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Article

Can mobile games be an option for teaching algebra?

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Abstract

The aim of this research is to analyze the experiences of seventh-grade students during the process of playing an educational mobile game that involves algebra topics and to reveal what they experience in such a learning environment, as part of a case study. Participants were nine seventh grade students who had low math achievement and spent a lot of time playing digital games. An educational digital game was developed regarding algebraic expressions and we asked students to play this game in their free times for two weeks. After practices with educational digital game for two weeks, semi-structured interviews were carried out with students. The collected data was analyzed qualitatively using the content analysis method. As a result, despite the technical challenges encountered by students in the game mechanics, they expressed overall satisfaction with the design of the game and the story employed in. The importance of game mechanics in the design of a mobile game was reaffirmed by the results obtained in this study

1. Introduction

It is known that it is recently difficult to imagine a modern education system without the infusion of digital technologies [1]. Mobile devices in the form of mobile phones and tablet computers, which have portable features, make it possible for education to be individualized, customized according to the needs of the student, and accessible anywhere and anytime [2],[3]. There are various definitions about mobile learning, which is considered within the scope of maintaining teaching and learning processes through mobile environments. Sarrab et al. [4] define mobile learning as learning that is carried out using mobile technologies with internet access and supports individual learning while providing the opportunity to participate in education at any time and place. Wang et al. [5] define mobile learning as the realization of learning independent of time and space with mobile devices such as phones with wireless access. Based on these definitions, providing flexibility in accessing educational content should be seen as an important advantage of mobile learning.

According to Larkin and Calder [6], mobile technologies offer new possibilities to develop students' mathematical thinking, engage them in the lesson and redesign their mathematics learning experiences. Mobile learning environments used in education enhance academic achievement by increasing motivation [7], providing flexibility in time and place for learning and ensuring accessibility [8], and making learning more enjoyable [9]. Çelik [10] stated that the use of mobile learning tools in education contributes to the individual learning speed of students and that they learn independently from the teacher. Mobile learning attracts students' interest in the course and facilitates them to manage their own learning processes by positively affecting their performance [11]. It is also possible to encounter learning processes within appropriately designed game-based applications in the context of mobile learning. Aktaş et al. [12] developed a mobile game for students to do the four operations (addition, subtraction, multiplication, division) mentally. They stated that the mobile game they developed increased students' mental operation skills. When Chang and Hwang [13] examined the trends in studies investigating mobile game-based learning, they stated that mathematics topics are rarely studied and worth exploring. In addition, Güler et al. [14] examined 22 experimental studies in the meta-analysis study in which they examined the effect of mobile learning on mathematics achievement and stated that it had a moderate effect in a positive direction as a result. With this research, it is aimed to make a contribution to the mathematics education literature on mobile game-based learning.

The aim of this study is to reveal the experiences of seventh grade students in an algebra course supported by an educational mobile game. According to this purpose, answers to the following research questions will be sought:

1. What are the students' views regarding their experience with the educational mobile game?
2. According to the students' views, how did the mobile game experience alter their problem-solving strategies?

2. Conceptual Framework

2.1 Game-Based Learning (GBL)

In the traditional learning model, there is a single-trial structure with input, process and output in which students perform tasks [15]. GBL model shown in Figure 1 is a model that allows the process to be more effective and efficient by using the game cycle in the input-process and output functioning in traditional teaching models. In educational games, the individual does not play the game once and quit, but can continue the game by improving himself/herself better with the loop and feedbacks in it. In GBL, by using this loop within the game, the learner is expected to continue the given tasks over and over again until they reach the desired level of success. This cycle is illustrated in Figure 1.

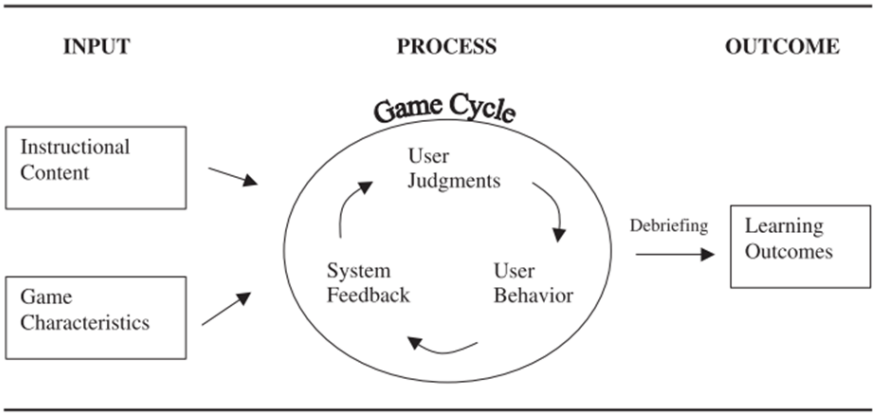

Figure 1. Input-process-output game model [15]

Intelligent tutoring systems that prioritize personalized instruction also support the learning process. Intelligent tutoring systems are complex software systems that apply artificial intelligence methods to the problems and needs of teaching and learning [16]. Despite their advantages in the teaching process, drawbacks such as high costs, low compatibility, high maintenance costs, and platform dependency [17] constitute the disadvantages of intelligent tutoring systems. In comparison to GBL, it is evident that they require significantly more software knowledge. In a study comparing intelligent tutoring systems and GBL, Wardaszko and Podgórski [18] stated that GBL significantly enhances students' enjoyment and motivation.

