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Research Article

Examining Game Designs Compatible with the Planning, Implementation, Evaluation Model in the Context of Science Education

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Abstract – This study aims to examine the general features, quality, PIE (Planning, Implementation, Evaluation) model compliance, and environmental literacy of games created by pre-service science teachers using the PIE methodology. The research participants were pre-service science teachers who were enrolled in the elective course "Science, Sustainability and Environment (SSE)" as third-grade undergraduate students. The pre-service teachers were instructed to create a game using the PIE model while taking into account the environmental learning outcomes listed in the Ministry of National Education's (MoNE) 2018 Science Curriculum. Three researchers assessed each of 13 designs independently, and reliability was determined using Miles and Huberman's formula (1994). The study's findings showed that the majority of the games were card games, and they were authentic. It was determined that the games met the PIE model's requirements for quality and compatibility. It was also established that the pre-service teachers primarily incorporated environmental awareness and subsequently knowledge in their games as part of the environmental literacy components.

Keywords: Educational games, science education, the PIE model, environmental literacy.

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Introduction

Since ancient times, one of the fundamental forms of entertainment for kids has been games. Researchers studying archaeology have found drawings and reliefs that show children were playing games even in antiquity. Despite the fact that games have been around for as long as humans, their educational implications date back to the 19th century (Aymen Peker, 2018). Games are now seen as important tools for education rather than just a way to enjoy time, thanks to a change in public perception (Gee, 2001; Kirriemuir & Mcfarlane, 2007). Games that are designed to fulfill a specific educational objective while considering the number of players, skill level of players, duration and tools and equipment to be used are referred to as educational games (Özen et al., 2019).

Every stage of a person's development can benefit greatly from playing educational games. A review of the literature on educational games led researchers to the conclusion that, from pre-school through high school, games have aided in the realization of some educational objectives (Durdut, 2016; Herodotou, 2018; Şentürk, 2020). Educational games give students a chance to participate actively in the learning process, enhance their critical thinking abilities, make learning more fun, and facilitate peer learning (Beker Baş & Karamustafaoğlu, 2020; Kocadere et al., 2019; Serdaroğlu & Güneş, 2019). In addition to these advantages, using educational games in science classes helps students develop positive attitudes toward science classes by helping them to hypostatize abstract concepts (Korkmaz, 2018; Özkan et al., 2020).

Examining science education curriculum reveals that curriculum has specific objectives, including teaching environmental science, helping individuals understand the world, fostering interaction, and increasing environmental consciousness (Ministry of National Education (MoNE), 2018). The purpose of environmental education is to raise and educate people who can solve environmental issues, safeguard the environment, and are sensitive to it (Mutlu Karanfil, 2022). Encouraging individuals to act responsibly when it comes to the environment is the primary goal of environmental education (Fidan Yazgan, 2023). One could argue that the objectives of environmental education and the previously stated science education objectives are similar. Environmental literacy is brought about when this context is assessed, and the objectives are turned into actions or observable behaviors (Bilim, 2012). Environmental education aims to create environmentally literate people by preparing students for scenarios they may face in the real world. The learning environments must be suitable to produce solutions to problems that are not encountered, enabling the student to participate actively (Külegel, 2020). Educational games can be considered one of

the techniques involving students' active participation in the process. The study by Kırmızıyüz et al., (2021) concluded that educational games positively influenced the students' perspective on environmental issues, and that more environmental concepts could be learned through games. Studies on environmental units with games have revealed notable changes in the attitudes of students toward the environment (Kefeli et al., 2018).

When considering the research, it can be concluded that educational games are likely to be efficacious in both science courses and environmental topics. Specific guidelines must be adhered to in order to enhance the efficacy of educational games pertaining to the topic and lesson. When creating educational games, it is important to take into account the topic or content of the lesson, the age of the students, their levels of cognitive and emotional development, their preferred learning styles, and any individual differences (Beker Baş & Karamustafaoğlu, 2020). Games ought to be designed and implemented within a particular framework, and this procedure should be undertaken attentively (Karamustafaoğlu & Kılıç, 2020). The following features should be considered in the designed game (Aymen Peker, 2018):

- It should be learning-oriented and clear and meet students' needs.
- It must be able to adapt to different situations.
- It should be performed in an attention-grabbing manner and in accordance with the intended objective.
- The suitability of the content should align with the specific context and qualities of the target audience, such as their age and educational level, time and physical conditions of the environment.

Research conducted with the pre-service science teachers has demonstrated that educational games enhanced the retention of learning, and that the games developed were qualified and educational. Nevertheless, the pre-service teachers expressed difficulties in finding and developing games during the game design procedure and expressed a desire for additional classes on how to effectively incorporate them into their teaching (Önen et al., 2012; Seçkin Kapucu & Çağlak, 2018). Research has shown that digital games, including those with educational purposes, enhanced the quality of the learning process, and participants expressed their willingness to create digital games using software (Akgül & Kılıç, 2020). Consequently, research has demonstrated that games can serve as an influential instrument in science education. Games facilitate students' comprehension of scientific subjects, foster their curiosity, and bolster their inclination towards exploration and discovery. The game design

components must be meticulously and clearly delineated. There must be a harmonious equilibrium between amusement and instruction. Research conducted with the pre-service science teachers also revealed that participants believed that games could be utilized not only to enhance the enjoyment of lessons, but also to facilitate the achievement of learning objectives. According to the educational objectives aimed, educational games can be designed in different ways.

The PIE (Planning, Implementation, Evaluation) model was employed in this study as an alternative framework for assessing pre-service teachers' game designs. The model, developed by Jacobson et al. (2006), is a customized game design model specifically designed for environmental purposes. The proposed framework outlines a three-step design process for creating a game to protect the environment. The effectiveness of these three steps is determined by the extent to which the questions posed at each stage are answered and how they are answered. The stage of planning refers to the part when game is planned and organized. To ensure optimal performance in planning, it is imperative to address these inquiries: "What are the intended learning outcomes for the participants?"; "What is the objective you aim to achieve?"; "What type of game are you seeking?"; "Will there be a narrative incorporated?"; "Will the game be conducted in an outdoor space or inside a classroom?"; "Which gamification elements will be used?"; "Are there different difficulty levels available?"; "Will there be any rewards? What will the rewards be?"; "Which material is required?"; "Do you have these materials?"; "If you do not have these materials, do you have to provide them?"; "How can you provide them?"; "Did you conduct any pre-implementation testing on the game?"; "Does the test result need to be modified?". The implementation phase refers to the stage in which the game is actively played. The question of whether the game can be played without any issues is significant. In the stage of evaluation, the information acquired in the game can be evaluated by posing questions like "What have you just experienced?", "What does this mean?", "Now what can you do with this knowledge?", and the game can be evaluated through the questions "Where did you get the most trouble in the game?", "What were the easy parts?", "Which part of the game would you like to change?" (Jacobson et al., 2006).

