games, educational digital games, and Scratch in teaching; however, research addressing the use of these tools in mathematics is limited. In both contexts, it is emphasized that digitalization and the use of Scratch facilitate learning and positively impact the teaching-learning process. Scratch facilitates mathematical thinking by fostering creative problem-solving and the development of logic and reasoning in response to various forms of feedback (Calder, 2010). Mathematical games designed with Scratch have been shown to reduce learning difficulties in mathematics for many students (Çubukluöz, 2019). Research by Selva Büşra Turan (2022) found that using Scratch enhances computational thinking skills and introduces fun and variety into mathematics instruction. Seher Avcu's (2023) research, however, indicated that prospective teachers reported that designing digital mathematics games with Scratch is time-consuming, may present coding challenges, and requires teachers to possess sufficient knowledge and skills in using Scratch.

3. Method

This section outlines the research design, sample selection, data collection procedures, validity and reliability of the data collection instruments, and the data analysis methods.

3.1. Research Design

A phenomenological research design was employed to examine how prospective primary school teachers conceptualize and experience “educational digital games” and to investigate their effects on them. Phenomenology is used to examine how people interpret their personal experiences and focus on the nature of meaning-making (Patton, 2002).

3.2. Participants

In qualitative research, purposeful sampling is used to identify suitable participants. Additionally, the study's purpose, research questions, and context must be carefully considered when selecting the sample. In this context, critical case sampling, a form of purposive sampling, was used. The rationale for purposeful sampling was to select information-rich cases for more in-depth research. In purposeful sampling, the researcher determines the purpose based on the information to be conveyed (Patton, 2002/2014). Therefore, a phenomenological design was used, and purposive sampling was employed to examine how prospective primary school teachers conceptualize and experience “educational digital games” and to investigate their effects on them. The sample comprised 16 final-year students from the Division of Classroom Education, Department of Primary Education, Faculty of Education, Pamukkale University. The research data were collected through semi-structured interviews with prospective primary school teachers during the spring semester of the 2023–2024 academic year.

Participants were voluntarily selected and informed of the research purpose before the study, and they provided written consent. Ethical approval was also obtained for the research. The number of

participants was within the recommended sample size range for phenomenological studies, and data saturation was achieved through the interviews.

Table 1 *Distribution of Prospective Primary School Teachers by Demographic Variables*

Variables		f	%
Gender	Female	10	%62.50
	Male	6	%37.50
Digital Game Playing	Yes	9	%56.25
	No	7	%43.75
Period of Digital Game Playing	Currently	5	%55.55
	7-15 years old	4	%44.45
Digital Game Players' Gender	Female	5	%55.55
	Male	4	%44.45
Non-Digital-Game-Players' Gender	Female	5	%71.42
	Male	2	%28.58

Table 1 shows that women constituted the majority of participants (62.50%). Furthermore, 56.25% of the participants reported playing digital games, while 43.75% reported not playing games. Among those who played digital games, 55.55% reported they were still playing, and 44.45% reported they had played at a young age. The gender distribution of digital game players showed that the percentage of women (55.55%) was similar to that of men (44.45%). In contrast, among participants who do not play digital games, the proportion of women (71.42%) exceeds that of men (28.58%).

Semi-structured interviews were conducted at the Faculty of Education in a suitable venue on a day and time determined by the participants. Research data were collected from interviews with prospective teachers. After the interviews, which lasted an average of 11 minutes, the data obtained were transferred to a computer. During the interviews, participants were asked to share their knowledge of digital games and the Scratch program, and to evaluate the usability of the designed educational digital games for mathematics instruction, as well as their visual and technical features, organizational structure, and curriculum alignment.

3.3. Data Collection Tool

Semi-structured interview forms were used to collect data for this research. A qualitative data collection method, semi-structured interviews rely on predetermined, basic questions but also allow for flexibility in asking additional questions based on participants' responses (Cresswell, 2013). This method was chosen as a suitable tool for gaining an in-depth understanding of participants' experiences, opinions, and perceptions.

The preparation of the semi-structured interview form involved four stages: (1) Determining Research Questions — interview questions were developed in accordance with the fundamental questions and objectives of the research; (2) Structuring the Questions — open-ended questions were designed to allow participants to express their opinions freely; (3) Expert Opinion and Pre-Test — the designed

form was submitted to field and subject matter experts for review and was revised accordingly (Yıldırım & Şimşek, 2018); (4) Finalisation — the form, which initially comprised 15 questions, was reviewed and the number reduced to 13, with pilot interviews conducted with three students outside the main sample. Sample questions included: “What are your views on the use of educational digital games in mathematics instruction?” “What challenges did you encounter while playing the designed games?”, and “How would you evaluate the games in terms of their suitability for the curriculum?”