Elements of entertainment in the learning process provide students with important features in terms of relaxation and intrinsic motivation [19]. Thanks to their characteristics, games not only provide students with fun and pleasure, but also increase participation [20]. Even a student who shows no interest in the subject, feels bored during math lessons, and eagerly waits for them to end can still participate in a game played in the classroom environment [21]. According to Garris et al. [15], the power of games can be harnessed to engage students and achieve desired teaching objectives. The entertainment elements used in educational games play a significant role in determining whether the targeted learning outcomes can be achieved and whether the player will engage in the game-learning process [22]. In her study, Aymen Peker [23] stated that educational digital games used in in-class and out-of-class environments increased the academic achievement of middle school students and reduced the misconceptions of them. Başün and Doğan [24] stated that the use of games in mathematics education increased academic achievement in middle school students and had a positive effect on retention.

2.2 Mobile Learning (ML)

Mobile devices enable learning anywhere and anytime with features such as portability, internet connectivity and sensors. ML consists of three main components: focusing on devices, learning outside the classroom, and student mobility, incorporating various characteristics within its structure [25]. In ML, students can access information whenever they desire. Due to the algorithms operating in the background, mobile applications begin to display more relevant information that aligns with what students are searching for. Students have the opportunity to communicate simultaneously or asynchronously with their teachers, peers, and other instructional materials. ML environments can support students in flexible and multidimensional thinking by combining many sources of information [26]. In studies, it is stated that ML improves mathematical thinking [6], increases academic achievement [27] and motivation, contributes to the development of higher-order thinking skills [28], and helps to develop positive attitudes towards the course [11],[29]. According to Bray and Tangney [30], the use of mobile technologies allows the classroom environment to be reorganized in a way suitable for project-based and collaborative activities.

In terms of mathematics teaching, the use of mobile technologies in education allows students to interact with mathematics in a meaningful way [30]. Buchholtz et al. [31] stated that ML supports mathematical modeling, associates mathematical concepts with different realistic contexts and strengthens the bond between them. Using ML in mathematics education is an effective way to present mathematical content and has a positive impact on students' comprehension skills and their belief that they can succeed in mathematics [32].

2.3 Mobile Game-Based Learning (MGBL)

Transforming existing materials, such as lecture notes or textbooks, into formats suitable for smartphone screens is insufficient to meet the learning needs of youth who are constantly interacting with smartphones. There is a need for ML opportunities that facilitate learning not only in an accessible and cognitive manner but also affectively [33]. One such opportunity is MGBL. Mobile games used in ML environment provide an interactive and enriched learning experience by enhancing students' motivation to learn and promoting the acquisition of gaming strategies [34]. ML facilitates the implementation of individualized instruction and provides flexibility in terms of time and location [35] has led to the increasing prevalence of research on MGBL, especially in recent years [36]. MGBL has been studied in many different fields ranging from language teaching [37] to history education [38].

Games are integrated into learning in various forms, such as GBL, simulation games, and gamification [39]. MGBL is one of these forms. Learning through mobile educational games is among the fastest-growing trends in interactive learning approaches. It offers numerous opportunities for both individual and team-based, formal and informal learning [39].

Mobile games for learning, or MGBL, are a type of game specifically designed for educational purposes that can operate on mobile phones, smartphones, PDAs, or handheld devices [33]. The combination of the entertainment factor of mobile games, the flexibility of ML, and the benefits of games has led to the development of MGBL [40]. Studies [39], [40] indicate that MGBL can facilitate mathematics learning and is a promising alternative learning approach.

The key role of mobile game design is to design a game that can increase student flow [41]. The challenging aspect of designing educational games is the necessity to satisfy as many individuals as possible while also providing effective educational solutions [41]. In order to increase students' participation in the game, game mechanics need to be used correctly and effectively. In various studies in the literature, the factors affecting the design elements of the prepared mobile game were also mentioned. In the experiential game model developed by Kiili [42], he stated that in order to increase participation in educational games, there should be challenges, clear goals, clear feedback and a storyline appropriate to the player's skill and that the sound effect used in the game negatively affected the participation of the students. Chen et al. [43] state that the competitive aspects in games has a significant main effect on learning and should be included in GBL environments. Lu et al. [44] and Chen et al. [45], in their studies on educational mobile games, state that games with a storyline are more liked by students and increase their immersion in the game. When considered from the perspective of mathematics instruction, Gurjanow et al. [46] developed a project called Mobile Math Trails for Europe (MoMaTrE) to create a fully gamified platform for learning mathematics. They identified that the gamification app in their project met many flow criteria, such as real-time feedback, control over the process, task focus, clear objectives, difficulty, and the need for skill. From this perspective, it can be considered that applications suitable for MGBL could also be developed in mathematics education.

In addition to these positive features, it is also possible to encounter some negative situations related to MGBL environments. Some users may not want to enter longer texts on a virtual touchscreen keyboard. The limited screen size compared to desktop computers can also be a barrier [47]. Bray and Tangney [30] argue that technology use continues to be overwhelmingly limited to content consumption, resulting in a regression. Wardaszko and Podgórski [18] stated that MGBL

facilitates short-term learning, but it is not equally successful in achieving lasting learning. Additionally, poorly designed ML activities can lead to a heavy cognitive load, negatively impacting students' performance [48]. While mobile games may not be perfect in every aspect, they should be enjoyable and relevant to the learners; otherwise, they will not be engaging [33]. In their experimental study, Huizenga et al. [38] stated that students who received education with MGBL method realized more learning than students who participated in project-based courses.

Kurt [49] found that with mobile games, students' mental processing skills improved and they could see the relationship between variables faster. Chen et al. [50], as a result of their bibliometric analysis, stated that game-based instruction is used in mathematics courses to increase student motivation and engagement and to reduce learning anxiety. By the help of the current study, it is aimed to reveal the students' opinions about the educational mobile game grounded in the process of teaching algebraic expressions; and it is predicted that the mobile game will contribute to the literature by providing a perspective on how the mobile game affects students' algebraic problem solving process.

