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Design and Use of a Mobile Game Developed to Raise Environmental Awareness in Secondary Schools

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Abstract

This design-based research aims to develop, improve, and evaluate a mobile game to improve secondary school students' environmental awareness. The research was conducted with 74 sixth-grade students and four teachers at a secondary school in Bursa during the 2022-2023 academic year. The environmental awareness scale, observation notes, and semi-structured interview forms were used as data collection tools. The results showed a significant difference between the scores in the pre-test and post-test in favour of the post-test. The developed mobile game significantly affects environmental awareness. The observation and interview data were analyzed using cyclic coding and thematic analysis methods. Three themes named "the effects on motivational processes," "the effects of structuring of knowledge," and "the effects of environmental awareness" emerged. Findings showed that the game mechanics included in the developed mobile game positively affected the "autonomy and self-efficacy" of the intrinsic motivation elements of the students to achieve their individual goals. Findings also revealed that the mobile game improves students' feelings of attention, interest, satisfaction, and confidence. In addition, it has been found that students structure their knowledge by resorting to reflection with the score table and instant feedback mechanisms in the mobile game.

Keywords: Digital game design, environmental education, mixed method, mobile game, mobile learning.

About the Article

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Introduction

Numerous studies emphasize the inevitability of incorporating educational software into education (Chen et al., 2020; Jagušt et al., 2018; van Roy & Zaman, 2018; Xi & Hamari, 2019). To benefit permanent learning, it is seen that various computer software is used in educational platforms (O'Rourke et al., 2017) with digital games being a notable example. Games with designed game mechanisms in digital environments to support users' academic and cognitive development are defined as "educational digital games" (Lameras et al., 2017). Digital games are used in science and many other areas of education. Designing teaching materials enriched with digital game technologies and providing guidance to science teachers also increases students' interest and curiosity in this course. Digital games contribute to concretizing abstract concepts and offer students more immersive learning environments within educational settings.

When the studies in which digital games are used in different areas of education are examined, a consistent trend emerges wherein incorporating these games into lessons positively affects students' different abilities and characteristics. For example, Chittaro and Sioni (2015). The findings of the studies conducted by Chittaro and Buttussi (2019) and Peng, Lin, Pfeiffer, & Winn (2012) showed that simulation and video games provide positive results on the self-efficacy of undergraduate and graduate students. Similarly, in another study conducted with undergraduate students, Kim, Schmierbach, Bellur, Chung, Fraustino, Dardis, and Ahern (2015) found that mobile game design significantly affected undergraduate students' autonomy. On the other hand, Frost, Matta, and Maclvor (2015) stated an inconsistent and complex relationship between the dynamics of playing mobile games in classes and students' motivation for the lesson and mentioned a non-significant relationship between the two.

Showing that students playing mobile games at different educational levels exhibit more autonomous behaviour compared to students not playing (van Roy & Zaman, 2019) and finding that mobile games have a significant effect on the satisfaction of these students' self-efficacy needs through quantitative and qualitative methods (Xi & Hamari, 2019). Studies (Jagušt et al., 2018; van Roy & Zaman, 2018) emphasize that digital games provide an advantage to students by increasing their academic success and positively affecting their motivation. Students express that they experience short-term satisfaction in the interviews, as they are rewarded when they know the answers to the questions while playing digital games. For example, as a result of their research with undergraduate students, Calvo-Ferrer (2018) stated that the rewards these students received while playing games and the satisfaction they felt immediately afterwards positively affected their instant learning outcomes. Very similar to this finding, All, Plovie, Nu˜nez Castellar, and Van Looy (2017); Bowen (2014); and Erhel & Jamet (2013) emphasized that instant feedback mechanisms in digital games have a positive effect on students' deep learning, self-efficacy and self-regulation skills.

Bandura (1982), regarded as the pioneer of Social Cognitive Theory, highlights the constructive impact of mobile games on shaping individuals' concepts such as self-

regulation and self-reflection. Middleton, Hall, and Raeside's (2019) research findings align directly with Bandura's theory, reinforcing the positive role of mobile games in this regard. The study of Chen, Lu, De, and Cheo (2019) emphasizes that adding questions at different difficulty levels to digital games positively contributes to students' self-regulation skills. Kara (2021) suggested that digital games to be used in education should have different difficulty levels and that these levels should be listed from simple to complex.

Theoretical Framework

Social Learning Theory, Social Cognitive Theory, Goal Setting Theory, ARCS Model, and Self-Determination Theory, which also include behavioural mechanisms, are used in robust game designs (Bandura, 1982; Locke, 1968; Özdamlı, 2018; Ryan & Deci, 2020; Skinner, 1953). In developing game interventions, serious games are required to contain the elements of attention, interest, confidence, and satisfaction. In developing the mobile game in the research, ARCS (Attention, Relevance, Confidence, Satisfaction) Motivation Model elements, which are important determinants of success goals, were considered (Keller, 1987). Another issue considered when designing a mobile game is that the game has difficulty levels, in line with the goal-setting theory (Locke, 1968). According to self-determination theory, clear and relevant goals support the need for competence and autonomy (Bandura, 1982; Ryan & Deci, 2020). In this context, care has been taken to develop a game presenting clear objectives to effectively complete the streaming experience. It is aimed to enable students to pursue course content through intrinsically rewarding experiences (Csikszentmihalyi, 2014).