The significance of PIE lies in its ability to engage students actively, enhance their learning experience, optimize learning outcomes, analyze performance-product-based challenges, and include the steps of planning, implementation and evaluation. PIE is a facilitating method that helps solve problems systematically, therefore providing a clear plan

and suggestions for situations that arise in education. It also helps instructors by guiding them through the steps of planning, implementation, and evaluation, which helps to minimize unexpected issues (Keleş et al., 2016). Developing teaching design model aims facilitate the selection of effective designs by comparing the designs based on the educator's alignment with the intended objective and the designer's knowledge of the design's origin (Andrews & Goodson, 1980). The main objective of this study is to analyze the game designs of pre-service science teachers regarding environmental issues, using the PIE model, and evaluate those designs in terms of game, model, and environmental literacy.

In this study, the PIE model was chosen due to its compatibility with the integration of various multimedia tools and technology (McPheeters, 2009; cited in Keleş et al., 2016) for the development of products both inside and outside the classroom (Gustafson & Branch, 2007; cited by. Keleş et al., 2016). When compared to other designing tools, one of the reasons the PIE model was selected for this study, was its suitability for basic level education, because pre-service teachers were expected to design games for middle school students. Also, this model promotes constructivist learning, pre-service teachers in the role of teachers focus on coordinating learning as guides of teaching rather than simply providing information. Hence, they meet their students with a great experience after graduation (Keleş et al., 2016). This study is significant because it provides a different perspective on the use of games in science education since there are very few studies about PIE model and its implementation in Türkiye. Hopefully, this study can inspire educators to use PIE model in environmental education.

The research questions of the study are as follows:

1. What are the general features of the games designed by the pre-service science teachers?
2. What are the qualities of the games designed by pre-service science teachers?
3. How do pre-service science teachers utilize the phases of PIE when designing games centered on environmental issues?
4. Which components of environmental literacy do pre-service science teachers employ when creating games based on the PIE model?

Method

Research Design

In this study which analyzed the game designs of pre-service science teachers focusing on environmental issues using the PIE model, a case study approach within the qualitative research methodology was applied. Case studies involve in-depth examination of one or more situations, with the goal of establishing associations with various factors (such as medium, individuals, events, processes, etc.) and producing outcomes (Yıldırım & Şimşek, 2021). In this study focusing on the game design process undertaken by pre-service science teachers, using the PIE model and the environmental literacy in those designs constituted the case of which sub-dimensions were being examined.

Participants

The study was conducted during the spring period of 2018-2019, involving 56 pre-service science teachers, 8 male and 48 female, enrolled in the Science Teaching Bachelor's Program. These candidates were in the third year of the program. The participants had taken courses about environmental education and games in science education before this study. Yet, they were not familiar with PIE model. Since the participants were already taking courses together, convenience sampling method was used in this study. This sampling method involves selecting participants who are readily accessible to the researcher, meaning that there is a pre-existing sample (Şimşek, 2018). The data source for the study consisted of 56 pre-service teachers, divided into 13 groups. Groups were sequentially named as G1, G2, ... and G13.

Implementation Process

The implementation process was delineated into two fields examined in the study. These were the environmental content and literacy and game design following the PIE model. The environmental concepts of the study were taught by one of the researchers and the lecturer of the class in a 3-hour Environmental Science class attended by all the pre-service teachers. The concepts about PIE model and game design were taught by the same lecturer during a three-hour elective class Science, Sustainability, and Environment (SSE) that all participants attended. The concepts of science, sustainability, and the environment were defined in the first weeks of the course and the concepts were subsequently deliberated with the students in a questioning environment, elucidating their interrelation using everyday life illustrations. The primary scope of the study, PIE model was conducted during the eighth

week of the course and spread out over a period of two weeks. Upon completion of the class, the pre-service teachers were expected to develop a game design based on the PIE model, for a specific subject or learning outcome from the MoNE 2018 science curriculum, and subsequently submit a report on it. In these reports, pre-service science teachers were expected to explain how they followed the steps of PIE model while designing an educational game. In the planning part the problem was introduced, the objective of the game, the level and prior experiences of the participants, and the limitations were described. In the implementation part, pre-service teachers were expected to describe possible changes after a pilot study and effectiveness of the planning part. In the evaluation part pre-service teachers were expected to describe the product and make suggestions to evaluate whether the method works. At the final part of the reports, participants included the game designs that they developed for teaching environmental concepts.

The pre-service teachers created this design by organizing themselves into groups consisting of their own acquaintances, with group sizes ranging from three to six individuals. It was thought that allowing pre-service teachers to be in a group with their preferred companions and to create their designs centered on an environmental theme of their personal preference would enable them to be motivated and self-assured. All pre-service teachers submitted reports as a compulsory part of the course and all the participants volunteered to have their reports used in this study. Given that the instructor had a minimum of five years of teaching experience, this study did not involve any pilot practice. Instead, the researchers relied on their own expertise.

Data Collection Tools

The data were assessed utilizing a measurement instrument devised based on four themes. These themes were derived from the general features and qualities of the games, their compatibility with the PIE model, and the environmental literacy components they produced. Extensive literature research was conducted for each specific field while preparing the measurement instrument (Akcanca & Sömen, 2018; Freitas & Oliver, 2006; Jacobson et al. 2006; Önen et al. 2012). The examination focused on the components of environmental literacy namely awareness, knowledge, attitude, skill, and behavior. During the analysis of these game components in the designed games, the definitions of the components and the corresponding keywords derived from those definitions were utilized. Environmental literacy components included the following definitions (Alınmaz, 2023; Altınöz, 2010; Benzer, 2010; Fang et al., 2022):

1) *Awareness* refers to a broad understanding or perception of environmental issues.
2) *Information* refers to the knowledge of environmental concepts, such as ecology; this includes understanding ecological information, environmental problems, and environmental issues.
3) *Attitude* refers to an individual's capacity for understanding and showing concern for the environment, while also displaying a positive outlook and being responsive to environmental issues (such as anxiety, fear, and motivation).
4) *Skill* refers to the capacity to effectively utilize one's acquired knowledge and attitudes to address environmental issues. (This includes analyzing, generating solutions, and making decisions.)
5) *Behavior* refers to the manifestation of one's environmental knowledge, attitude, and skill, which leads to active engagement in environmental matters and concerns.