3. Methods and Material

3.1 Research Design

This study, which focuses on the process of mobile game-supported algebra teaching, seeks to address issues related to uncovering the strategies used by seventh-grade middle school students in solving algebra problems and their experiences with mobile games. To address these issues, a case study approach, one of the qualitative research designs, was employed. The aim of case studies is to obtain in-depth information about a particular situation [51]. Yin [52] classified case studies as a qualitative research design used to answer 'how' and 'why' research questions. In this study, case study approach was chosen because the students' gaming experiences will be evaluated based on their reflections after playing the game.

3.2 Participants

The study consists of nine students studying in the 7th grade in the 2022-2023 academic term. Gao et al. [53] stated that MGBL can provide more benefits for low-performing students. For this reason, the selection of the participants was determined by low level of math achievement and high digital game playing time. Participants were selected from among students with extensive gaming experience so that they could compare the mechanics of the developed educational game with those of other games. Additionally, the aim was to engage students who were curious about the game and attract their interest in the lesson through gameplay. The average mobile game playing time of 30 7th students at the same school was determined to be 4.8 hours, and students above this average were included in the study. Similarly, the average of questions answered correctly by the students in the last five mathematics exams being below the general average was used as the second criterion. Thus, nine students who met the criteria and volunteered among 30 students studying at the same level (7th grade) were included in the study. Table 1 shows the correct answers numbers of the students who participated in the study calculated over 20 math questions and their weekly game playing time in hours.

Table 1. Participants' average math scores and weekly game playing time

Participant Code	Gender	Average of Correct Answers (n=20)	Game Playing Time (h)
S1	Male	8	7
S2	Male	9	8

S3	Female	11	6
S4	Female	10	5
S5	Male	11	7
S6	Male	9	6
S7	Male	8	5
S8	Male	10	6
S9	Male	11	7

3.3 Data Collection

The data were collected through interviews conducted with the students after the educational mobile game playing process. Audio recordings were made during each of the interviews, which lasted quarter an hour each. A semi-structured interview form was prepared to determine the opinions of the students about the educational game used. The questions in the interview form are based on the framework developed by Phan et al. [54] to measure players' satisfaction with the user experience. The semi-structured interview form consists of five sections: using the game, immersion in the game, having fun in the game, problem solving and problems in the game. The positive or negative experiences of the students while playing the game were tried to be revealed with the question "What are the positive or negative experiences you have encountered while playing the game?", while the changes in their thoughts were examined with the question "What changes occurred in your thinking as you solved the problems in the game?". The interview form also included algebra questions that the students encountered in the educational mobile game in order to reveal the strategies they used in the solution process.

3.4 Process

3.4.1 Educational mobile game development subsections

The digital game-based learning and teaching model developed by Zin et al. [55] was used in the design of the educational game. In the model, the game is used as a platform for teaching educational content. Although the model was developed for historical educational games, it was thought that it could also be used for mathematical educational games. The model blends game dynamics (such as competition, challenge, reward, fun, rules and feedback) and pedagogical aspects based on collaborative learning. The model consists of five main stages: analysis, design, development, quality control, implementation and evaluation. Subtasks are defined under each step. The model can be seen in Figure 2.