Problem Statement

In order to create a sustainable society, individuals at an early age should be given a sense of social responsibility for the environment. Environmental education for secondary school students contributes to building a sustainable future by strengthening the environmental awareness of both individuals and society. Several studies (Alp & Coskun Onan, 2023; Daglı & Yazıcı, 2021; Douven et al., 2014; Ducrot et al., 2015; Hamid et al., 2017; Tokmak et al., 2023) suggest using digital comics, drama method, life-based learning approach and social media in lessons to improve environmental awareness. In these studies, it is emphasized that teachers should use these digital tools in lessons to develop environmental awareness and thus be able to integrate environmental concepts with different disciplines.

An analysis of the iTunes App Store shows that 60% of the most downloaded educational applications target primary school and kindergarten-age children (Noorhidawati et al., 2015). It is thought that an application that will be prepared by experts in terms of content, pedagogy and software in accordance with the concepts and acquisitions in the science course for middle school students is missing. According to Topuz and Kaptan (2017), since the most important criterion in digital mobile application design is the

target audience, experts are needed to address the developmental characteristics of the learner's age and the achievements in the learning field as a whole.

Upon reviewing the literature, it appears that utilizing mobile games designed for schools, particularly for environmental awareness, is not widely accepted. Studies have found that mobile games are primarily used for leisure purposes by families and children (Ince, 2022). While there is a significant amount of research on the impact of mobile games on academic achievement, problem-solving, collaborative learning, and motivation (Altınpulluk, 2021; Chen, 2018; Chen et al., 2022), there appears to be a lack of studies exploring the effects of mobile games on environmental awareness. The research questions on Stages 1 and 2 are as follows:

Stage 1 (Design-based research):

The research questions for Stage 1 are:

1. How appropriate is the mobile game to the cognitive and developmental level of students?

2. How can the developed mobile game be improved?

Stage 2 (Sequential explanatory mixed research):

The research questions for Stage 2 are:

1. Is there any difference between the students' pre and post-test scores from the Environmental Awareness Scale?

2. What are the teachers' opinions about mobile games?

3. What are a student's opinions on mobile games?

Method

Within the scope of this research, there are four purposes of this research. These purposes are to design, improve, and evaluate a mobile game to develop environmental awareness, and to reveal the effects of this mobile game on environmental awareness.

This research was carried out in two stages. Design-based research with a pragmatic approach was used in the first research stage. Design-based research (DBR) is a cyclic approach aiming to create an innovative learning environment or theory based on a design founded on a theoretical framework. This process involves discussions and input from stakeholders in the relevant context (Cobb et al., 2003). This research method has been recommended recently due to its effectiveness in short-term projects (Pool & Laubscher, 2016) and its suitability for technological interventions (Zheng, 2015). The DBR method was chosen for this study due to its suitability for online learning conditions,

flexibility in research procedures, and ability to provide contextualized data through multiple tools (McKenney & Reeves, 2013).

The mixed method is considered an approach requiring the researcher to think objectively, subjectively, inductively, and deductively within a study (Morgan, 2007). In the second stage, a mixed method was chosen to ensure that the findings obtained from quantitative and qualitative data collected during the design and use of mobile games to create environmental awareness can be compared and integrated. This design allows for practical analysis and interpretation of the data. The study used a sequential explanatory mixed design (Creswell & Plano Clark, 2011) to explain generalizations obtained from the environmental awareness scale with qualitative data. It is possible to identify explanatory situations that demonstrate quantitative research results through the chosen design. Thus, it aims to identify the similarities and differences between the results obtained from qualitative and quantitative data (Yıldırım & Şimşek, 2018). It is thought that it is essential to use development, one of the prominent functions/justifications of the mixed method, by the nature of this research. What is meant by the concept of improvement is the use of one method to improve another. The quantitative data in this research will enable the creation of data collection tools and processes of the qualitative method. Expanding is another function of the mixed method that stands out in this research. By the holistic nature of the mixed method, this study corresponds to the expansion function by conducting research with different methods of developing, improving, and evaluating mobile games to improve environmental awareness. The data collection process can be seen in Table 1.

Table 1.

Application Process-sequential Explanatory Mixed Pattern

Data Collection Tools	Intervention	Data Collection Tools	Intervention	Data collection tools
Environmental Awareness Scale Pretest	Using the Mobile Game	Observation Interview	Using the Improved Mobile Game	Environmental Awareness Scale Posttest

The concept of "association" is important in integrating quantitative and qualitative data, especially in descriptive and exploratory designs (Creswell & Plano Clark, 2011). In the explanatory design, the qualitative phase follows the quantitative phase, and qualitative data supports the quantitative data (Creswell, 2003). The contribution of the methods to each other occurs in the realization of the next stage. In this type of research, it is necessary to relate different stages to each other and to build the bridge properly in presenting the findings (Yıldırım & Şimşek, 2018). In this study, qualitative and quantitative data were collected to support each other. Table 2 presents the design-based research steps used in the data collection process:

Table 2.