3.4. Role of Researchers and Educational Digital Game Design (Scratch Learning Process)

Various educational digital game designs (EDGs) are implemented at every stage of education, from primary school onward. The Scratch program is seen as a coding tool used in education and has become widespread with digitalisation. Block-based and free, Scratch can be used online and offline and can run on both desktop computers and various mobile devices. In this study, the researcher conducted comprehensive preliminary research into digital game design and the Scratch programming language before initiating the EDG design process. Through online resources and instructional videos, the researcher became familiar with the Scratch interface, menu options, and game design. After a learning period of approximately 1 to 1.5 months, the researcher attained proficiency in designing various digital games, such as snake, maze, and football games. Having acquired the necessary knowledge and skills, the researcher then developed two digital games covering proper, improper, and mixed-number fractions, aligned with the learning outcomes of the 4th-grade elementary school mathematics curriculum. A classroom teacher was consulted for feedback on the games, and refinements were made accordingly.

Figure 1 Space Game



The astronaut “Pay” gives the player instructions on earning points by traveling through planets and stars in a spaceship. The space game is played using the space bar, arrow keys, and mouse.

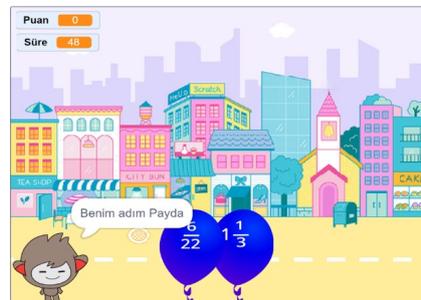
Figure 2 Space Game



The game aims to foster interdisciplinary connections by enabling players to explore planets before the game begins. When players click on a planet, they hear a unique sound for that planet and can learn about it, establishing connections across multiple disciplines.

Figure 3 *Space Game*

The primary objective is for players to start collecting points when they land on proper fraction stars and earn +6 points within 60 seconds. If the player lands on an improper fraction star instead, their score decreases by 1 point. If the player fails to earn +6 points within the allotted time, Astronaut Pay will encourage them with the message “Try again, don’t give up...”

Figure 4 *Balloon Popping Game*

In the balloon-popping game, after choosing a colourful city, colourful balloons are programmed to fly around. Balloons serve as puppets, and the Nano puppet “Payda” functions as the avatar. The balloon-popping game is played only with the mouse.

Figure 5 *Balloon Popping Game*

In the first balloon game, the objective is to start earning points by clicking on improper fraction balloons and to earn +6 points within 30 seconds. If the player clicks on a proper fraction balloon, a warning sound plays, and no points are earned. If the player cannot earn +6 points in time, the Avatar (Nano) “Payda” will encourage them with “Try again, don’t give up.”

Figure 6 Balloon Popping Game

Under the same guidelines and rules, the final game aims to pop mixed-number-fraction balloons. Sound effects play an essential role in Scratch designs; in the balloon-popping game, a balloon-popping sound and a warning sound for incorrect clicks are used.

3.5. Data Analysis

The qualitative data obtained in the study were analysed using content analysis. The analysis process followed the procedures outlined by Miles and Huberman (1994) and Yıldırım and Şimşek (2022). In this context, the participants' statements were first transcribed, and the texts were read multiple times to ensure familiarity with the data. The data were examined using the open coding technique, and sub-codes were generated from expressions with similar meanings. These codes were grouped within the framework of semantic integrity, categorised, and finally developed into themes. Throughout the coding and thematicization process, the data were continuously reviewed, and care was taken to ensure consistency and validity across themes.

3.6. Data Reliability

To increase coding reliability, two researchers independently coded the data; the resulting codes were then compared, and any agreements and disagreements were discussed. Inter-coder agreement was calculated using the formula proposed by Miles and Huberman (1994), and the mean reliability for the themes was 96% (range: 75–100), indicating agreement between the researcher and the independent expert. Direct quotations from participant statements were included to support the findings and strengthen the validity of the interpretations. Both inductive and deductive approaches were used during the analysis.