Following the completion of the research, the researchers convened to develop the initial version of the measuring instrument. The initial version of the measuring instrument comprised two primary components. The initial version comprised items pertaining to the game's quality and the steps of PIE model. To ensure the validity of items, researchers consulted both a field and a language expert. The measuring instrument was divided into four sections based on the feedback received, and adjustments were implemented in the part of scoring. Using this rubric, an evaluation was conducted on three games designed by the pre-service teachers. Following the pilot implementation, experts reached a consensus to revise certain items and omit some other items, resulting in the finalization of the measuring instrument. The final version of the rubric consisted of 14 items that described the general features of the games, 11 items that outlined their qualities, 13 items that assessed their compatibility with the PIE model, and 5 items that evaluated their environmental literacy components.

Data Analysis

For the first part, in the evaluation of the general features of the games, the type and authenticity of the game, and number and grade level of players and the frequency of using game elements included were expressed. In the second part, during the evaluation of the games' qualities, three researchers classified the games into four categories: "0" (no data), "1" insufficient (data available but design not suitable), "2" partially sufficient (design contains appropriate data but not enough), and "3" sufficient (design has data that fully corresponds to the item). The frequencies of each score value for the items included in the measurement

instrument were also computed by three researchers. The maximum attainable score in this particular section was 33. Excerpts from sample designs that received the maximum score were shown in Table 1.

Table 1 Explanation that Received the Maximum Score on the Game Quality

Game		3 point-samples
Item 1	Learning outcomes	"Our activity consisted of the group game designed in order to make students comprehend the learning outcomes stated in the unit of 8th grade Science Education titled Cycles of the Matter and Environmental Problems, namely 'Students will be able to discuss the causes of global climate change and its potential outcomes.' ." (G11)
Item 2	Objective	"In our game design, it is crucial that participants learn through enjoyable experiences. Our game aims to enable participants to be individuals who possess a strong awareness of environmental issues and a comprehensive understanding of the potential consequences of global climate change resulting from these issues." (G11)
Item 3	Rules	"Rule**:** Prohibited words written on the cards cannot be uttered. No portion of the words written on the card may be used as a clue. Sign language cannot be used. Songs cannot be explained through mere whispers of the melody or the recitation of lyrics. You cannot explain a word by articulating words in any foreign language except Turkish." (G8)
Item 4	Difficulty	The game's level of difficulty was assessed by analyzing the students' prior learning and the consistence between the learning outcomes and objectives targeted by the game. "Prior learning; At the fifth grade, students are presumed to have attained the knowledge and skills related to the learning outcomes in the unit of the Human and Environment. S.5.6.2.1. Students will be able to recognize the significance of the interaction between humans and the environment, denote the detrimental impacts of environmental pollution on human well-being. Learning outcomes targeted by the game; S.8.6.3.3. Students will be able to discuss the causes and potential consequences of global climate change." (G2) Since the designed game was designed for the 8th grades, prior learning and targeted learning outcomes are coherent.
Item 5	Time management	"One group is assigned the task of monitoring the passage of time, while a member from another group is provided with a set of cards at the beginning of the time period. The individual's own group is then instructed to explain the words written on the cards within duration of 1 minute, without using any forbidden words." (G8)

Table 1 (continued)

Game		3 point-samples
Item 6	Instructing	"The objective is to teach students the determinants that impact global warming, the greenhouse effect, and the potential consequences of environmental issues on the future of the Earth and human existence." (G11)
Item 7	Reinforcing	"The product of the game designed for 7th grade students is defined as students' having a thorough understanding of which waste materials can be recycled. The game's deck comprises various waste materials, and students are required to differentiate between them. The consistency between the aimed learning outcomes and game concepts has been acknowledged as a means of reinforcement." (G4)
Item 8	Evaluation	"Following the game, the teacher can understand whether objectives were realized or not by examining the quantity of stickers collected by students and administering a quiz." (G12)
Item 9	Social interaction	"Related to skills, the student develops proficiencies in areas such as communication, self-expression, collaboration, and time management." (G8)
Item 10	Competing	"A mysterious bicycle journey which was set on with 24 golden coins... During this expedition, we both have the opportunity to get to know the cities and acquire new information. As we learn, we embark on adventurous journeys. If we fail to do something for the environment, these adventurous paths will be our nightmares. Furthermore, we have the opportunity to engage in commerce along those paths. However, what matters more is not the money but the points. Let's see who will rack up the most!" (G10)
Item 11	Active learning	"The game helped students to be active and remember previous learning." (G12)

The evaluation of the compatibility of the game designs with the PIE model for the 13 items in the measurement instrument was similar to the evaluation made in the qualities of the game. For "0," the PIE model was never taken into account; "1" was graded as insufficient enough to the PIE model, "2" was only partially sufficient, and "3" was graded as sufficient to the PIE model. For each item, the analyses were tabulated to provide frequency. Maximum score was 39. Excerpts from the designs are shown in Table 2 as examples of the evaluation.

Table 2 Explanations with a Maximum Score Based on the PIE Model

Game		3 point-samples
Item 1	Issue/problem handled	"Human-environment relation. Positive and negative impacts of human beings on environment. Harms caused by human beings on environment (Consciously or accidentally)" (G1)
Item 2	Objective and purpose	"To increase sensitivity to environmental problems caused by human activities. To develop the ability to protect and improve the environment. To question recycling in terms of resource efficiency, environmental pollution and economic development." (G4)
Item 3	Levels/features of participants	"They should answer the questions sincerely. They should be 5th grade students. Participants are interested in environment and environmental problems." (G1)
Item 4	Prior experiences of participants	"They have information about the beneficial or harmful situations in the human-environment interaction. They have the required information and skill for the solutions to environmental problems." (G4)
Item 5	Change	"Students can distinguish recyclable materials from nonrecyclable materials in the cards they are given during the game. They plan how to recover the materials written in their cards." (G4)
Item 6	Planning process	"For the factors to be included in the game like the resources, types of plants, types of animals, any elements students demand can be included in the game. They can be allowed to include their own city names. Their expectations and demands can be asked before playing." (G2)
Item 7	Limitations	"There may be troubles related to the accuracy of the answers given by students during the activity. Students may not be honest about their answers just because they want to win the game. It may be hard to play the game in a crowded classroom. The number of the cards may be increased based on the class size." (G1)
Item 8	The impact of instructions on knowledge, attitude and behavior	"When feedback related to the mistakes of students are given via red dots until reaching the best world among four different ones, instructions may have much influence upon changing the negative attitudes of students. The examples given in the orientation parts of the game include attitudes and behaviors that are highly applicable in everyday life (e.g. greengrocer, market). So, the fact that students can demonstrate positive behavior change can be of great importance in terms of accelerating." (G7)

Table 2 (continued)

Item 9	Implementation-pilot	"Due to the game applied, students acquire detailed information on air pollution, which is an important form of environmental pollution. They learn the results of the impact of air pollution on earth. They utilize the behaviors and attitudes acquired in the game. (G5)
Item 10	Finance	"It is financially suitable to prepare the game. Students can prepare this game using their own stationery materials." (G5)
Item 11	Working of evaluation method	"Before applying the method, a survey which aims to measure knowledge, attitude and behavior related to the topic is implemented. After the method is tried, the same survey is implemented again. Comparing the first and the latter, the change is examined." (G6)
Item 12	The output of the program	"Students can discern the factors that cause environmental problems, think about them, interpret them; their opinions change, and they are motivated. And all those factors make students more sensitive to the environment, and their behaviors change." (G6)
Item 13	Success indicators	"Yes, we make assessments via surveys implemented. Also, we can understand which component of the environment challenge students most by examining at what level students often lose the game." (G6)

To see which components of environmental literacy were included in designed games, the evaluation of the environmental literacy components in game designs was conducted independently by three researchers. Among the environmental components, the following ones were included in the scope of the study: awareness, knowledge, attitude, skill and behavior. Table 3 presents excerpts from sample designs that received the maximum score for environmental literacy.