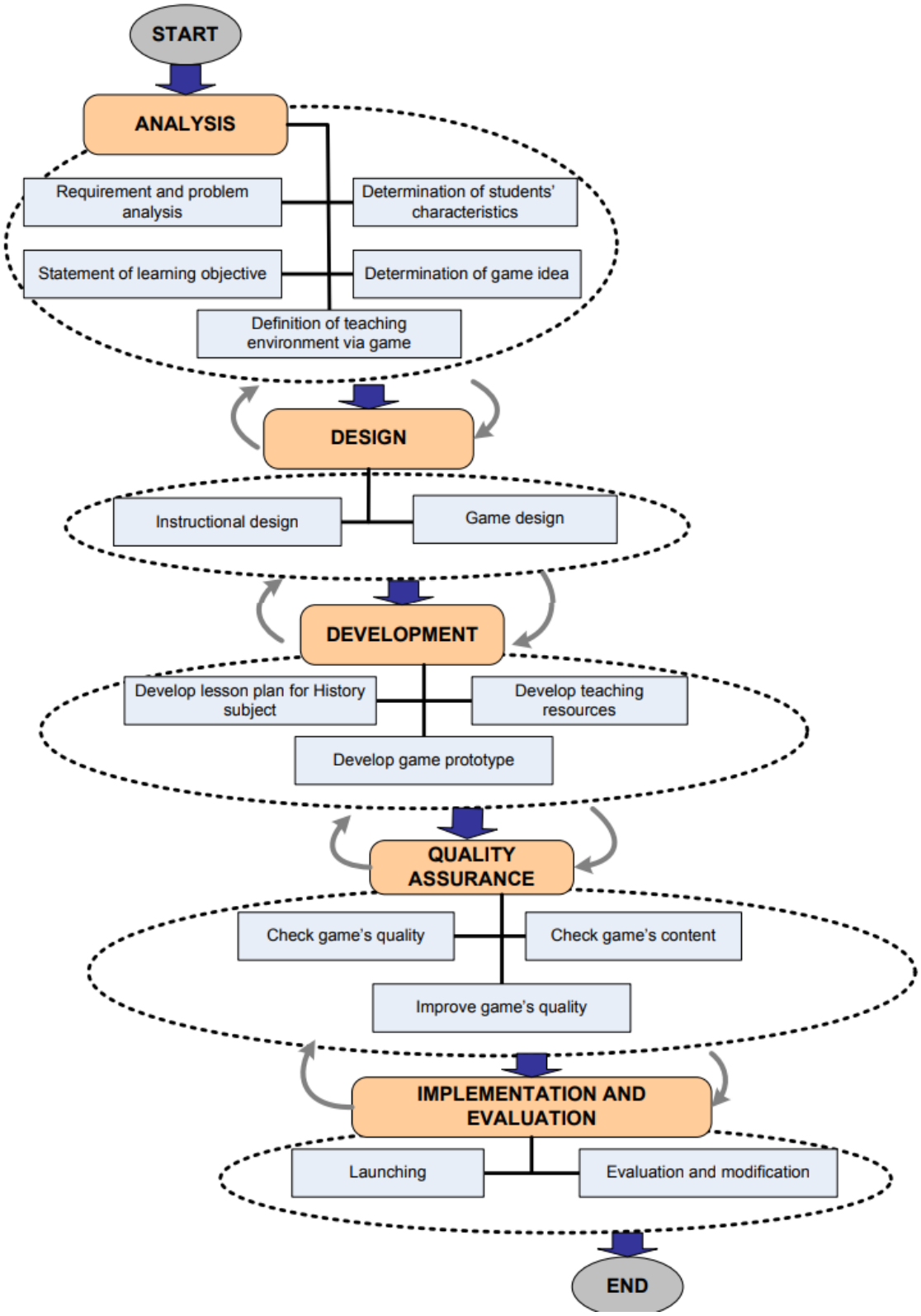

Figure 2. Digital game based learning-instructional design model (DGBL-ID) [55]

As a result of the needs analysis conducted within the framework of educational needs and the characteristics of the target audience, the mathematics subjects that students have the most difficulty with and the types of games they play the most were determined. In the study conducted by Dierks [56], the most played game types were determined as sports games (41%), adventure and action games (37%), role-playing games (35%), strategy games (28%) and platform games (26%). According to the results of the questionnaire applied in this process, it was determined that students played adventure

and strategy type games the most and that they had difficulty in algebra subjects mathematically. Based on this information, it was decided to create a game story that included questions about addition and subtraction with algebraic expressions and generalization of number patterns using algebraic expressions.

In the developed game, it was focused on educational objectives secondly. The different aspect of educational games compared to normal games is that they have educational purposes [57]. For this purpose, in the educational design phase, a total of 900 algebra questions for procedural skills were placed in the game. A game mechanic was created to ensure that students encounter different questions each time.

The questions in the game were composed of three separate groups. Based on the player's experience points, questions from the first group were presented first, followed by those from the second and finally the third group. Specific criteria were considered during the process of writing the questions for the game. After the questions were drafted, the opinions of two mathematics teachers were gathered. The criteria for the first group of questions were "the multiplication, addition, and subtraction of integers involving expressions with a single variable in algebraic expressions, as well as finding specific terms of a given number pattern or determining the general term of a number pattern."

Examples for the first group:

1. Question: Al-Khwarizmi: The code you need to unlock this chest is: 5y+20
Chest code: (y+4)
a.) .(5y) b.) .(5) c.) +(5y+16) d.) -(6y+16)

2. Question: Al-Khwarizmi: The code you need to unlock this chest is: 4x+6
Chest code: (2x+3)
a.) .(2) b.) +(2) c.) -(6x+6) d.) .(2x)

3. Question: Al-Khwarizmi: You must find the 3rd term of the pattern whose general term is given on the chest.
Chest code: 3n+1
a.)9 b.)4 c.)10 d.)7

The criteria for the second group of questions were "the addition and subtraction of expressions containing two variables in algebraic expressions, the multiplication of expressions with two variables and integers in algebraic expressions, finding several future terms of a pattern by providing the first three terms, and finding a future term by counting based on the given general term of the pattern, which can be time-consuming."

Examples for the second group:

1. Question: Al-Khwarizmi: The code you need to unlock this chest is: 7y+13-5b
Chest code: 4y-2+3b
a.) +(3y-15+8b) b.) +(3y+15-8b) c.) -(3y+15-8b) d.) .(3y+15)

2. Question: Al-Khwarizmi: The code you need to unlock this chest is: 2xy+5y
Chest code: (2x+5)
a.) .(5y) b.) .(2x) c) .(2y) d.) .(y)
3. Question: Al-Khwarizmi: You must find the difference between the 99th term and the 98th term of the pattern whose general term is given on the chest.
Chest code: 3n+2
a.) 3 b.)2 c.)4 d.)1

The criteria for the third group of questions are: "the addition or subtraction of variables containing two or more variables, where the order of the variables is altered; the multiplication of variables

containing two variables; finding the general term of a pattern based on the information provided within the problem; and determining one of the three consecutive terms of the pattern from its general term."

Examples for the third group:

1. Question: Al-Khwarizmi: The code you need to unlock this chest is: $2a^2-1$

Chest code: $(8-2a^2)$

a.) $-(9-4a^2)$ b.) $-(4a^2-9)$ c.) $+(4a^2-9)$ d.) $+(9+4a^2)$

2. Question: Al-Khwarizmi: The code you need to unlock this chest is: x^2+2x-3

Chest code: $(x+3)$

a.) .$(x+3)$ b.) .$(1-x)$ c.) .$(x+1)$ d.) .$(x-1)$

3. Question: Al-Khwarizmi: On the chest, three consecutive steps of the pattern are given. If the general term is 3n-2, you must find x.

Chest code: ..., 13, x, 19, ...

a.)14 b.)16 c.)18 d.)20

At this stage, design elements to be considered throughout the game were also included. As can be seen in Figure 3, the educational game to be used by taking these elements into consideration during the development phase of the mobile game was developed and uploaded to the Google Play Store to be accessed by students. In the game design phase, mechanics within the game (such as neighborhood, Al-Khwarizmi character, leaderboard and etc.) were designed.

Figure 3: Screenshot showing the game mechanics

3.4.2 Game mechanics

The game mechanics, which are a component of educational digital games, are processes and fundamental mechanisms that implement pedagogical principles and learning objectives as defined by game designers. In other words, game mechanics define the structures, interactions, rules, and algorithms aimed at creating game experiences that enhance intrinsic motivation [58]. To facilitate students' learning experiences through games and reduce their cognitive load, alignment between game mechanics and learning mechanics is essential [59]. Generally, while learning and pedagogical aspects are considered an abstract interface, game mechanics are viewed as the concrete interface of educational digital games. The mechanics of the developed educational mobile game are as follows.