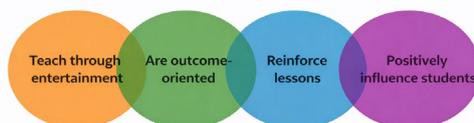
4. Findings

Content analysis of interview data from prospective teachers identified five primary themes: Educational Digital Games, Application of Educational Digital Games in Mathematics Instruction, My Design, Challenges Encountered in the Game, and Feedback on Design. Pseudonyms were assigned to all participants to ensure confidentiality.

4.1. Educational Digital Games

Participants were asked about their understanding of educational digital games. They described these games as tools that are educational, teach through entertainment, are outcome-oriented, reinforce lessons, and positively influence students. Four sub-themes were identified: Learning Through Fun, Attention Engagement, Reinforcement Tool, and Outcome-Oriented Learning (Figure-7).

Figure 7 Educational Digital Game Theme and Sub-Themes



4.1.1. Learning Through Fun

Participants indicated that educational digital games serve not only entertainment purposes, but also support students' learning processes by enabling them to learn through fun.

Damla, "digital games are for spending free time, ... educational digital games are for teaching and entertaining."

Nehir, "digital games are for spending my free time, they entertain... educational digital games... students both have fun and learn something."

4.1.2. Attention Engagement

Participants observed that educational digital games play a significant role in capturing students' attention during the lesson.

Ahmet, "As someone who enjoys games, I find it essential that a game captures attention at the outset..."

Ayşegül, "In first and second grades, students' attention is often easily diverted. However, when I introduce content through a game or an application on the smart board, students become more attentive, and the lesson becomes more engaging... I tried it in third grade and fourth grade as well, and I observed similar results; they demonstrated increased focus during lessons..."

4.1.3. Reinforcement Tool

Participants indicated that educational digital games are used to reinforce students' achievements in lessons and to further support their learning.

Kaan, "digital games ... are intended for entertainment, while educational digital games ... are to reinforce learning lessons."

Ela, "they are...used to reinforce learning outcomes..."

4.1.4. Outcome-Oriented Learning

Participants indicated that educational digital games are intentionally designed to align with curriculum learning outcomes and contain content that supports educational objectives.

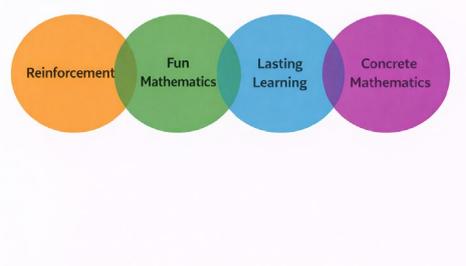
Lale, "digital games are not designed according to specific purposes and instructions, whereas educational digital games are games developed in accordance with the learning outcomes outlined in the curriculum."

Elif, "digital games are primarily for enjoyment and generally do not contain educational content, whereas educational digital games address subjects related to specific learning outcomes..."

4.2. Application of Educational Digital Games in Mathematics Instruction

Prospective primary school teachers were asked about the potential effects of educational digital games on mathematics instruction. They stated that the use of educational digital games could make lessons more engaging and tangible, effectively reinforce the lesson, and promote retention. Four sub-themes emerged: Reinforcement, Fun Mathematics, Lasting Learning, and Concrete Mathematics (Figure-8).

Figure 8 The Theme of Using Educational Digital Games in Mathematics Teaching and Sub-Themes



4.2.1. Reinforcement

Zeynep, "...I think they are very effective, ... as we are in the digital age, students are interested in games, so educational digital games are important in education and greatly contribute to reinforcement. I also find them beneficial in mathematics instruction as they allow students to learn without becoming bored."

Fatma, "...there are positive aspects. ...educational digital games may be suitable for reinforcing instruction."

4.2.2. Fun Mathematics

Elif, "It can be enjoyable, after all, there are competitions or various appealing visuals. They can be used in math teaching... so they can be used in math teaching, it would be fun."

Mehmet, "For lessons to be enjoyable and for students to take pleasure in learning, they need something fun. These games are both educational and fun, and I find them quite useful. They can be used especially in math teaching."

4.2.3. Lasting Learning

Damla, "... math is a bit challenging subject for children in general... games both entertain children and make learning more permanent, so I think they can be used in math..."

Veli, "...Concepts are more memorable for students, that is, we actually integrate them into their daily lives because they are doing themselves, they are playing themselves, so I think games enhance retention and facilitate learning."