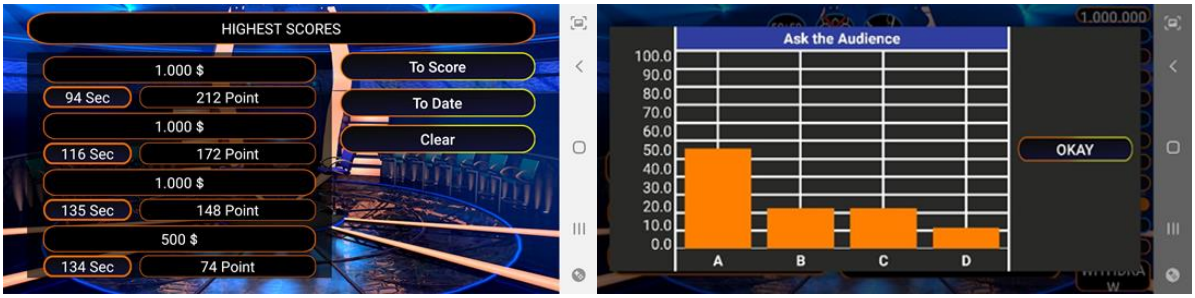
Design-Based Research Steps in the Data Collection Process

1. Analysis Phase	Literature review Creation/development of data collection tools Obtaining information from teachers about sixth-grade students' cognitive and affective development characteristics.
2. Design Phase	"Who wants to be a millionaire?" Developing the scenario of the game Testing workflow and prototype applications (UI-user interface design and UX-user experience design) Codes of the game's interface in Java and C++ languages in Android Studio Completion of device-specific testing, performance, and usability tests
3. Improvement Phase	Testing of the draft design by five teachers Conducting semi-structured interviews with teachers Testing the draft design in a sixth-grade branch Conducting semi-structured interviews with students Improving the mobile game based on feedback
4. Implementation Phase	Application of the Environmental Awareness Scale as a pre-test Use of the improved version of the mobile game by students Application of the Environmental Awareness Scale as a posttest Semi-structured teacher and student interviews
5. Analyzing Data	Analyzing and reporting data

Mobile Game Design

The mobile game created in the study is aimed at students to question the causes and consequences of environmental problems, to gain knowledge and skills about biodiversity, and endangered creatures and what needs to be performed to protect these living species, and sensitivity to environmental problems caused by human activities, and the solution of these problems. The interface of the developed game is presented in Figure 1.

Figure 1.
Mobile Game Interfaces



"Who wants to be a millionaire?" there are 110 questions in the question pool of the mobile game. A total of 12 questions were randomly presented to the player: four easy, four medium, and four difficult level questions, respectively. As the player progresses, the points he earns also increase. The player has the right to connect by phone once, the right to eliminate two wrong choices once, and the right to ask the audience once. Not every wild card right leads to the correct answer. If desired, the scores in the game can be accessed. Regarding the questions in the game content, Table 3 below shows how many questions are included in each part of the unit according to their difficulty levels:

Table 3.
Distribution of Questions by Difficulty Levels and Units

	Easy Number of Level 1 Questions	Medium Number of Level 2 Questions	Difficult Number of Level 3 Questions
Part 1 of the Unit	9	10	9
Part 2 of the Unit	10	15	10
Part 3 of the Unit	5	5	5
Total	24	52	24
Question Pool	110		
Number of Questions to be Selected in the Quiz Competition	4	4	4

The developed mobile game overlaps with the following main objectives of the Science Curriculum (2018): 1. To provide basic knowledge about environmental sciences, 2. To produce solutions to the problems encountered in the process of exploring nature and understanding the relationship between humans and the environment, 3. To realize the mutual interaction between the individual, environment and society; to develop awareness of sustainable development regarding society, economy and natural resources, 4. To arouse interest and develop attitudes towards events occurring in nature and its immediate surroundings.

Research Group

The research was conducted with 74 students (36 boys, 38 girls) and four teachers (two science teachers, two information technologies teachers) studying in two 6th grade branches of a public secondary school in Bursa in the 2022-2023 academic year. The average age of the teachers is (40) and the average age of the students is (10.25).

Data Collection Tools

Researcher Observation Form

In this study, one of the authors completed the observation form as a participant observer. The form was designed to observe the experiences and behaviors of 6th grade students before, during and after playing the mobile game developed about environmental awareness in the Science course. There are 20 items in the observation form prepared by the first researcher after receiving expert opinions from five academicians.

Semi-Structured Interview Form

Interview forms were created to determine how to improve the developed mobile game, students' wishes to use the mobile game, and teacher and student opinions regarding the mobile game. The teacher interview form consists of 7 questions and the student interview form consists of 5 questions. For the validity of the prepared semi-structured interview forms, opinions were received from six people, including teachers, graduate students, and academicians. Expert opinion support was received from other science teachers at the secondary school where the data were collected, other doctoral students at the faculty of education, and faculty members who are experts in their fields.

Environmental Awareness Scale

The Environmental Awareness Scale was used (Erten, 2000) as a quantitative data collection tool to examine the environmental awareness levels of 6th-grade students. The scale consists of 19 items on attitudes towards the environment, 17 on environmental knowledge, and 19 on behaviours aimed at protecting the environment. The statements on the scale are on a 5-point scale from positive to negative (Completely agree, Agree, Slightly agree, Disagree, Completely disagree).