Table 3 Explanations with a Maximum Score Related to Environmental Literacy

Environmental literacy component	3 point-samples
Environmental awareness	"While evaluating the designed games regarding the environmental awareness, the inclusion or exclusion of environmental issues in games has been examined. Environmental concerns were incorporated into the majority of the games, with the intention of providing changes in the students related to the topics on environment. Ina game of which content was stated, the following explanation was made: "acquiring knowledge about household waste, its recovery and recycling, and cultivating appropriate behavior"." (G9)
Environmental knowledge	"To distinguish between recyclable and non-recyclable waste, accurately categorize recycled waste, and obtain information about the advantages of recycling." (G13)
Environmental attitude	"The game consists of a maze with two possible exits. In the pathways of the maze, items related to the environmental attitude and behavior are included. These items are annotated with short marks such as 'yes-no' or 'do-do-not'. Via the marks, the game concludes with two possible outcomes: one leads to a nice and clean environment, while the other leads to an environment that is contaminated and inhospitable." (G7)
Environmental skill	"The game, which is played by a minimum of two groups, and improving the capacity to make rapid decisions and categorize by engaging in competitive time-based challenges." (G13)
Environmental behavior	"The purpose of the designed game will be to design the most environmentalist city ever, in other words, Eco-City. The virtual tabs will contain many different resources. There will be many energy options, from wind turbines, for example, to nuclear power plants. There will be a recycling center, regular storage facilities. The city will be founded by the students' choices. The student will pay attention to the characteristics that are environmental when building a city, in other words, they will display a behavior. This game is thought to contribute to environmental behavior thanks to gaining points and levels." (G2).

Reliability

The games were assessed by three researchers independently. Below are the specifics of the data that underwent descriptive analysis using closed encoding. As a result of the conducted analyses, the consistency among researchers was examined using the matching formula proposed by Miles and Huberman (1994). For the graded parts of the rubric sections (the features of the game, components of PIE and environmental literacy), consistency of researchers were examined one by one. The researchers' consistency was measured at 0.80 for quality, the PIE components at 0.77, and the environmental literacy at 0.75. The calculated

consistency values can be considered suitable in relation to the research's reliability (Miles & Huberman, 1994).

Findings

To answer four research questions of this study, the reports, which were filled by participants and included designed games, were analyzed. The results were organized into four research questions.

General Features of the Games

The first research question of this study was "What are the general features of the games designed by pre-service science teachers?". The general features included the type of game, game authenticity, number of players, game level and game components. The findings regarding to the first research questions are presented in Table 4.

Table 4 General Features of the Games Designed by the Pre-service Teachers

Type of game	f	Game authenticity	f	Number of players	f	Game level	f	Game components	f
Card game	5	Authentic	8	Individual	4	Grade 4	1	Goal setting	13
Board game	3	Adaptation	5	Group	7	Grade 5	4	Re-playing	13
Digital game	3			Both	2	Grade 7	3	Giving feedback	13
Other	2					Grade 8	3	Setting rules	12
						Not specified	2	Interesting	12
								Reward	8
								Challenge	6
								Time	3
								Level	3
								Narration	1
Total	13		13		13		13		84

f: frequency

The data from Table 4 shows that card games (38.4%) were the most used ones among the games designed by the pre-service science teachers. The card games were followed by board games (23.1%), digital games (23.1%), and other games (15.4%). To assess the authenticity of the games, they were categorized into two groups: authentic games and adapted games. Out of the 13 games developed, 8 games (61.5%) were identified as authentic, while the remaining 5 games (38.5%) were classified as adaptations. The games were analyzed in three groups based on the number of players; namely individual games, group games, and games that allowed both individual and group playing. Out of 13 games, 4 games

(30.8%) were played individually, 7 games (53.8%) were played as a group, and 2 of them (15.4%) could be played either individually or in groups. When grade levels of the designed games were examined, the games were mostly designed for Grade 5 (30.7%), followed by Grade 7 (23.1%) and 8 (23.1%). 2 games (15.4%) did not have a level, and 1 game (7.7%) was specifically created for students in the fourth grade. Upon evaluating the games created by the pre-service teachers in terms of game components, it was found that all of the 13 games included objectives and gave feedback and were designed to facilitate re-playability. Furthermore, the rules were explained properly in 12 games (92.3%), and 12 games (92.3%) were designed in an interesting way. 8 of the games (61.5%) specified the reward, while 6 games (46.1%) incorporated the component of challenge. The games had minimal references to time and level, with only 3 games (23.1%) providing explicit specifications for both. Only one of the games (7.7%) included a narrative component.

Qualities of the Game

To seek an answer to the sub-problem as "What are qualities of the games designed by pre-service science teachers?'', the game's qualitative features have been examined. Findings are presented in Table 5.

Table 5 Findings Related to the Qualities of the Designed Games

Items	None (0) f	Insufficient (1) f	Partially (2) f	Sufficient (3) f
1. The designed educational game corresponds to the learning outcomes mentioned.	1	2	2	8
2. The purpose of the designed game is identified.	0	0	4	9
3. The rules of the designed game are stated.	1	0	2	10
4. Difficulty levels of the designed game correspond to the level of students.	1	1	0	11
5. The designed educational game is well constructed in terms of time management.	10	1	0	2
6. The designed educational game has an instructive feature.	0	0	3	10
7. The designed educational game reinforces the new information related to the subject.	0	1	3	9
8. The designed educational game can be used for evaluation.	0	5	4	4
9. The designed educational game increases the social interaction among participants.	0	2	3	8
10. The designed educational game creates a competitive relation among participants.	0	4	2	7
11. The designed educational game creates an active learning environment for participants.	0	1	2	10
Total	13	17	25	88