4.2.4. Concrete Mathematics

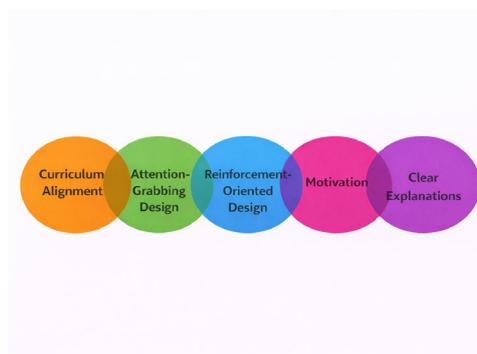
Hasan, "...children think concretely, and since mathematics is abstract, it is beneficial to make it concrete and teach it through games."

Jale, "...because mathematics is a highly abstract subject; many topics are difficult for children to visualise in their imagination. Therefore, I think it is useful to concretise and visualise topics."

4.3. My Design

Prospective classroom teachers were asked for their opinions on the educational digital game developed by the researcher. Participants generally reported that the game aligned with the curriculum, contained attention-grabbing elements, featured an engaging space-and-planet theme, had a clear, straightforward design, and effectively enhanced student motivation. Five sub-themes were identified: Curriculum Alignment, Attention-Grabbing Design, Reinforcement-Oriented Design, Motivational Value, and Clear Explanations (Figure-9).

Figure 9 My Design Theme and Sub-Themes



4.3.1. Curriculum Alignment

Ayşe, "...the sequence of topics already goes like this, first we teach proper fractions, then improper fractions, and finally mixed-number fractions, so it is appropriate for the goal and learning outcomes..."

Nehir, "Proper fractions and improper fractions are already 4th-grade topics, ...they are very suitable for the curriculum. ...I can have the children play these games constantly."

4.3.2. Attention-Grabbing Design

Ayşegül, "...learning about planets at first allows them to acquire knowledge about planets independently of mathematics... and this captures their attention... they feel the need to learn proper fractions, improper fractions, and mixed-number fractions with the motivation to succeed in the game."

Ali, "The games are engaging; space already attracts children's attention, and planets, stars, and spaceships are great, so students will have an enjoyable learning experience while playing."

4.3.3. Reinforcement-Oriented Design

Lale, "...it can be implemented during the teaching phase; however, as a game, it can be much better in the reinforcement phase."

Ela, "...in terms of reinforcement, it's not because it doesn't introduce new information. Students without prior knowledge of the subject won't know proper fractions, but for reinforcement, the game is appropriate."

4.3.4. Motivational Value

Ahmet, "...it's a game to be played calmly, while the second one demands increased speed, so players can recognise their progress as the difficulty increases... There are motivational words even in the messages at the end, particularly when students are unsuccessful, which I think is a very positive feature..."

Ayşe, "... Motivational words are included in the end-of-game messages when you can't succeed in it, which I think is very nice, and I think it's quite appropriate for maintaining the integrity of games."

4.3.5. Clear Explanations

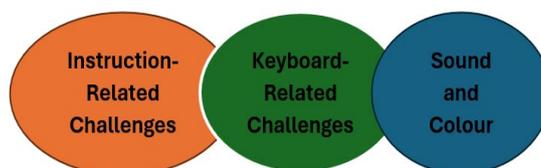
Veli, "I think it's understandable because the instructions are always like that, that is, you'll start now, you have 30 seconds, you'll get points for each one, you need to reach 6 points, etc. The instructions were clear, that is, they were nice."

Hasan, "The instructions in the games were clear and concise; they were very understandable and easy from the students' perspective."

4.4. Challenges Encountered in the Game

Participants reported that specific challenges in the designed game stemmed from the avatar's instructions during gameplay and from keyboard usage. Additionally, some participants identified sound and colour effects as sources of difficulty. Three sub-themes were identified: Instruction-Related Challenges, Keyboard-Related Challenges, and Sound and Colour Effects (Figure-10).

Figure 10 *The Theme of Challenges Encountered in the Game and Sub-Themes*



4.4.1. Instruction-Related Challenges

Mehmet, "...the instructions appeared too quickly in the second game, whereas they were more appropriately paced in the first game..."

Ayşe, "I only missed the instructions, I mean, if there were verbal instructions... it would be more suitable for elementary school students, and when I missed the instructions, I missed parts of the game."

4.4.2. Keyboard-Related Challenges

Veli, "The first game... was somewhat difficult because we played with the keyboard, but using the mouse made gameplay a bit easier... it might be a little difficult for younger children. It could be easier if we play with the mouse, but a 4th-grade student could play it more comfortably..."

Elif, "...we press the space bar to move...but we press the arrows for direction in normal digital games, in online games, a single key is used to both change the direction and move forward ... I got a little confused about that..."