Data Analysis

Quantitative data was collected from 6th-grade students both before and after using a mobile game designed for environmental awareness. Qualitative data, including interview and observation data, was collected during and after students played the mobile game. The qualitative data was analyzed using the cyclic coding and thematic analysis methods described by Braun and Clarke (2006). To protect student privacy, code names were used instead of real names for the nine students in the group where qualitative data was collected. The Results and Discussion sections provide a holistic interpretation of the answers to the research questions, as per the nature of the sequential mixed design used in this study.

Credibility and Ethics

For the validity and reliability of the data in the study, Miles and Huberman's (2017) concepts of "objectivity", "reliability", "transferability", "internal validity" and "suitability for use" were taken as a basis. Care was taken to ensure that the design used in the research

was compatible with the research purpose. The information obtained through observation was confirmed through interviews. In addition, expert review, long-term interaction, depth-oriented data collection, getting feedback from the participants, and triangulation were used. After analyzing the data, the transcripts of the interviews were presented to the participants before proceeding to the coding stage. After the data analyses were carried out, the results of the study were shared with the participants, parents, and administrators.

Quantitative Results

The fact that the data of the participant group to which the Environmental Awareness Scale was applied was not normally distributed necessitated non-parametric tests. Wilcoxon Signed Ranks test was used to reveal whether there was a significant difference between the participants' answers to the Environmental Awareness Scale before using the mobile game developed to raise environmental awareness at the secondary school level and the answers they gave after using it (Table 4). According to the results of the Wilcoxon Signed Ranks test, a significant difference was detected between the scores of the students in the pre-test ($\bar{X}$ =160) and post-test ($\bar{X}$ =206) in favour of the post-test [z=-5.929, p<.001]. The fact that the difference scores are in negative ranks, in favour of the initial measurement, shows that the developed mobile game significantly affects environmental awareness.

Table 4.
Wilcoxon Signed Rank Test Results

	Sign	N	Mean Rank	Sum of Ranks	z	p
Post-test-pre-test	Negative ranks	14[a]	20.50	287	-5.929	<.001
	Positive ranks	60[b]	41.47	2488		
	Ties	0[c]				

*a.posttest<pretest
b.posttest>pretest
c.posttest=pretest

Qualitative Results

The themes explained in this section were obtained through semi-structured interview forms and researcher observation forms. In direct quotations, the abbreviations of student interview form (SIF) and teacher interview form (TIF) were used. As a result of the cyclic coding, themes such as the effects of mobile games on motivational processes, effects on structuring knowledge, and effects on environmental awareness emerged. Themes are presented to the reader, supported by direct quotations. The "effects on motivational processes" theme consists of two categories. Categories and codes belonging to the theme are shown in Figure 2.

Figure 2.
Categories and Codes Related to the Theme of Effects on Motivational Processes

The category of effects on achieving individual goals consists of autonomy and self-efficacy codes. Teacher 1 emphasized the autonomy code with the following words: "One of the most positive aspects of this game is that it allows students to determine their own goals. Since students receive instant feedback, they can take responsibility for their learning" [Teacher 1, TIF]. Student 2 revealed his self-efficacy for achieving his individual goals with the following words:

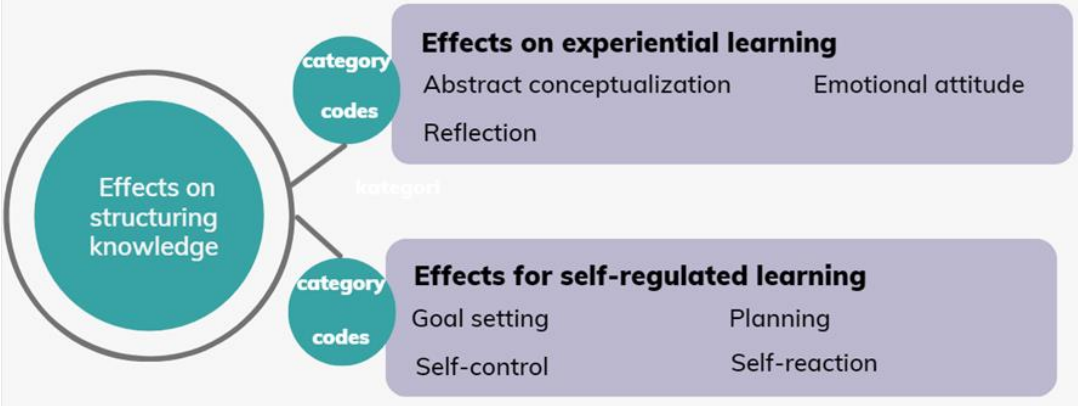
When I downloaded the game to my phone, I did not think I would love it this much. The screen, visuals, and questions were very original. I am shocked. When I saw the first question, my biggest goal was to advance in the game. I wanted to play again and again, become a millionaire many times, proudly show my scoreboard to everyone, and prove my success in this course. As I played the game, my confidence increased. I have the intelligence to achieve my goal. I keep my knowledge fresh by practising [Student 2, SIF].