Initially, when the student opens the game, they encounter the Al-Khwarizmi character, as shown in Figure 4. In this instance, the Al-Khwarizmi character first introduces himself, and then explains that he will guide the player throughout the game and that they should enjoy mathematics while playing. Thus, an effort is made to reduce the cognitive load of the player who is entering the game for the first time [59].

Figure 4: The first scene

Figure 5: The first scene of environment

After pressing the 'Play' button, the student is incorporated into the game and encounters the Al-Khwarizmi character once again. This time, the character instructs the player on what to do and assigns tasks. He informs the player that they can utilize the map, which is one of the game mechanics, to complete the assigned tasks. The player is expected to locate the chests, designed to resemble a neighborhood environment, within ten minutes. Each time the player starts the game, the locations of the chests are randomized. The screen features game mechanics indicating how many chests the player needs to find and the remaining time. In the upper right corner of the screen, there is a map providing a bird's-eye view of the game environment. The player's guided avatar is represented by a small arrow, indicating its current position and direction of view. The chests that the player is tasked with finding are also marked on the map. The dialogues presented in Figures 4 and 5 appear only during the first three entries into the game. This design aims to prevent students from becoming bored with repetitive dialogue screens by allowing them to learn the game and its rules without encountering the same interactions continuously.

Figure 6: The environment of the game

Figure 7: The questions

After the Al-Khwarizmi character explains the tasks and rules, he disappears, and the player enters a three-dimensional game environment, as shown in Figure 6. The lower left corner of the screen features a button to move the avatar, while the lower right corner includes components for changing direction, jumping, and running quickly. The upper left corner displays the experience points as a percentage, and the total gold collected is shown in the upper right corner. The player aims to find as many chests as possible within the time limit.

When the player approaches a chest, the Al-Khwarizmi character appears, informing them to select the correct key to open it, as depicted in Figure 7. Each chest presents different questions. If the player answers correctly and chooses the right key, the chest opens, and the gold inside is animatedly added to their total, as shown in Figure 8. The amount of gold increases with the difficulty level of the questions. Once added, the chest disappears, allowing the player to search for the remaining chests within the given time.

Figure 8: Chest opening

Figure 9: Wrong answer scene

In Figure 9, when a student answers a question incorrectly, they encounter a dialog that allows them to retry for a cost of 50 gold. Upon pressing the 'Try Again' button, 50 gold is deducted from their total, and the question is presented again. The game concludes when the player finds all the chests or when the 10-minute time limit expires, at which point they are directed back to the main page.

Figure 10: Main page

Figure 11: Statistics Table

In Figure 10, the student's avatar is visible on the main page of the game. The student can also acquire other avatars in exchange for gold. Figure 11 contains a statistics table that tracks the number of minutes' students played on which days.

3.4.3 The process of using the educational game

The practices of the developed educational mobile game were carried out in two phases as pilot and main study. In the pilot study, general information about the purpose and subject of the game was provided firstly. Then, in addition to demonstrating how to download the game to mobile devices, a sample guide containing the installation steps was distributed to the students, considering that there might be students who had difficulty in downloading and installing the game.

The pilot study took place for one day and one class hour. First, the students were allowed to review and play the game one by one, and then they played the game on their own devices for one day at home. Afterwards, a short interview was conducted to learn about the problems in the game or the students' suggestions. As a result of the interviews, students suggested several game mechanics, including extending the game duration, displaying the number of remaining chests at the top of the game, and keeping the question on the screen until it is solved after approaching the chest and opening the question. Necessary arrangements were made in cooperation with the game developer and the game was finalized. Approximately two months elapsed between the pilot study and the main implementation. The main implementation occurred about four months after the algebra topic was covered. The participants of both the pilot study and the main study consisted of different students at the seventh-grade level. In the main study, after the information was given, the download link for the game was sent to the students' phones for those who could not download the game. After playing the game once in the classroom, the students were told that they could play the game anytime and anywhere they wanted for two weeks. The parents of the students were also informed about the study within the scope of ethical permissions and were asked to allow the students to play the game with their mobile devices. During the pilot implementation process, monitoring studies were conducted to evaluate the problems encountered in downloading, installing and playing the game. After two weeks,

semi-structured interviews were conducted with the students to determine their opinions about the game and their processes of solving the algebra questions they encountered in the game.

3.5 Data Analysis

The semi-structured interviews conducted after the students played the game were audio recorded and transcribed. The collected data were analyzed by content analysis method. In order to ensure validity in the analysis of the data, the transcripts of the interviews with two students (S1 and S2) were analyzed separately by three researchers. The coding of all three researchers was compared. Similar codes were combined and grouped under a common theme. Finally, the coding was agreed upon. After reaching a consensus on category and theme nomenclature, the collected data from the remaining seven students were analyzed by only one of the researchers. To ensure confidentiality, each student was assigned a pseudonym (e.g., S1, S2) in order to protect their anonymity.

4. Results

The findings obtained as a result of the practices carried out within the scope of the research are presented below.

4.1 Findings Related to Students' Mobile Game Experiences

The findings obtained from the interviews with the students regarding the first research problem " What are the students' views regarding their experience with the educational mobile game?" were tried to be explained under three themes as "Game Design", "Affective" and "Cognitive" and the findings obtained from these themes are presented in Table 2, Table 3 and Table 4.

Table 2. Theme and Categories of Game Design.