f: frequency

The initial item in evaluating the quality of the games was about the compatibility of the designed games with the mentioned learning outcomes. There was 1 design out of 13 (7.7%) that did not incorporate any learning outcome in this item, resulting in a score of zero. 2 designs (15.4%) received a score of 1 point, 2 designs (15.4%) received a score of 2 points, and 8 designs (61.5%) received a score of 3 points. The second item pertains to the purpose of the educational games that were designed. In this item, there were no designs that had a score 0 or 1. 4 designs (30.8%) that failed to state their purpose properly got 2 points. 9 designs (69.2%) received a score of 3 points for properly and sufficiently expressing their objective. The third item pertains to the rules of the designed games. One design (7.7%) that did not adhere to any rules received a score of zero. There were no designs that had a score of 1. Two designs (15.4%) got 2 points, while 10 designs (76.9%) received 3 points. The fourth item pertains to the difficulty level of the designed educational game and its compatibility with student's level. There was 1 design (7.7%) with 0 point, and one design (7.7%) with 1 point, but there were no designs with 2 points. 11 designs (84.6%) received a total of 3 points. The fifth item pertains to the time management of educational games designed. There were 10 designs (76.9%) with a 0-score. One of the designs (7.7%) received a score of 1 point. There were no designs with 2 points, but there were 2 designs (15.4%) that got 3 points each. The sixth item is about instructive feature of designed games. No design was assigned 0 and 1 points. 3 designs (23.1%) got 2 points and 10 designs (76.9%) got 3 points. The seventh item pertains to reinforcement of knowledge. No game was assigned 0 point. One game (7.7%) received a score of 1 point, 3 games (23.1%) received a score of 2 points, and 9 games (69.2%) received a score of 3 points. The eighth item is about using designed games for evaluation. No game was assigned 0 point. There were 5 games (38.4%) with 1 point, and 4 games (30.8%) with 2 points, 4 games (30.8%) with 3 points. The ninth item is about social interaction. No game was assigned 0 point. Two games (15.4%) received a score of 1 point, 3 games (23.1%) received a score of 2 points, and 8 games (61.5%) received a score of 3 points. The tenth item pertains to competition among participants of game. Four designs (30.8%) got 1 point, 2 designs (15.4%) got 2 points and 7 designs (53.8%) received 3 points. The eleventh item is about providing an active learning environment. No game got 0 point. There was 1 game (7.7%) with 1 point. There were 2 games (15.4%) with 2 points, 10 games (76.9%) with 3 points.

PIE Evaluation

In this section, research findings related to the problem namely "While designing a game on environmental issues, how do the pre-service science teachers utilize the stages PIE?" were presented. The results are summarized in Table 6.

Table 6 Findings Pertaining to the Compatibility of the Designed Games with the PIE Model

Items	None (0) f	Insufficient (1) f	Partially (2) f	Sufficient (3) f
1. What is the problem/issue/topic you would like to handle?	0	0	7	6
2. What are your aims and objectives?	0	0	1	12
3. What are the qualities and levels of the participants you will work with?	1	0	1	11
4. What are the previous experiences, needs, interests and actions of the participants?	2	0	1	10
5. What action and what kind of change are expected for each student?	1	0	3	9
6. How can students be included in the planning process?	0	1	2	10
7. Are there limitations/difficulties and/or resources? If yes, what are they?	1	0	0	12
8. Which guidelines or activities do you think will have the greatest impact on the change in information, attitudes and behavior?	0	1	5	7
9. After conducting pilot studies on the activities and materials to be implemented, what specific modifications have been identified?	3	3	1	6
10. Is the plan, finance and employment prepared for the implementation suitable, sufficient and efficient?	2	0	2	9
11. How would you know whether the method worked or not?	0	0	2	11
12. What is the product or outcome of the program?	0	0	2	11
13. Can you assess the metrics of achievement (attainment of objectives) such as the student's cognitive proficiency, disposition, and conduct, or alterations in the surroundings?	0	2	4	7
Total	10	7	31	121

f: frequency

The games were evaluated based on the control list of PIE; the initial 8 items in the control list concern planning; items 9 and 10 concern implementation and items 11, 12 and 13 concern evaluation. The first item of the planning section of PIE pertains to the problems and topics to be handled in the designed games. There were no designs with a score value of 0 or 1. 7 designs (53.9%) acquired 2 points and 6 designs (46.1%) got 3 points. The second item concerns the aims and objectives. There were no designs with a score of 0 or 1. One design

(7.7%) got 2 points and 12 designs (92.3) got 3 points. The third item concerns the qualities and levels of participants in the games. There was only one design (7.7%) with a score of 0. There were no designs with 1 point; there was one design (7.7%) with 2 points and 11 designs (84.6%) with 3 points. The fourth item concerns the previous experiences, needs and actions. There were two designs (15.4%) with 0 point. There was no design with 1 point. One design (7.7%) got 2 points and 10 designs (76.9%) got 3 points. The fifth item concerns actions and changes made by each of the students. 1 design (7.7%) got 0 point. There was no design with 1 point. 3 designs (23.1) got 2 points and 9 designs (69.2%) got 3 points. The sixth item is about planning process. There was no design with 0 point. One design (7.7 %) got 1 point. 2 designs (15.4 %) got 2 points and 10 desings (76.9 %) got 3 points. The seventh item pertains to limitations and difficulties of designed games. There was only one design (7.7%) with 0 point. There were no designs with 1 and 2 points. 12 designs (92.3 %) got 3 points. The eighth item is about the greatest impact on change in attitude and behaviour. There was no design with 0 point. One design (7.7%) got 1 point. 5 designs (38.4%) got 2 points and 7 designs (53.8%) got 3 points. The nineth item is about changes after pilot implementation. 3 designs (23.1%) got 0 point. There were 3 designs (23.1%) with 1 point, 1 design (7.7%) with 2 points, 6 designs (46.1%) with 3 points. The tenth item pertains to the plan and finance for the implementation. 2 games (15.4%) got 0 point. There was no game with 1 point. 2 games (15.4%) got 2 points and 9 games (69.2%) got 3 points. The eleventh item evaluates whether the method works. There were no with design 0 and 1 points. 2 designs (15.4%) got 2 points and 11 designs (84.6%) got 3 points. The twelfth item is about the product or outcome of the program. There was no design with 0 and 1 points. There were 2 games (15.4%) with 2 points and 11 games (84.6%) with 3 points. The thirteenth item is about assessment of the metrics of achievement. There was no design with 0 point. 2 designs (15.4%) got 1 point. 4 designs (30.8%) got 2 points and 7 desings (53.8%) got 3 points.

Environmental Literacy

The games designed by the pre-service teachers were examined in the framework of environmental literacy components through the research question “Which components of environmental literacy are employed by the pre-service science teachers while designing games based on the PIE model?’’. Which component was included mostly in the games by the pre-service teachers is presented in Table 7.