The effects category for positive reinforcement includes attention, interest, satisfaction, and confidence codes. Student 7 stated that progressive questions increased his attention with the following words: "As I progressed in the game, I was wondering how difficult the next question might get. At that moment, it was as if I was in another universe, and I was paying all my attention to the question in front of me." [Student 7, SIF]. The following words of Student 5 are the source of the interest code: "The reward of becoming a millionaire at the end increased my interest in the game even more. I also love this unit" [Student 5, SIF]. Student 1 points to the satisfaction code with the following words: "No game has ever made me this happy and satisfied. The scoring table and reward make the game even better. It increases my desire to learn" [Student 7, SIF].

Categories for the effects on structuring knowledge are divided into effects on experiential learning and self-regulated learning (Figure 3). The codes in the category of effects on experiential learning were determined as abstract conceptualization, emotional attitude, and reflection. Touching on the role of reflection in structuring knowledge, Teacher 2's words are as follows:

"Based on my observations while playing the game, I can say that this mobile game provides the necessary environment for students to reflect on what they have learned. A detailed score table in the game supported students in developing awareness of their thinking system. Proceeding in line with instant feedback mechanisms, students organized and rediscovered their own knowledge and decision-making skills." [Teacher 2, TIF].

Figure 3.
Categories and Codes Related to the Theme of Effects on the Structuring of Knowledge



The effects category for self-regulated learning consists of goal setting, planning, self-control, and self-reaction codes. It is thought that the statement "I was happy that they developed the possible strategies necessary to win the game before their other friends, determined their own goals for learning and strived for this" corresponds to the goal setting code [Teacher 1, TIF]. The importance of planning for self-regulated learning is emphasized by Teacher 3 with the following words: "I witnessed the students who made plans to use this joker right from the following question before starting the game and saw the last question" [Teacher 3, TIF]. In self-regulated learning, student performance in structuring knowledge appears to be related to self-control. Teacher 3 said: "They implemented what they planned at the beginning of the game and continued the game by learning from their past mistakes, which enabled them to succeed." [Teacher 3, TIF]. The following words of Student 7, who is thought to resort to avoidant reactions in self-regulated learning, are the source of the self-reaction code:

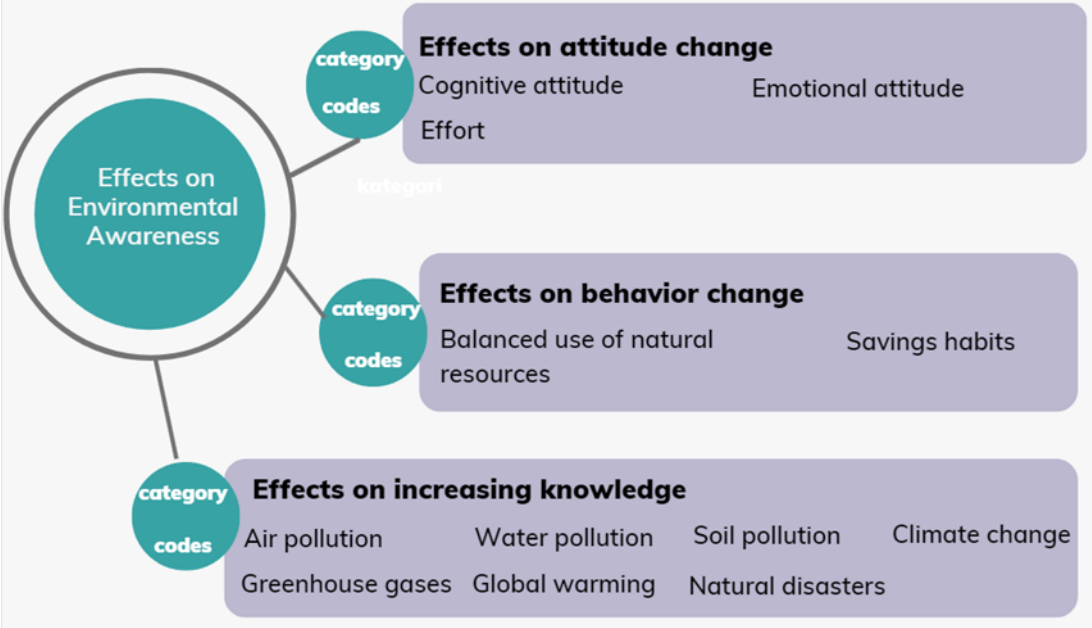
"Previously, I used to use my wildcard right when I was first unsure. I have now decided not to use my right to at least two wild cards until the last three questions. I stopped marking the answer given by my friend, who I think is knowledgeable. "I no longer think of asking the audience because they might give the wrong answer when I ask them."

Under the theme of effects on environmental awareness, there are three categories: effects on attitude change, effects on behaviour change, and effects on increasing knowledge (Figure 4). Effects on attitude change were determined as cognitive attitude,

emotional attitude, and effort. Student 8's words, which are the source of the cognitive attitude code, are presented below:

"The questions in the game reminded us that we should be aware of a disaster such as an earthquake. I now know that our country is in the Alpine-Himalayan earthquake zone, meaning we may face an earthquake anytime. Learning the lie, cover, trap and hold movements is vitally important. We should avoid objects such as windows and cabinets that could collapse on us. We should not use the elevator or the stairs. We must wait for the earthquake to end to leave the building" [Student 8, SIF].