Theme	Category	Codes	Students
Game Design	Negative Aspects of Game Mechanics	Technical problems	S1, S3, S4, S5, S6, S7, S9
		Challenges caused by visual elements	S1, S2, S4, S5
	Positive Aspects of Game Mechanics	Targets are clear	S1, S3, S4, S5, S6, S7, S8, S9
		The story is interesting	S1, S2, S3, S4, S5, S6, S7, S8, S9
		Sounds good	S1, S5, S6, S7, S8, S9
		Visual is good	S1, S4, S5, S6, S7, S8, S9
		Easy to learn the game	S3, S4, S5, S6, S8, S9
		Alternative to other games	S4
	Suggestions for the Game Content	Use in alternative subjects	S2, S6
		Questions can be more difficult	S2
		Use in alternative math topics	S1, S3, S4, S5, S6, S8
	Suggestions for Game Mechanics	Jumping higher	S2, S8
		Different maps	S1, S5, S6
		Changes to visual elements	S1, S2, S6, S7, S8
		Duration may be shorter	S1

	Rotate from anywhere on the screen	S6, S8
	Faster rotation	S8
	Action	S8, S9
Strategies in the Game Playing Process	Following the Map	S1, S3, S4, S6, S7, S9
	Pressing the speed key	S5, S7
	Move according to the location of the ballot boxes	S3, S4, S6

Table 2 shows that students' opinions on game design were distributed in categories such as positive and negative aspects of game mechanics, game playing strategies, game content and suggestions for game mechanics. Under the category of negative aspects related to game mechanics; students' criticisms about the placement of objects in the game, the difficulty of the location of the chests, the difficulty of seeing the questions clearly, and the environment being like a maze were expressed with the code of difficulties arising from visual elements. Technical problems were coded as directional buttons not being sensitive, getting stuck in the chest and the leaderboard not working. Under the category of suggestions regarding game mechanics, students' suggestions such as having people walking, an older neighborhood appearance, cars in the middle and the chests inside them were expressed with the code of changes in visual elements. In the category of strategies in the game-playing process, students' statements about memorizing the location of the chests, starting from the closest chest, and going to the side with too many chests were expressed with the code of acting according to the location of the chests.

When the opinions identified under the negative aspects in the game mechanics were analyzed, it was understood that most of the students had problems while controlling the character in the game. Some students found the character's rotation speed slow, while others found it fast and dizzying. While the student coded S1 expressed this situation as *"I had some difficulty in turning left and right. It turns a little slow."*, S4 said, *"While using the button to turn the character, it makes me dizzy. It is a bit boring."*. With his opinion, his negative thoughts about the characters in the game were understood. S6 stated that *"I did not like the button that rotates the avatar left and right. It would be better if we could rotate it from anywhere on the screen with our hands."* and according to his opinion it was understood that it would be better if the character rotated from anywhere on the screen, not just from one place, as in some games.

Among the difficulties arising from visual elements, there were negative situations such as the difficulty of ballot box locations, squeezing behind the ballot box, and not being able to see the directions clearly. S1 said, *"You go to the chest and when you open the question, it is behind the box. You get stuck behind it and I had a hard time getting out of there."*. He stated that he was stuck behind the box. S2 expressed that it was difficult to find the locations of the ballot boxes by saying *"I wish the ballot boxes were in places that are easier to find, they are in very difficult places."*.

One of the technical problems in game design was the negative situations related to time. Regarding the duration, S4 found the duration of the game inadequate and distracting *as "I was very distracted because I was going to lose time while solving questions."*, while S7 said, *"It does not take ten minutes. I finish it in five minutes. I finish it fast. The speed button was good, otherwise it would have taken longer"* and stated that the duration was sufficient. Considering the generality of the students, only one student found the duration insufficient, while S3 said, *"When we give the correct answer to the ballot box, it waits a little bit. I think it would be better if you remove that wait."* and expressed another part about the duration.

When the student opinions regarding the positive aspects of the game mechanics were evaluated in general, it was understood that the game was immersive, the story used in the game was interesting,

the goals were clear, the visuals were close to reality and easy to learn. Only one student stated that it could be an alternative to other mobile games. S4 stated that the educational mobile game was also preferred outside of class time as *"...I play this game when I take my phone in my free time."*. S2 stated that he could easily play the game developed within the scope of the course by characterizing the fact that the game did not require internet connection as a positive situation with his opinion that *"When we go to visit or something, there is no Wi-Fi,, internet connection at my grandparents' house, I go and play the game to pass the time there."*.

On the other hand, it is noteworthy that students suggested that the game content could be developed for different mathematics subjects and alternative courses such as science or native language courses. In addition, S8 said, *"It can be about whole numbers. If there were rational numbers involved, the solutions would be very challenging with paper or something like that. But for example, whole numbers and then shorting rational numbers can be added."*. In parallel with these statements, some students expressed their opinions about the possibility of similar games related to equations, angles, rational numbers and integers in mathematics. In addition, among the other suggestions offered by the students, their tendency towards game mechanics brought a different perspective to game design. When we looked at the suggestions given by the students regarding the game mechanics, it was mostly stated that there should be more different maps in the game and the environment could be more spacious. One of the male students said, *"The environment is good, but it could have been a little more spacious. You memorize after a certain period of time. Something different could come. For example, if someone chases us in some places."* and it is suggested that there could be a chase or a different kind of action as in action-style games.

When the strategies used by the students while playing the game were examined, it was observed that many different elements in the game were utilized. Among these, direction finding feature was used the most. It is noteworthy that maps were used for this purpose. As an example of this situation, the statement of S3 *"There was a map on the screen and I was looking at it and finding the locations of the boxes."* showed how important the map, which is one of the game elements, was for the completion of the game. One student stated that he finished the game in a very short time and passed the obstacles very easily just by following the map. In addition, the speed buttons in the game were among the components that students used the most. It was seen from the statement of S7 as *"Normally, he runs slowly and I find him by looking at the map by pressing the acceleration button."* that the speed buttons were an important and useful game mechanic to finish the game in the given time.