Table 7 Environmental Literacy Components

Environmental literacy components	Number of games included the component	Number of games did not include the component
Environmental awareness	13	0
Environmental knowledge	12	1
Environmental attitude	11	2
Environmental skill	1	12
Environmental behavior	8	5

When data in Table 7 were examined, the graphs demonstrated that all of the pre-service teachers employed environmental awareness among the components of environmental literacy, while utilizing environmental skills (7.7%) the least. After the environmental awareness, there came environmental knowledge (92.3%), environmental attitude (84.6%) and environmental behavior (61.5%) respectively.

Discussion

The study evaluated the educational games created by the pre-service science teachers based on their general features, quality, compatibility with the PIE model, and inclusion of environmental literacy components. Initially, when examining the attributes of games, it has been observed that games were typically intended for group play. Due to the overcrowded nature of educational system in Türkiye, students face increased challenges in participating in individual or extracurricular games, primarily due to constraints in time management and adherence to game rules. One possible explanation for why the pre-service teachers favor group games could be due to this factor. Regarding the type of games that were created, it has been discovered that the majority of them were card games. When Cop and Kablan (2018) analyzed the studies on the educational games in Türkiye, it was seen that the mostly used games in the studies were computer-based games. Nevertheless, not all teachers possess the expertise and resources to create a computer game. One possible explanation for the prevalence of card game design in this study is that it does not necessitate specialized knowledge or skills, such as "technology". Most of the games designed by the pre-service teachers, the components, such as objectives, feedback, rewards, and rules, were appropriately defined. Furthermore, these games were designed to be engaging and capable of being played multiple times. In the study by Önen et al. (2012), most of the games designed by the pre-service science teachers had rules defined clearly and there was a special care for games' being enjoyable. At this point, it can be said that the pre-service teachers had positive skills and knowledge related to the usage of games in science education.

Upon reviewing the literature on educational games, numerous studies have discovered that a key advantage of incorporating games in education is the active engagement of students in the classroom (Çakır, 2022; Dolunay & Karamustafaoğlu, 2021; Kılıç & Karamustafaoğlu, 2020; Yıldız et al. 2016). Upon examining the attributes of the games created by the participants in this study, it was discovered that the games they designed excelled in terms of "facilitating an engaging educational setting". As well as games, PIE design is also instrumental in engaging students. Keleş et al. (2016) characterized this model as a means of promoting student engagement, enhancing learning outcomes, analyzing performance-based issues, and utilizing the steps of planning, implementation and evaluation. Moreover, the qualities of the games designed by the pre-service teachers have been evaluated as sufficient in terms of these criteria, as the learning outcomes, class level, objectives and rules were specified in most of the games. Nevertheless, due to the absence of a predetermined timetable for game sessions, the designed games have been deemed insufficient in terms of time allocation and organization. Another crucial aspect of the games developed in this study was their ability to augment social interaction and foster competition among participants. Lee et al. (2011) found interactive educational games involving social interaction and competition to be more effective in terms of learning processes compared to individual offline ones. The games designed were also found to be sufficient for instruction and reinforcement, but insufficient for evaluation purposes. Earlier studies on educational games have also shown that educational game is used more as a teaching technique (Fırat, 2011; Karamastafaoğlu & Baran, 2020; Kılıç & Karamustafaoğlu, 2020), while it is used less for evaluation purposes (Yıldırım & Can, 2017). Nevertheless, games have a significant potential to incorporate the utilization of knowledge and abilities within the educational setting. In an environment characterized by motivated students who engage in enjoyable activities to assess their knowledge and skills, teachers can conduct evaluations, and students' self-evaluations can also be valuable.

Upon evaluating the designed games in relation to PIE components, it was found that they were sufficient in terms of many components within the framework. The implementation of a question-and-answer paper, with clearly defined PIE components, as a means of collecting data from the pre-service teachers has resulted in a high level of satisfaction with the participants' responses. Given that PIE's framework is a specialized model tailored for pre-service teachers interested in environmental game design, it is anticipated that these pre-service teachers will achieve success in this field.

When the games designed by the pre-service teachers were examined, it was discovered that the most prevalent environmental literacy component was awareness, followed by knowledge and attitude while the skill components have been identified in a single design. There have been two different interpretations of this result. One possibility is that the pre-service teachers may have incorporated similar components drawing from their own environmental literacy. When studies on this topic were examined, it was discovered that the pre-service teachers generally exhibited a high level of environmental attitude (Özgürler, 2014; Şahin et al., 2016) but a low level of knowledge and behavior (Altınöz, 2010; Bilim, 2012; Özgürler, 2014; Şahin et al., 2016; Teksöz et al., 2010). The high level of attitude observed in the studies and the pre-service teachers' involving environmental attitude in higher rates in their designed games aligns with our interpretation. Moreover, environmental knowledge and awareness were utilized in this study with high frequency. It was perceived as a positive reflection of the game designs because they were developed in an environmentally focused class in a term when SSE was taught.

In addition to these findings, the utilization of the environmental skill component in game designs was observed to be the least frequent. An analysis of learning outcomes in the 2018 science curriculum (MoNE, 2018) in terms of environmental literacy revealed that the learning outcomes related to knowledge and skill were mostly included in game designs, and the learning outcomes related to awareness, attitude and behavior were not included enough. (Fidan Yazgan, 2023). As the pre-service teachers adhered to the 2018 curriculum when creating their designs, it was observed that there was consistency in the learning outcomes related to knowledge, however there was a difference in the skill component. In this reference, it can be said that environmental skill component included in the environmental learning outcomes of the science education curriculum was not much adhered too much. This may be associated with the complexity of environmental problems and the utilization of multidiscipline for their solution. Here in, it can be asserted that the pre-service teachers created their designs based on their professional qualifications, individual differences, and their own environmental knowledge and perspectives, rather than the achievements they discussed.

Conclusions and Suggestions

Upon considering all the findings, it was seen that pre-service teachers did not encounter too many problems with the game components in general while designing games. According to the findings of the study, it was noticed that the pre-service teachers did not

include environmental literacy components sufficiently in their game designs, especially skills and behaviour component. Based on this, it can be suggested to emphasize environmental literacy components during the course. For this purpose, the methods or contents of the course may be modified. For this study, it may be a limitation that only the reports submitted by the pre-service teachers were used as data collection tools. The use of observation forms or conducting interviews with participants may provide more detailed information for further studies. Additionally, providing pre-service teachers an opportunity to apply the designed games in the schools with students may affect their professional development positively. Because of the attractive nature of fames for students, introducing elective courses for pre-service teachers at the faculties of education, focusing on how to design a game and its integration into their classes can enhance their professional development.

