Instructional Technology and Lifelong Learning Vol. 6, Issue 1, 229-259 (2024)

https://dergipark.org.tr/en/pub/itall

ITALL

Research Article

ISSN: 2717-8307

Thinking Through Play: How Designing Educational Games Enhances Critical Thinking, Motivation and Achievement in Science Classes

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Abstract

The aim of this study was to investigate the effects of designing an educational game on the topic of Force and Motion within the context of a sixth-grade science course on students' critical thinking skills, science learning motivation, and academic achievement. The study adopted a single-group pre-test–post-test design, one of the experimental methods in quantitative research. The sample consisted of 29 sixth-grade students attending a public middle school located in the central district of Bartin, Türkiye. As data collection tools, the Marmara Critical Thinking Tendencies Scale, the Science Motivation Questionnaire, and the Force and Motion Achievement Test were administered both before and after the intervention. Prior to implementation, the unit objectives were covered over approximately four weeks, after which the pre-tests were administered. The intervention phase lasted six weeks, during which the students, under the guidance of their science teacher, designed and developed educational games related to the Force and Motion unit. After completing the game design process, students played the games they had created with their peers and provided written feedback on each other's games. Subsequently, the post-tests were administered. The data obtained from the pre- and post-tests were analyzed using repeated measures tests to determine whether the educational game design process had a statistically significant impact on students' critical thinking skills, motivation to learn science, and academic achievement. The results revealed that the educational game design process had a significant positive effect on all three variables. Furthermore, the gender variable did not yield a statistically significant difference. The findings were interpreted and discussed in relation to existing literature in the field of science education.

Keywords: Science education, educational games, critical thinking skills, motivation to learn science, science achievement, force and motion unit.

Citation: Çetin Dindar, A., & Kurt, E. (2025). Thinking Through Play: How Designing Educational Games Enhances Critical Thinking, Motivation and Achievement in Science Classes. *Instructional Technology and Lifelong Learning, 6(1)*, 229 - 259. https://doi.org/10.52911/itall.1592036

Oyun Yoluyla Düşünmek: Fen Bilimleri Dersinde Eğitsel Oyun Tasarımının Eleştirel Düşünme, Motivasyon ve Başarıya Etkisi

Özet

Bu araştırmanın amacı, altıncı sınıf fen bilimleri dersi kapsamında "Kuvvet ve Hareket" konusuna yönelik eğitsel oyun tasarımı sürecinin öğrencilerin eleştirel düşünme becerileri, fen öğrenmeye yönelik motivasyonları ve akademik başarıları üzerindeki etkisini incelemektir. Çalışma, nicel araştırma yöntemlerinden deneysel desenler içerisinde yer alan tek gruplu öntest-sontest modeline göre desenlenmiştir. Araştırmanın örneklemini, Bartın ili merkez ilçesinde yer alan bir devlet ortaokulunda öğrenim görmekte olan 29 altıncı sınıf öğrencisi oluşturmaktadır. Veri toplama aracı olarak; Marmara Eleştirel Düşünme Eğilimleri Ölçeği, Fen Bilimleri Motivasyon Ölçeği ve Kuvvet ve Hareket Başarı Testi kullanılmıştır. Uygulama öncesinde, ilgili ünitenin kazanımları yaklaşık dört hafta süresince öğretim programına uygun biçimde işlenmiş, ardından veri toplama araçları ön-test olarak uygulanmıştır. Müdahale sürecinde, öğrenciler fen bilimleri öğretmeninin rehberliğinde altı hafta boyunca Kuvvet ve Hareket konusuna ilişkin eğitsel oyunlar tasarlamış ve geliştirmiştir. Süreç sonunda, öğrenciler geliştirdikleri oyunları akranlarıyla oynamış ve oyunlara ilişkin yazılı geribildirimlerde bulunmuşlardır. Uygulamanın ardından son-testler uygulanmıştır. Toplanan veriler SPSS yazılımı kullanılarak analiz edilmiş; ön-test ve son-test puanları arasındaki farkı belirlemek ve eğitsel oyun tasarımı sürecinin etkisini değerlendirmek için tekrarlı ölçümler testi uygulanmıştır. Elde edilen bulgular, eğitsel oyun tasarımı sürecinin öğrencilerin eleştirel düşünme becerileri, fen öğrenmeye yönelik motivasyonları ve akademik başarı düzeyleri üzerinde istatistiksel olarak anlamlı bir etki yarattığını ortaya koymuştur. Ayrıca, cinsiyet değişkeninin anlamlı bir farklılık oluşturmadığı belirlenmiştir. Elde edilen sonuçlar, mevcut alanyazın çerçevesinde tartışılmış ve yorumlanmıştır.