When evaluated overall, it can be stated that students appreciated the game mechanics that provided more functionality to the avatar (such as the acceleration and jumping buttons) and frequently used them within the game. However, it can be noted that they did not favor the avatar rotation mechanic as it did not closely resemble those in other games. Additionally, it was observed that they liked the game mechanics that guided them within the game, such as the character of Al-Khwarizmi and the map.

The categories and codes created under the affective theme from the students' responses are presented in Table 3.

Table 3. Affective Theme and Codes.

Theme	Codes	Students
Affective Components	More comfortable question solving over time	S1
	Sense of achievement	S1, S5, S7, S9
	Motivating problem solving	S3
	Increasing interest in math	S4, S6, S7, S8
	Attitude becomes positive	S4, S6, S7, S8
	Boredom in easy questions	S2, S5
	Interesting	S1, S4, S5, S6, S7
	It's fun	S1, S3, S4, S5, S6, S7, S8, S9
	Stress release	S1, S2, S3, S4, S5, S6, S7, S9

As seen in Table 3, students who played the educational game stated that the game was fun and that they relieved stress by playing the game. Five of the students found the game interesting. In addition, four of the students stated that their interest in mathematics increased and they started to develop positive attitudes towards mathematics. Negatively, two students said that they were bored with easy questions. S8 said that he found the game fun and immersive: *"Once, I played a game for 20 minutes. Then I realized that I had accumulated 12 thousand gold coins. I looked at the duration and it was 55 minutes."*. His expression of engagement with the game environment can be understood. While S3 focused on the stress relief dimension of the game, S1 and S7 stated that they felt more successful as they solved the questions. The students' statements are presented below.

"...I relax when I play the game." (S3)

"I started to feel more successful." (S1)

"I knew the patterns and it became more understandable."(S7)

It is seen that the educational mobile game, which attracts students' attention with its design and the story used in it, has a great potential to improve students' achievement, interest in mathematics and attitude positively. However, based on the statements of the students who stated that they were bored with easy questions, it is necessary to ask questions appropriate to their level and to encounter obstacles and difficulties that they can cope with.

The categories and codes created under the cognitive theme from the students' answers are presented in Table 4.

Table 4. Cognitive Theme and Codes

Theme	Codes	Students
Cognitive Components	Simple/medium questions	S1
	Gaining practicality	S2, S5
	Increased speed (problem solving)	S1, S2, S3, S4, S5, S6, S7, S8, S9
	Better understanding of the subject	S2, S3, S6, S7, S8
	Increasing visual memory	S5
	Solving mentally	S7, S8
	Contribution to problem solving skills	S3, S5, S9

As seen in Table 4, the students who participated in the study stated that there was no change in their problem solving strategies, but their speed increased and they were able to solve algebraic questions more easily. In addition, five students stated that they understood the subject better. Two students stated that they could now solve algebra questions mentally. S7 stated that he understood the subject better with his statement as: *"We had already taken the test in the school, I was doing a little bad normally, but this time I started to do better when it was algebraic"*. S5, on the other hand, expressed that the game environment could improve visual memory with a different point of view by saying, *"I think it can improve our visual memory at a level, I think the visual is good."*. S2 stated that he was able to make practical solutions by saying *"I think it improved my practice."*.

4.2 Finding Related to The Solutions of Algebra Questions

In order to answer the second research problem "According to the students' views, how did the mobile game experience alter their problem-solving strategies?", students' algebraic solutions were interviewed among the questions in the mobile game. Although all of the students stated that their problem-solving strategies remained unchanged, they noticed an increase in their question solving speed. The strategies used by the students while solving the questions are given in Table 5. When the strategies used by the students while solving the questions were analyzed, it was seen that most of the students used the options for elimination.

Table 5. Problem Solving Strategies Theme and Codes.

Theme	Codes	Students
Problem Solving Strategies	Working backwards	S1, S2, S3
	Use the options for elimination	S1, S2, S4, S5, S6, S9
	Trial and error	S1, S2, S5
	Analyzing the difference between algebraic terms	S4, S6, S7, S8, S9
	Using Paper & Pencil	S6
	Examining variables one by one	S3, S8, S9

It was found that three students solved the question by examining the variables one by one. S6's answer regarding examining the variables one by one is exemplified below.

"I still go by trying the choices one by one. I just started to solve a little faster." (S6)

It was observed that S9 examined the difference between the terms in the question "Desired Code: 9x+3y-5, Chest code: y+3x+2". S9's explanation for the solution was as follows:

"I added 6x to 3x and found 9x...and added 2y to 9x." (S9)

It is seen that S9 first examined the variables one by one while solving the question and then tried to reach the result by finding the difference between these variables. It is seen that S1 reached the result by finding the difference between the desired algebraic expression and the terms in the algebraic expression on the box.

All of the students stated during the interview that they started to solve algebraic questions faster and mentally. S7's statement about speed and mental processing is as follows:

"...I was trying to do it over and over again by writing it on the paper. Now I look at x and then I look at y variable and I solve it faster." (S7)

5. Conclusion and Discussion

The key role of educational game design is to design a game that can increase student flow [30]. In order to increase students' participation in the game, game elements need to be used correctly and effectively. Kiili [42] also emphasized the importance of game design elements for students' active participation. In the educational mobile game developed in this study, game elements were used carefully. As a result, it can be said that a game that attracts students' interest was developed based on their experiences. The ultimate aim of this study was to reveal the experiences of seventh grade students in algebra instruction supported by an educational mobile game. According to this purpose, the study, which consists of two research questions, firstly focused on evaluating the process of playing the educational mobile game after it was experienced by the students. Based on the data collected in this context, students' experiences were categorized into three categories: game design, cognitive and affective components. Although students encountered some technical problems in the game design, they generally liked the design of the game and the story used in the game. Technical problems were seen to be important in the context of game design. It can be said that a technical problem encountered causes the student to have difficulty in playing the game and hesitate to play again. According to Asteriadis et al. [60], technical glitches in the game increase frustration and reduce engagement, leading to negative attitudes towards the game. In other words, the situations arising from the game design also affected the students in the affective dimension. In this context, although the game experience was divided into three categories in this study, it can be said that these dimensions affect each other and especially the affective dimension is intertwined with the design dimension.