Figure 4.
Categories and Codes Related to the Theme of Effects on Environmental Awareness



Among the participating students, some expressed their feelings, such as empathy and anger towards possible situations that may arise due to events in human-environment relations. Student 9 expressed his emotional attitude towards environmental awareness with the following words: "I felt sorry for endangered creatures. I now know that humans, like dinosaurs, may one day disappear from the face of the earth. "People who pollute nature with toxic gases and waste and cut down trees make me very angry." [Student 9, SIF]. Some of the students seem to effort for environmental protection. "We must stop the unconscious consumption of water resources. We should not run water unnecessarily while brushing our teeth and washing our hands. "From now on, if garbage is thrown on the beach while walking by the sea, I will collect it" [Student 3, SIF].

The effects on behaviour change category consist of codes for balanced use of natural resources and savings habits. Student 1 points out the balanced use of natural resources with the following words: "I learned that without the resources that people need to live,

such as water and clean air, the human species will disappear like the mammoths. After playing the game, I told him we should install a solar panel in the house, and my family said yes, too." [Student 1, SIF]. It was revealed that some of the students developed savings habits after using the mobile game. "If we go to bed early, we will not waste electricity. I will not dry my hair with a dryer in hot weather. I will ensure the windows are closed if the air conditioning is on. I will not run the air conditioner if unnecessary" [Student 6, SIF].

The codes belonging to the impact category for increasing knowledge are divided into seven: air pollution, water pollution, soil pollution, climate change, greenhouse gases, global warming, and natural disasters. The following words of Student 1 can be presented as an example data source for the air pollution code: "After playing this game, I learned that air pollution causes serious respiratory diseases such as asthma and lung cancer" [Student 1, SIF]. Student 7 reveals that he is informed about water pollution with the following words: "After playing this game, I learned that the waste oils we pour into sinks also pollute the water" [Student 7, SIF]. The words of Student 3, who emphasizes climate change, are as follows: "Rise in sea water level, melting of glaciers and scorching weather are the harbingers of climate change" [Student 3, SIF]. The direct quote, "I learned by using my wildcard right in the game that global warming is one of the factors that threaten biodiversity," is the source of the global warming code [Student 8, SIF]. The following words of Student 5 are the source of the natural disasters code: "It is important to be informed when dealing with natural disasters. In this game, we learned the duties of organizations such as AFAD. You should not go out to the balcony during an earthquake. We learned what should be in the earthquake kit" [Student 5, SIF].

Discussion, Conclusion and Recommendations

Observation of a statistically significant difference between the scores of students on the Environmental Awareness Scale before and after using a mobile game developed to promote environmental awareness shows that the mobile game has a significant effect on environmental awareness. It is thought that our study contributes to the literature by presenting the effects of a well-designed mobile game on students in quantitative and qualitative ways to promote environmental awareness.

Within this study's scope, it has been determined through qualitative analysis that using a mobile game designed to raise environmental awareness in secondary school impacts students' motivational processes, knowledge structuring, and environmental awareness. Using the developed mobile game enriched the understanding of student motivation and provided implications for new-generation learning applications. In the qualitative findings, firstly, the role of the game mechanics designed to perform the learning tasks on the motivational processes of the students' autonomy and self-efficacy (Bandura, 1982), which are internal motivation elements to achieve their individual goals, was discovered. This result is in line with studies that found that simulation and video games provide positive results on the self-efficacy of undergraduate and graduate students

(Chittaro & Sioni, 2015; Chittaro & Buttussi, 2019; Peng et al., 2012). Previous studies have shown that the reported game design affects undergraduate and graduate students' self-efficacy. The significant (Kim et al., 2015) and non-significant effects (Frost et al., 2015) on students' autonomy have revealed the inconsistent and complex relationship of game dynamics with motivation. Our findings are consistent with a study that revealed through quantitative and qualitative means that undergraduate students exhibit autonomous behavior after feeling competent (van Roy & Zaman, 2019). Additionally, this study's findings extend the study's findings, which reported a significant effect of gamification elements on the satisfaction of internal needs, such as autonomy and self-efficacy of adult game users, with qualitative elements in a different age group (Xi & Hamari, 2019).

Secondly, in the qualitative findings, the role of the game mechanics designed to perform learning tasks on attention, interest, satisfaction, and confidence towards positive reinforcement, which Skinner (1953) emphasized with the reinforcement theory, was discovered in motivational processes. These four elements also presented through direct quotations in the findings section, are also ARCS Model elements (Keller, 1987). Many participants stated that the mobile game, which included questions of increasing difficulty, increased their attention and satisfaction. Within the framework of motivation theories (e.g., ARCS Model), it was once again confirmed by the qualitative data in this study that satisfaction, goal-oriented success expectations, and confidence are closely related to self-efficacy (Bandura, 1982).

This research expanded the implications of research using the ARCS Motivation Model in the evaluation of serious games. For example, Calvo-Ferrer (2018) found the positive impact of game rewards and instant gratification on undergraduate students' learning outcomes. Similarly, the qualitative data in this study revealed that secondary school students developed attention, interest, satisfaction, and confidence, while the quantitative data revealed that they developed environmental awareness. In addition, this study supports the conclusion that the use of attention, interest, satisfaction, and confidence elements in gamification in the programming course revealed a significant difference in favor of the experimental group (Özdamlı, 2018). However, the findings of this study do not align with another study that found no significant impact of game design on satisfaction (Frost et al., 2015).