4.4.3. Sound and Colour Effects

Ahmet, "...the background colours in the balloon game were overly bright and complex...the background was too striking, too colourful, I think it could be a little simpler... it might be more appropriate if the colours were a little closer to reality."

Elif, "...there was only an auditory signal to indicate incorrect answers; we could support that signal with a visual indicator, such as a cross; it could give a warning for incorrect answers."

4.5. Feedback on Design

Regarding the researcher's game design, participants primarily evaluated the speed of the games. They also offered various suggestions concerning time management and the sizes of the shapes used in the game. Four sub-themes were identified: Game Speed, Time Management, Shape Size, and Feedback-Based Adjustments (Figure-11).

Figure 11 *The Theme of Design Feedback and Sub-Themes*



4.5.1. Game Speed

Mehmet, "Initially, the instructions in the second game progressed quickly, actually, however, the first game was a bit more suitable for the game features..."

Kaan, "...the game featuring stars could have exhibited a more fluid progression, and the spacecraft could move at a consistent speed... The speed could have been made adjustable, for example, we could have placed a speed variable on the interface, 0.5, 1, 1.5, etc., allowing for automatic adjustment..."

4.5.2. Time Management

Ayşegül, "...the allotted time in the second and third games could have been extended. Children get used to the game within 30 seconds, and the time expires. The duration could have been extended in the balloon game."

Mehmet, "...In the first game, the time was a bit limited; in my opinion, there were too many fractions presented for the available time... For elementary school students, the first game might be too brief, whereas the second game was appropriate in terms of timing."

4.5.3. Shape Size

Nehir, "The background in the space game was very nice; however, the planets were a bit small... It would be better if they were a bit bigger. The spaceship could also be bigger and have a different shape... it could be more colourful and eye-catching because I had difficulty seeing it initially."

Zeynep, "...I thought what if the spaceship could be a little smaller... The space between stars could be increased, or the spaceship could be smaller... the image of the planets could be enlarged."

4.5.4. Feedback-Based Adjustments

Fatma, "...the balloons might not have come one after another, that is, they appeared to overlap, making the fractions on the back balloon difficult to see... the characters and avatars were eye-catching and appealing to students. Could a human have been used instead of an avatar?..."

Ali, "In the space game, when you add proper fractions, your score increases, and then identifying improper fractions within the same game would further increase points, so the one with the highest score would win, fostering competition among students."

5. Discussion and Conclusion

The research findings indicate that prospective teachers regard educational digital games as effective tools for supporting student learning by making lessons enjoyable, capturing attention, enhancing motivation, and reinforcing acquired knowledge. In mathematics instruction, such games contribute to lesson enjoyment and concreteness, facilitate comprehension of abstract concepts, and promote long-term retention. Participants reported that the game aligned with the curriculum, featured attention-grabbing themes, and had clear, simple narration. However, certain aspects, including the speed of the game instructions, keyboard use, and sound and colour effects, posed challenges. These results indicate that educational digital games have significant potential to enhance student motivation and learning processes in mathematics instruction.

In the 21st century, children's play culture is changing in response to a world that is developing and evolving. Along with the changing play culture, digital games have become increasingly prominent in children's lives. This has attracted educators' attention, prompting them to seek ways to use digital games in education and leading to the emergence of the concept of "Educational Digital Games" (EDG). According to the results of this research, participants differentiated between EDG and digital games when defining EDG. They stated that digital games are non-educational, intended for entertainment and leisure, and can have negative consequences, while defining EDGs as educational, development-oriented games that reinforce lessons and positively influence students. The effect of a gamified educational application on a group of students is closely linked to the enjoyment experienced during gameplay (Ar and Akgün, 2014).

The study found that prospective primary school teachers believe that using EDGs in mathematics instruction would make lessons more enjoyable and concrete, thereby increasing their effectiveness and supporting long-term retention. These findings suggest that knowledge acquired in EDG-supported lessons can be retained and that EDGs can play a significant role in facilitating permanent learning (İlkay & Atik, 2024). Edusei (2022) also notes that when students regard learning mathematics as enjoyable and engaging, they are more likely to develop positive attitudes towards mathematics. The findings from this research are consistent with previous research (Aydın & Ata, 2024; Öztop, 2022; Yıldız, Tarım & Aktaş, 2024; Yong et al., 2021; Zabala-Vargas et al., 2022).