Compliance with Ethical Standards

Disclosure of potential conflicts of interest

Authors declare that they have no competing interest

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The fourth author implemented the study. All authors took part in writing the article. First author also made editing and reviews as corresponding author.

Research involving Human Participants and/or Animals

This study was carried out taking ethical rules into account.

Fen Eğitiminde Planlama, Uygulama, Değerlendirme Modeline Uygun Oyun Tasarımlarının İncelenmesi

Özet:

Bu çalışmanın amacı, fen bilgisi öğretmen adayları tarafından PIE (Planla, Uygula, Değerlendir) modeline göre tasarlanan oyunları; genel özellikleri, niteliği, PIE modeline uygunluğu ve çevre okuryazarlığı bileşenleri açısından incelemektir. Bu amaçla 3. Sınıfta öğrenim gören ve Fen, Sürdürülebilirlik ve Çevre (FSÇ) seçmeli dersini alan fen bilimleri öğretmen adayları araştırmaya katılmıştır. Öğretmen adaylarından Millî Eğitim Bakanlığı 2018 Fen Bilimleri Öğretim Programındaki çevre konulu kazanımlar ele alınarak PIE modeline göre oyun tasarımı yapmaları istenmiştir. Tasarımlar üç araştırmacı tarafından birbirinden bağımsız olacak şekilde değerlendirilmiş ve Miles ve Huberman'in (1994) sunduğu uyuşum formülü ile güvenirliğine bakılmıştır. Çalışma sonucunda oyunların çoğunlukla kart oyunu türü olduğu ve özgün tasarım oldukları görülmüştür. Oyunların nitelik bakımında yeterli ve PIE modelinin çerçevesine uygun tasarımlar olduğu sonucuna ulaşılmıştır. Öğretmen adaylarının oyunlarında çevre okuryazarlık bileşenlerinden en çok farkındalık ardından da bilgi bileşenlerine yer verdikleri tespit edilmiştir.

Anahtar kelimeler: Eğitsel oyunlar, fen eğitimi, PIE modeli, çevre okuryazarlığı.

References

Akcanca, N., & Sömen, T. (2018). Prospective teachers' educational game designing and applications. *Electronic Turkish Studies, 13*(27), 49-71. http://dx.doi.org/10.7827/TurkishStudies.14506

Akgül, G., & Kılıç, M. (2020). Preservice science teachers' views on educational digital games and KODU implementations. *Fen Bilimleri Öğretimi Dergisi*, *8*(2),101-120. https://dergipark.org.tr/tr/pub/fbod/issue/71992/1158003

Alınmaz, N. (2023). *Investigation of pre-school teachers' competencies on environmental literacy* (Publication No. 774963) [Master's thesis, Kastamonu University]. Council of Higher Education Thesis Center.

Altınöz, N. (2010). *Environmental literacy levels of prospective science teachers* (Publication No. 274704) [Master's thesis, Sakarya University]. Council of Higher Education Thesis Center.

Andrews, D. H., & Goodson, L. A. (1980). A comparative analysis of models of instructional design. *Journal of Instructional Development*, *3*(4), 2-16. https://link.springer.com/article/10.1007/BF02904348

Aymen Peker, E. (2018). *Evaluation of teaching the unit of titled 'Let's travel and learn about the living world' for 5th grades with classic educational games and educational games supported with technology* (Publication No. 492301) [Doctoral dissertation, Ondokuz Mayıs University]. Council of Higher Education Thesis Center.

Beker Baş, M., & Karamustafaoğlu, O. (2020). An educational game on central and peripheral nervous system. *Gazi Journal of Educational Science, 6*(1), 80-92.

https://dergipark.org.tr/tr/pub/gebd/issue/53429/643014

Benzer, E. (2010). *The effect of environmental education lesson prepared with project-based learning approach on pre-service science teachers' environmental literacy* (Publication No. 279892) [Doctoral dissertation, Marmara University]. Council of Higher Education Thesis Center.

Bilim, İ. (2012). *Sustainable environment perspective faculty of education students' levels of environmental literacy* (Publication No. 330235) [Master's thesis, Afyon Kocatepe University]. Council of Higher Education Thesis Center.

Cop, M. R., & Kablan, Z. (2018). The analysis of studies on educational games in Turkey. *Kocaeli University Journal of Education*, *1*(1), 52-71. https://dergipark.org.tr/tr/pub/kuje/issue/37623/422759

Çakır, A. (2022). *The effect of educational games developed for the third grade science course five sense unit on the academic success of students* (Publication No. 770891) [Master's thesis, Amasya University]. Council of Higher Education Thesis Center.

Dolunay, A., & Karamustafaoğlu, O. (2021). Opinions of science teachers about educational games: "The fastest sound" game". *International Journal of Turkish Educational Sciences*, *2021*(16), 48-69.

https://dergipark.org.tr/tr/pub/goputeb/issue/62038/872860

Durdut, A. (2016). *Improving an educational computer game in mathematics for vocational school students and the effects of success* (Publication No. 456152) [Master's thesis, Balıkesir University]. Council of Higher Education Thesis Center.

Fang, W. T., Hassan, A. A., & LePage, B. A. (2022). *The living environmental education: Sound science toward a cleaner, safer, and healthier future*. Springer.

Fırat, S. (2011*). The effects of mathematics teaching performed through educational computer games on conceptual learning* (Publication No. 301095) [Doctoral dissertation, Adıyaman University]. Council of Higher Education Thesis Center.

Fidan Yazgan, P. (2023). *Comparison of the objectives in the national science curriculum and optional environmental education programs in the context of environmental literacy* (Publication No. 783659) [Master's thesis, Marmara University]. Council of Higher Education Thesis Center.

Freitas, S., & Oliver, M. (2006). How can exploratory learning with games and simulations within the curriculum be most effectively evaluated?. *Computers & Education*, *46*(3), 249-264. https://doi.org/10.1016/j.compedu.2005.11.007

Gee, J. P. (2003). What video games have to teach us about learning and literacy?. *Computers in Entertainment*, *1*(1), 1-4. http://dx.doi.org/10.1145/950566.950595

Herodotou, C. (2018). Mobile games and science learning: A comparative study of 4 and 5 years old playing the game Angry Birds. *British Journal of Educational Technology*, *49*(1), 6-16. https://doi.org/10.1111/bjet.12546

Jacobson, S. K., McDuff, M. D., & Monroe, M. C. (2006). *Conservation education and outreach techniques (Techniques in ecology and conservation).* Oxford University Press.