It was seen that the game mechanics used in the game (scoring, map, direction keys, etc.) had an important place in educational game design. It can be said that these mechanics are effective in students' developing positive or negative attitudes about the game. For example, the speed button used in the game allowed students to find the chests within the given time and students liked it. Likewise,

the map showing the locations of the chests was actively used in the game as it helped the students to find them. In addition, the button that routes the character in the game caused negative experiences for students and it was understood that it needed to be improved. The mechanics of game design that capture players' attention can vary widely [61]. The time indicator used in the game distracted one student and caused him to have trouble focusing on the questions. This shows that even a small detail used in the game can affect participation in the game negatively. Similarly, Kiili [42] stated in his study that the sound effect used in the game affected students' participation negatively. This result emphasizes the synergy between the design dimension and the affective dimension. All of the students found the game story interesting, and the fact that the story was engaging allowed them to immerse themselves in the game and affected them in an affective sense. This result is also consistent with the results of Lu et al. [44] and Chen et al. [45]. Change and curiosity increase students' interest and are important for learning [62].

According to Kiili and colleagues [61], educational games are not as successful as commercially developed games because they do not focus on user experience. Educational games cannot succeed unless they are understood quickly. Therefore, a game dynamic in the form of the Harezmi character was added to the developed educational game to accelerate students' learning processes and reduce their cognitive load. As a result, most students stated that the game was easy to learn and that the objectives were clear. A player who becomes immersed in the game engages so deeply with goal-oriented activities that nothing else seems to matter. This type of intrinsic motivation is crucial for serious games [34]. States of flow are evident in student expressions regarding the developed educational game. For instance, one student said, *"I didn't hear when those around me called out,"* while another mentioned, *"I was getting so absorbed in the game that I didn't hear my mom calling me."*.

Based on the findings, it can be said that a well-designed educational mobile game can be an alternative to other games for students, and they can both play games and deal with mathematics in their free time. It was determined that the educational mobile game developed in this study encouraged students to solve problems and developed positive attitudes. This result is also consistent with the results of Chen et al. [43]. In their studies, they stated that game-based instruction was used in mathematics courses to increase student motivation and engagement and to reduce learning anxiety.

Looking at the results obtained in the cognitive components, it was determined that students stated that they were able to perform faster and mental operations after using mobile games. The acceleration of students in solving questions and the improvement of their mental computation skills are consistent with the results obtained by Aktaş et al. [12] and Kurt [48]. In the current study, it was observed that the use of educational mobile games contributed to a better motivation for algebra.

Through the second research question, it was investigated how did the mobile game experience altered students problem-solving strategies. Aktaş et al. [12] developed a mobile game for students to do the four operations (addition, subtraction, multiplication, division) mentally. They stated that the mobile game they developed increased students' mental operation skills. And the algebraic questions and problems which we used in this mobile game required these four operations. So we wondered if mobile gaming changed the strategies students used to solve math problems. Based on the interviews conducted in the current study, it was observed that there was no change in the students' ways of solving algebra questions. This finding contrasts with prior research suggesting that digital games can enhance mathematical problem-solving [63]. These studies report improvements in general problem-solving skills but may not address specific domains like algebra. In contrast to more open-ended problem solving domains, algebra requires students to follow specific procedures, which may not be influenced by game experiences that are designed to encourage flexibility and creativity in problem solving. Another potential factor may be the design of the educational games. The design of the educational game may have lacked a focus on algebra, limiting opportunities for students to apply or refine algebraic reasoning. Although this result may seem contradictory with students' faster question solving and development of mental processing skills, what is actually emphasized here are the strategies preferred by students in the process of solving the questions. For example, while students

solved a multiple-choice algebra question through trial and error before the mobile game experience, they continued to use the same strategy after the mobile game experience. However, they have improved their ability to perform operations faster and mentally.

6. Suggestions

The importance of game mechanics in the design of a mobile game has emerged again from the results obtained in this study. It is also seen that the affective dimension is a unifying element as the intersection of the design and the cognitive dimension. In future studies, mobile game designs can be made by considering the unifying feature of the affective dimension and game elements can be used effectively in this context. Becker [64] stated that in order to the MGBL method to be successful, the content of the course, students, complex and advanced programming must be known by the researchers and the games are difficult to make. Considering that designing educational mobile games takes time and requires expertise, working with an expert will increase the quality of game elements and mobile game design. In this way, positive changes in affective and cognitive dimensions can be observed in students. In addition to collaborating with expert game developers, it would be more beneficial for researchers working on MGBL to develop their skills in game development and reach the level where they can create their own mobile games. This will reduce the cost and pave the way for designing or modifying the game according to the desired content. Moreover, in the current study, students stated that they would like to use mobile games in different subjects and courses.

In this study, we tried to reveal the experiences of students in the process of using an educational mobile game developed for algebra topics and thus tried to discuss whether mobile games can be an option in algebra teaching. In the light of the results obtained, it can be said that educational mobile games prepared by paying attention to game mechanics in the context of increasing students' motivation and supporting their processing skills can be effective materials that can be used in the teaching and learning process. By extending the duration of game-based interventions or modifying the game mechanics to focus on procedural fluency could yield more positive outcomes.

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Conflicts of interest

There are no conflicts of interest.

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