In the digital age, teaching materials that facilitate concretisation are evolving and increasingly being replaced by digital teaching tools. Contemporary students are immersed in the digital world and its technologies; considering their interests when structuring and concretising lessons will facilitate learning. Therefore, the undergraduate education of prospective primary school teachers is critically important. Indeed, to use a game effectively as a teaching tool in the classroom, teachers need to align it with the curriculum and plan the entire lesson accordingly (Tokarieva, 2019). In conclusion, educational programs must keep pace with digitalisation and be enriched with content that supports the use of technological tools (Alagöz, 2023).

Participants in this study generally reported that the EDG design was compatible with the curriculum, enriched with attention-grabbing elements, understandable and straightforward, effective in increasing student motivation, and focused on reinforcement. Participants' statements that the simple and clear structure of the games increased motivation align with studies emphasising that motivational elements are decisive in game design (Malone & Lepper, 1987; Hamari et al., 2016). From this perspective, these findings show that game-based designs encourage students to play a more active role in the learning process. Öztürk (2019) also emphasised that content that provides opportunities for visualisation, practice, and reinforcement contributes more to student learning.

Motivation is a crucial component of the learning process. Highly motivated individuals are more willing and diligent in comprehending information. As a result, motivated individuals tend to enjoy their learning experiences. İşçi's (2020) research findings indicate that prospective teachers believed that educational digital games make education more enjoyable, increase students' motivation and interest in school, support the teaching of complex subjects, and improve students' academic achievement. One way to ensure motivation is to integrate elements that students use and enjoy in their daily lives into lessons.

In our study, some prospective classroom teachers found that the instructions in the balloon game progressed quickly, while those in the space game were slower and more appropriate. Difficulties experienced by prospective teachers in using the keyboard indicate that technical skills are also essential for implementing the designed game. In conclusion, sound and colour effects are critical for enhancing the pedagogical impact of EDGs and supporting in-game interaction.

Based on feedback, the duration of the designed space game could be increased to 90 seconds, and the balloon-popping game to 60 seconds. EDGs can accelerate learning processes. They allow students to receive instant feedback, thus speeding up the learning process. Technology will be most effective when integrated into classroom applications, rather than replacing teachers. In conclusion, educators should consider incorporating gamified instruction into coding education while taking students' individual needs and preferences into account (Taş et al., 2023).

The Scratch program, used by the researcher in game design, has also been utilised in previous studies and has contributed to the design and application of EDGs. Turan's study (2022) highlighted the importance of adapting the block-based programming tool Scratch for planning mathematics lesson outcomes. According to research by Pilon & Ruales (2024), teacher-made digital games significantly improved students' academic performance in 3rd-grade Mathematics.

5.1. Limitations and Future Directions

Based on the findings of this research, it is recommended that educational digital games that facilitate the concretisation of concepts and increase student interest should be systematically incorporated into primary school mathematics lesson plans. In undergraduate programs, modules can be implemented to develop prospective primary school teachers' competencies in designing digital games aligned with pedagogical objectives, and the effectiveness of these games can be measured through experimental research. Sample scenarios, instructional guides, and materials can be prepared to help teachers select and implement appropriate games for their lessons.

Given students' individual differences, different speed and level options can be offered in the games, and the impact of these variables on learning outcomes can be investigated experimentally. Finally, the effectiveness of themes that increase student interest and achievement-oriented content in mathematics lessons can be examined comparatively across different grade levels and subjects to determine which types of games and themes are more effective in concept teaching.

6. Declarations

6.1. Author Contributions (CRediT)

Author 1 (Mustafa Mızrak): Data curation; Formal analysis; Writing—original draft; Writing—review & editing; Visualization.

Author 2 (Name Surname): Conceptualization; Methodology; Investigation; Writing—review & editing.

6.2. Conflict of Interest

The authors declare that they have no known competing financial interests, institutional affiliations, or personal relationships that could have appeared to influence the work reported in this paper.

6.3. Funding Statement

This research received no external funding. Where applicable, the funder(s) had no role in the study design; data collection, analysis, or interpretation; manuscript preparation; or the decision to publish the results.

6.4. Data Availability Statement

Data are available from the corresponding author upon reasonable request.

6.5. Ethics Approval

This study was approved by the Pamukkale University Social and Humanities Research and Publication Ethics Committee (Approval No: E-93803232-622.02-449302; Approval Date: 06.11.2023). It has been determined that the research application demonstrates appropriate scientific conduct with respect to procedures and ethics. Informed consent was obtained from all participants prior to data collection.

6.6. Use of Artificial Intelligence (AI) Tools

After using this tool/service, we reviewed and edited the content as needed and take full responsibility for the publication's content.

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