Thirdly, abstract conceptualization, emotional attitude, and reflection towards experiential learning attract attention to the qualitative findings. Previous studies have reported the effects of instant feedback mechanisms embedded in digital games on deep learning, self-efficacy, and self-regulation (All et al., 2017; Bowen, 2014; Erhel & Jamet, 2013). The findings, which revealed that students structured their knowledge by resorting to reflection with the scoreboard and instant feedback mechanisms in the designed mobile game, expanded the results of previous studies.

Fourthly, in the qualitative findings, the emphasis on goal setting, planning, self-control, and self-reaction was discovered among the self-regulated learning elements. Our

findings once again revealed the role of concepts such as self-regulation and self-reflection, which Social Cognitive Theory also refers to, in structuring knowledge through mobile games (Bandura, 1982; Middleton et al., 2019). The findings from this study's qualitative analysis that difficulty level placement in game-based learning supports self-regulation are compatible with the findings reported in the research of Chen et al. (2019).

Fifthly, qualitative findings emphasized that the designed mobile game positively changed students' cognitive attitudes, emotional attitudes, and behavioral actions related to environmental awareness. As presented in the direct quotations in the findings, students have developed a cognitive attitude towards disasters such as earthquakes and an emotional attitude with feelings such as empathy and anger towards the negative consequences that may arise in human-environment interaction, such as the extinction of living species. Considering the student quotes that directly indicate that they are aware of the environment and willing to take action, it is a remarkable result that the students using mobile games are trying to protect the environment.

The sixth result in the qualitative findings is that behavioural changes occurred in the students who used the developed mobile game regarding the balanced use of natural resources and savings habits. No study with a similar finding has been found in the literature. The seventh result in the qualitative findings is that students using mobile games increase their knowledge about air pollution, water pollution, soil pollution, climate change, greenhouse gases, global warming, and natural disasters and develop environmental awareness. Our research results coincide with Douven et al.'s (2014) studies reporting the positive effect of educational mobile games in solving water resources-related problems. Similarly, our findings of participants who developed solutions to avoid polluting water and made some decisions in their lives after learning the causes of water pollution support the study of Ducrot et al. (2015). However, these two studies were designed for adults to raise awareness about water pollution.

In previous studies, it was recommended to use digital comics, drama method, life-based learning approach, and social media in lessons to develop environmental awareness (Author & X, 2023; Daglı & Yazıcı, 2021; Hamid et al., 2017; Tokmak et al., 2023). The scenario of the developed mobile game provided students with the opportunity to set their own goals. This result highlighted the use of a mobile game based on quizzing to support students' need for autonomy (Ryan & Deci, 2020). Based on all the quantitative and qualitative results obtained from this study, the following suggestions can be made to other researchers:

1.This research showed that students enjoyed mobile games that included detailed score tables more. The development and use of such games by Science teachers can be widespread.

2.The results of this research show that students solve questions at different levels, with difficulty levels increasing from accessible to difficult, with a higher motivation. Mobile games are designed with these features.

3.Sixth-grade students participating in the data collection process within the scope of this research were pleased with the science teachers' use of this mobile game in classes to improve environmental awareness and its effective integration with information technologies, and they expressed this in the interviews. Based on these results, in-service training can be given to our teachers on how to play such mobile games in classes, and science teachers can be encouraged to use such digital teaching tools in their classes.

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Conflicts of Interest

The author has no conflicts of interest to declare that are relevant to the content of this article.

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Genişletilmiş Türkçe Özet

Bu araştırmanın amacı, öğrencilerin çevre bilincini geliştirmek için bir mobil oyun tasarlamak, iyileştirmek, değerlendirmek ve oyunun çevre bilincinin gelişimi üzerindeki etkisini araştırmaktır. Araştırma, 2022-2023 eğitim-öğretim yılında Bursa'da bir devlet ortaokulundaki 74 altıncı sınıf öğrencisi ve dört öğretmenin katılımıyla yürütülmüştür. Tasarlanan mobil oyunda dörder adet kolay, orta ve zor düzey soru oyuncunun karşısına 110 soruluk bir oyun havuzundan rastgele çıkmaktadır. Oyuncunun bir kez telefon ile bağlanma, bir kez iki yanlış seçimi eleme ve bir kez seyirciye sorma hakkı vardır. Her joker hakkı doğru cevaba götürmemektedir. İstenildiği takdirde oyundaki puanlara ulaşmak mümkündür. Veri toplama aracı olarak çevre bilinci ölçeği, gözlem notları ve yarı yapılandırılmış görüşme formları kullanılmıştır.