Karamustafaoğlu, O., & Baran, S. (2020). Teachers' views about science teaching with 'Force capturing' the educational game. *Fen Bilimleri Öğretimi Dergisi*, *8*(1), 76-91. https://dergipark.org.tr/tr/pub/fbod/issue/71986/1158007

Karamustafaoğlu, O., & Kılıç, M. F. (2020). Investigation of national scientific studies about educational games. *Atatürk University Journal of Kazım Karabekir Education Faculty,* (40), 1-25. https://dergipark.org.tr/tr/pub/ataunikkefd/issue/55385/730393

Kefeli, N., Taş, E. & Yalçın, M. (2018). The effect of teaching science with word games on the attitudes of students towards environment. *International e-Journal of Educational Studies*, *2*(3), 44-52. https://doi.org/10.31458/iejes.388619

Keleş, E., Fiş Erümit, S., Özkale, A., & Aksoy, N. (2016). A roadmap for instructional designers: A comparison of instructional design models. *Ankara University Journal of Faculty of Educational Sciences*, *49*(1), 105-139. https://doi.org/10.1501/Egifak_0000001377

Kılıç, M., & Karamustafaoğlu, O. (2020). Teachers' view on blood catching educational game. *Journal of Science Mathematics Entrepreneurship and Technology Education, 3*(3),144-158. https://dergipark.org.tr/tr/pub/fmgted/issue/60204/838898

Kırmızıyüz, E., Ercan, D., & Uz Bilgin, Ç. (2021). Designing, developing and implementing an educational mobile game on electrical energy conversion and recycling. *Yıldız Journal of Educational Research*, *6*(1), 48-60. https://doi.org/10.51280/yjer.2021.013

Kirriemuir, J., & McFarlane, A. (2003, January). Use of computer and video games in the classroom [Conference Paper] Proceedings of DiGRA 2003 Conference: Level Up, Utrecth, Holland. https://www.researchgate.net/publication/221217309_Use_of_Computer_and_Video_Games_in_the_Classroom

Kocadere, S. A., Özhan, Ş. Ç., Bayrak, F. & Kibar P.N. (2019). Story of Hercules: An educational game development model proposal. *Educational Technology Theory and Practice*, *9*(1), 230-250. https://doi.org/10.17943/etku.451990

Korkmaz, S. (2018). *Development and effectiveness of educational games in science teaching as supplementary material on students' achievement and attitude towards science* (Publication No. 502718) [Master's thesis, Bartın University]. Council of Higher Education Thesis Center.

Külegel, S. (2020). *A research to improve the 21st century skills of gifted and talented students of environmental education-based science, technology, engineering, mathematics activities* (Publication No. 640643) [Master's thesis, Yıldız Teknik University]. Council of Higher Education Thesis Center.

Lee, K. M., Jeong, E. J., Park, N., & Ryu, S. (2011). Effects of interactivity in educational games: A mediating role of social presence on learning outcomes. *International Journal of Human–Computer Interaction, 27*(7), 620-633. https://doi.org/10.1080/10447318.2011.555302

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook* (2nd ed.). Sage.

Ministry of Education (MoNE) (2018). İlköğretim kurumları (ilkokullar ve ortaokullar) fen bilimleri dersi (3,4,5,6,7 ve 8. sınıflar) öğretim programı. https://mufredat.meb.gov.tr/Dosyalar/201812312311937-FEN%20B%C4%B0L%C4%B0MLER%C4%B0%20%C3%96%C4%9ERET%C4%B0M%20PROGRAMI2018.pdf

Mutlu Karanfil, B. (2022). *Investigation of the effect of portfolio-based environmental education with family participation on environmental awareness of 5th grade students* (Publication No. 708253) [Master's thesis, Trakya University]. Council of Higher Education Thesis Center.

Önen, F., Demir, S., & Şahin, F. (2012). Science teacher candidates' views about games and evaluating prepared games by them. *Ahi Evran University Journal of Kırşehir Education Faculty, 13*(3), 299-318. https://dergipark.org.tr/tr/pub/kefad/issue/59486/854950

Özen, G., Timurkaan Akçınar, S., Güllü, M., Meriç, F., Uğraş, S., & Çelik Çoban, D., (2019). Spor liseleri 12. sınıf eğitsel oyunlar ders kitabı. Milli Eğitim Bakanlığı.

Özgürler, S. (2014). Investigation of environmental literacy level and ecological footsprint of teacher candidates (Publication No. 380580) [Master's thesis, Amasya University]. Council of Higher Education Thesis Center.

Özkan, G., Akça, E., & Umdu Topsakal, Ü., (2020). The effect of game-based teaching on students' attitudes towards the science course and views. *The Journal of International Social Research, 13*(70), 794-800. http://dx.doi.org/10.17719/jisr.2020.4135

Serdaroğlu, C., & Güneş, M. H. (2019). Effects on academic achievement and attitude of game based learning in teaching of reproduction, growth and development unit in 6th grade plant and animal. *Necatibey Faculty of Education Electronic Journal of Science and Mathematics Education, 13*(2), 1015-1041. https://doi.org/10.17522/balikesirnef.570616

Şahin, S., Ünlü, E., & Ünlü, S. (2016). Investigation of teacher candidates' environmental literacy awareness level. *Education Sciences, 11*(2), 82-95. https://dergipark.org.tr/en/pub/nwsaedu/issue/19844/212575

Seçkin Kapucu, M., & Çağlak, S. (2018). Pre-service science teachers' skills and experience on designing educational games: A case study. *Adıyaman University Journal of Social Sciences,* (29), 536-573. https://doi.org/10.14520/adyusbd.364051

Şentürk, C. (2020). The effects of game-based science learning experiences on academic achievement, retention, attitudes and learning process. *The Journal of National Education, 49*(227), 159-194. https://dergipark.org.tr/tr/pub/milliegitim/issue/56322/616595

Şimşek, A. (2018). *Sosyal bilimlerde araştırma yöntemleri*. Anadolu Üniversitesi.

Teksöz, G., Şahin, E., & Ertepınar, H. (2010), Environmental literacy, pre-service teachers and a sustainable future. *Hacettepe University Journal of Education, 39,* 307-320. https://dergipark.org.tr/tr/pub/hunefd/issue/7799/102184

Yıldırım, A., & Şimşek H. (2021). *Sosyal bilimlerde nitel araştırma yöntemleri*. Seçkin.

Yıldırım, M., & Can, S. (2017). "Deal or no deal": Should science lesson be taught with instructional games?. *Atatürk University Journal of Kazım Karabekir Education Faculty, 35*,14-30. https://dergipark.org.tr/tr/pub/ataunikkefd/issue/33367/336640

Yıldız, E., Şimşek, Ü., & Araz, H. (2016). The effect of the educational game method on academic achievement and motivation towards science learning in teaching of circulatory system. *Mustafa Kemal University Journal of Social Sciences Institute, 13*(36) 20-32. https://dergipark.org.tr/tr/pub/mkusbed/issue/44301/547052