Anahtar Kelimeler: Fen Eğitimi, Eğitsel Oyunlar, Eleştirel Düşünme Becerileri, Fen Öğrenmeye Yönelik Motivasyon, Fen Başarısı, Kuvvet ve Hareket Ünitesi

Date of Submission	27.11.2024
Date of Acceptance	09.01.2025
Date of Publication	30.06.2025
Peer-Review	Double anonymized - Two External
Ethical Statement	This study was carried out with the permission decisions taken by the Bartin University Ethics Committee with session number 2022-SBB-0620dated 02.02.2023.
Acknowledgments	This article is extracted from my master thesis entitled "Fen Bilimleri Dersinde Eğitsel Oyun Tasarlamanın Öğrencilerin Eleştirel Düşünme Becerilerine, Motivasyonlarına ve Başarılarına Etkisi ", supervised by Ayla Cetin-Dindar (Master's Thesis/, Bartin University, Bartın, 2024).
Author(s) Contribution	**Kurt:** Conceptualization, Methodology, Data curation, Writing-Original draft preparation. **Cetin-Dindar:** Methodology, Writing-Original draft preparation, Writing- Reviewing and Editing.
Plagiarism Checks	Yes - Turnitin
Conflicts of Interest	The author(s) has no conflict of interest to declare.
Complaints	Itall.journal@gmail.com
Grant Support	-
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1. Introduction

In contemporary education systems, a central priority is the cultivation of individuals equipped with critical thinking and reasoning skills, effective problem-solving abilities, and strong communication competencies. Furthermore, fostering the capacity to read, analyze, and interpret scientific information, along with developing science and technology literacy, has become increasingly essential. With the rapid advancements in science and technology, the demands of the 21st century require individuals who can adapt to evolving societal and professional challenges. In response to these demands, many developed countries place significant emphasis on science education as a cornerstone of their educational systems. By enhancing the structure and function of science curricula, these nations aim to prepare individuals who not only possess scientific knowledge but can also apply it innovatively and responsibly to address real-world issues.

This focus on science education reflects its pivotal role in shaping scientifically literate citizens who are prepared to engage in critical discourse, contribute to technological progress, and make informed decisions in an increasingly complex and interconnected world. In the 21st century, critical thinking skills have emerged as one of the most essential competencies expected from individuals, enabling them to analyze information, solve complex problems, and make informed decisions in an increasingly dynamic and information-driven world (Galinsky, 2010). Today, science education extends far beyond the mere transfer of knowledge to students. Its primary objectives now include sustaining students' interest in science, fostering their critical thinking skills, and equipping them to apply these skills across diverse contexts and real-world situations. However, achieving these goals presents significant challenges, particularly when instruction relies heavily on traditional, teacher-centered teaching approaches. In conceptually intensive courses such as science, students often struggle with understanding abstract and conceptual concepts, which can lead to frustration and disengagement. This lack of engagement not only diminishes students' interest in science but also negatively impacts their academic performance, hampers the development of critical thinking skills, and lowers their motivation to pursue and science learning. Consequently, addressing these issues has become a pressing priority in modern education systems to ensure students are prepared for the demands of an increasingly scientific and technologically driven society.