Çevre bilincinin teşvik edilmesine yönelik geliştirilen bir mobil oyunun kullanılması öncesi ve sonrası öğrencilerin Çevre Bilinci Ölçeği'nden aldıkları puanlar arasında istatistiksel olarak anlamlı bir farklılığın gözlenmesi, mobil oyunun çevre bilinci üzerinde anlamlı etkisinin olduğunu göstermektedir. Çalışmadaki gözlem ve görüşme verileri döngüsel kodlama ve tematik analiz yöntemleri kullanılarak analiz edilmiştir. "Motivasyonel süreçler üzerindeki etkiler", "bilginin yapılandırılması üzerindeki etkiler" ve "çevre bilinci üzerindeki etkiler" olmak üzere üç tema ortaya çıkmıştır. Geliştirilen mobil oyunun kullanılması, öğrenci motivasyonunun anlamlandırılmasını zenginleştirmiş ve yeni nesil öğrenme uygulamaları için çıkarımlar sağlamıştır. Bulgular, geliştirilen mobil oyunda yer alan oyun mekaniklerinin öğrencilerin bireysel hedeflerine ulaşmalarında içsel motivasyon unsurlarından "özerklik ve öz yeterliliği" olumlu yönde etkilediğini göstermiştir. Nitel bulgularda ikinci olarak, öğrenme görevlerini gerçekleştirme amacıyla kurgulanan oyun mekaniğinin, Pekiştirme Teorisi ile vurgulanan olumlu pekiştirmeye yönelik dikkat, ilgi, memnuniyet ve güven üzerindeki etkilerinin motivasyonel süreçlerdeki rolü keşfedilmiştir. Nitel bulgularda üçüncü olarak, deneyimsel öğrenmeye yönelik soyut kavramsallaştırma, duygusal tutum ve yansıtma dikkat çekmektedir. Ayrıca öğrencilerin mobil oyundaki puan tablosu ve anlık geri bildirim mekanizmaları ile yansıtma yoluna başvurarak bilgilerini yapılandırdıkları tespit edilmiştir.

Nitel bulgularda dördüncü olarak, öz düzenlemeli öğrenme unsurlarından hedef koyma, planlama, öz kontrol ve öz tepki vurgusu keşfedilmiştir. Bulgularımız, Sosyal Bilişsel Teori'nin de atıfta bulunduğu öz düzenleme ve öz yansıtma gibi kavramların mobil oyun aracılığıyla bilginin yapılandırılmasındaki rolünü bir kez daha ortaya koymuştur. Beşinci olarak, nitel bulgular tasarlanan mobil oyunun öğrencilerin çevre bilinci ile ilgili bilişsel tutum, duygusal tutum ve davranışa yönelik eylemlerinde olumlu yönde değişiklikler meydana getirdiğini vurgulamıştır. Bulgularda doğrudan alıntılarda sunulduğu gibi öğrenciler, deprem gibi felaketlere karşı bilişsel tutum, canlı türlerinin yok olması gibi insan-çevre etkileşiminde ortaya çıkabilecek olumsuz sonuçlara karşı empati ve öfke gibi hisleriyle duygusal tutum geliştirmişlerdir. Çevre konusunda bilinçlendiğini ve harekete geçmek için istekli olduğunu belirten öğrenci alıntılarından da yola çıkıldığında, mobil oyunu kullanan öğrencilerin çevreyi koruma çabası içinde olmaları dikkat çekici bir sonuçtur. Nitel bulgulardaki altıncı sonuç, geliştirilen mobil oyunu kullanan öğrencilerde

doğal kaynakların dengeli kullanımı ve tasarruf alışkanlıkları konularında davranış değişikliklerinin meydana gelmesidir. Yedinci sonuç, mobil oyunu kullanan öğrencilerin hava kirliliği, su kirliliği, toprak kirliliği, iklim değişikliği, sera gazları, küresel ısınma ve doğal afetler konularında bilgilerinin artması ile birlikte çevre bilinci geliştirmeleridir. Geliştirilen mobil oyunun senaryosu, öğrencilere kendi hedeflerini belirleme olanağı sağlamıştır. Bu sonuç, öğrencilerin özerklik ihtiyacının desteklenmenin bir yolu olarak bilgi yarışına dayanan bir mobil oyunun kullanılmasının altını çizmiştir.

Bu araştırmanın sonuçları, öğrencilerin içinde detaylı "en yüksek puan tablosu" barındıran mobil oyunlardan daha çok keyif aldıklarını göstermiştir. Bu tür oyunların fen bilimleri öğretmenleri tarafından geliştirilip kullanılması yaygınlaştırılabilir. Bir diğer dikkat çekici sonuç, zorluk seviyesi kolaydan zora doğru artan farklı seviyede soruları, öğrencilerin daha yüksek bir motivasyonda tamamladıklarının ortaya konulmasıdır. Fen bilimleri dersindeki eğitsel mobil oyunlar bu özelliklere uygun olarak tasarlanmalıdır. Araştırmadaki katılımcı öğrenciler, çevre bilincini geliştirmeye yönelik olarak fen bilimleri öğretmenlerinin derslerde bu mobil oyunu kullanmalarından ve bilişim teknolojileri ile etkili biçimde bütünleştirilmelerinden hoşnut olmuş, bunu yapılan görüşmelerde dile getirmişlerdir. Bu sonuçlardan hareketle, öğretmenlerimize bu tür mobil oyunları derslerde nasıl tasarlayacakları yönünde hizmet içi eğitimler verilebilir ve fen öğretmenlerinin derslerinde bu tür dijital öğretim araçlarını kullanmaları özendirilebilir.

Anahtar Kelimeler: Çevre eğitimi, dijital oyun tasarımı, karma yöntem, mobil oyun, mobil öğrenme.

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