To ensure active students engagement in the learning process, it is essential for educators to design and implement instruction that accounts for individual differences by employing effective, student-centered strategies. Among such approaches, educational game design has emerged as an innovative and effective teaching strategy, particularly within the context of science education. This study investigates the impact of educational game design on students' critical thinking skills, motivation to learn science, and academic achievement. Integrating games into instruction has been shown to make learning more engaging, enjoyable, and meaningful for students. In the 21st-century educational paradigm, it is not only essential for students to learn how to simply access information but also to understand how to apply that knowledge, develop critical thinking skills, and stay motivated throughout the learning process (Akınoğlu, 2003). Within this framework, science education provides an ideal platform for fostering analytical and critical thinking abilities, as it inherently encourages inquiry, exploration, and problem-solving. Among the approaches designed to enhance science education, educational games serve as a powerful pedagogical tool, capable of transforming abstract scientific concepts into concrete, accessible ideas while simultaneously fostering students' interest and enthusiasm. The integration of educational games thus helps bridge the gap between theoretical knowledge and real-world application, supporting a more interactive, student-centered, and cognitively engaging learning experience.

The act of designing educational games further amplifies the pedagogical benefits of game-based learning by encouraging students to take on active roles in their own learning processes. This process not only sharpens their critical thinking and problem-solving skills but also enhances their scientific process skills, analytical reasoning, and ability to conduct research effectively. Through designing games, students are encouraged to access, evaluate, and apply information critically, thereby deepening their conceptual understanding and strengthening their connection to scientific content. The use of educational games, recognized as one of the innovative approaches in education, holds significant potential for increasing students' interest in science lessons and making abstract concepts more comprehensible. By incorporating elements of fun and interactivity, educational games promote active student participation and enhance engagement in the learning process. Moreover, involving students in the design of these games can foster their creativity, problem-solving abilities, and critical thinking skills, offering a more holistic learning experience. Educational games are specifically designed tools

that aim to make the learning process more engaging, enjoyable, and interactive. In addition to content mastery, they support the development of essential social and emotional competencies (Çavuş & Balçın, 2017). Through their interactive nature, educational games help individuals cultivate problem-solving and critical thinking abilities, which are critical for success in both academic and real-life contexts. Empirical research indicates that as students become more actively involved in classroom activities through educational games, their academic performance tends to improve significantly. By combining entertainment with educational content, these games provide a dynamic learning environment that encourages students to engage deeply with the material while enhancing their motivation and long-term retention. Furthermore, these games foster learner autonomy by encouraging students to take initiative and responsibility for their own learning.

Students' motivation plays a crucial role in the learning and teaching process, as it directly influences their engagement, persistence, and academic success (Keller, 1979; Keller & Keller, 2010). Motivation serves as the driving force behind students' willingness to participate in learning activities, overcome challenges, and achieve their academic goals. Educators who understand the dynamics of motivation can better design instructional strategies that inspire and sustain student interest. Importantly, motivation is not a stable, trait-likecharacteristic but is instead highly context-dependent and domain-specific (Linnenbrink & Pintrich, 2002). This means that a student's level of motivation can vary significantly across different subjects, tasks, or environments. For instance, a student may be intrinsically motivated to engage with science due to a natural curiosity about the subject, while displaying less motivation in areas they perceive as less meaningful or relevant. Contextual factors such as classroom climate, instructional strategies, and the perceived relevance of content can all influence a student's motivation. Supportive and autonomy-enhancing classroom environment is more likely to foster intrinsic motivation, whereas a highly controlled or overly competitive environment may hinder it. Furthermore, the alignment of instructional content with students' interests, needs, and prior experiences can significantly enhance their engagement and sustained motivation to learn.

Numerous studies (e.g., Alamri et al., 2020; Lawlor et al., 2016) have highlighted a positive relationship between student autonomy and intrinsic motivation. When students are given opportunities to make choices and take responsibility for their own learning, their engagement

and motivation tend to increase. Deci and Ryan (1985) through their Self-Determination Theory (SDT), emphasize the critical role of autonomy in fostering intrinsic motivation. According to SDT, intrinsic motivation, engaging in activities for inherent satisfaction rather than external rewards, is more likely to thrives when individuals feel they are acting on their own desire, free from external pressures or controls. This autonomy fosters deeper connections to personal values and promotes genuine interest, enjoyment, and persistence in learning tasks. The SDT also acknowledges the role of extrinsic motivation, which involves engaging in activities for external outcomes such as rewards, recognition, or avoiding penalties. While extrinsic motivation may be effective in certain contexts, it is often associated with short-term compliance rather than sustained engagement. Ryan and Deci argue that learning environments that prioritize autonomy and nurture intrinsic motivation lead to improved long-term outcomes, including higher levels of academic performance, engagement, and psychological well-being (Ryan & Deci, 2000). Creating autonomy-supportive learning environments involves instructional practices such as offering students meaningful choices, providing rationale for tasks, acknowledging their perspectives, and minimizing controlling language. These practices not only enhance intrinsic motivation but also encourage psychological growth, creativity, and persistence. On the other hand, controlling environments that rely heavily on external rewards or punishments may undermine intrinsic motivation, leading to decreased engagement and lower satisfaction over time. Studies have consistently shown that students who are intrinsically motivated tend to exhibit higher levels of academic success, persistence, and intellectual curiosity (Algharaibeh, 2020; Covington & Meller, 2001; Fuertes et al., 2020; Lepper et al., 2005; Yamauchi & Miki, 2003).

Additionally, learning activities that promote autonomy, such as goal setting, peer assessment, and self-assessment, play a crucial role in fostering intrinsic motivation (Alamri et al., 2020; Larsen et al., 2020; Mikami, 2020). According to Larsen et al. (2020), activities involving self- and peer-monitoring have a particularly significant impact on cognitive learning outcomes. These activities not only enhance students' knowledge but also alleviate feelings of anxiety and boredom, creating a more positive and productive learning environment. Peer-monitoring, in particular, facilitates collaborative learning, encouraging students to engage actively while providing mutual support in understanding and applying concepts. By integrating such autonomy-supportive practices into educational games, educators can cultivate a more self-

directed and motivated learning experience, leading to both academic and emotional benefits for students.

Despite these promising benefits of educational games, there is a noticeable gap in the literature regarding the effects of the educational game design process, particularly on students' critical thinking skills, motivation to learn science and academic achievement. In this context, designing educational games specifically for middle school students on the topic of Force and Motion offers a valuable opportunity for both pedagogical innovation and empirical investigation. Yılmaz and Deniş Çeliker (2022) mentioned that since there has been the limited number of studies, particularly on the Force and Motion unit, it is a significant opportunity for this study to address gaps in the literature and examine the effects of developing educational games on various factors. Therefore, not only does this approach actively involve students in the learning process, but it also has the potential to improve their critical thinking skills, enhance their motivation to learn science, and positively influence their overall academic performance. Therefore, the present study aims to design and implement an educational game development process for sixth-grade students focusing on the Force and Motion unit. Accordingly, the study seeks to address the following overarching research problem: "What is the effect of designing an educational game in science courses on students' critical thinking skills, motivation to learn science, and academic achievement in science?"

To explore this problem comprehensively, the research is structured around the following sub-research questions:

- Does designing educational games in sixth-grade science courses have a significant effect on students' critical thinking skills?
- Does designing educational games in sixth-grade science courses have a significant effect on students' motivation to learn science?
- Does designing educational games in sixth-grade science courses have a significant effect on students' academic achievement in the Force and Motion unit?
- What are sixth-grade students' views on the process of designing educational games in the Force and Motion unit?

This research aims to provide insights into the potential benefits of integrating educational game design into science education, with a particular focus on enhancing students' cognitive

and motivational outcomes, as well as their academic performance in conceptually challenging topics.

2. Methodology

In this study, the "Single-Group Pretest-Posttest Design," which is considered a weak experimental design within quantitative research methods, was employed (Fraenkel, Wallen, & Hyun, 2012). This design involves administering pre-test and post-test measures to assess the effect of an intervention applied to a single group of participants. The pre-test provides baseline data, while the post-test allows for an evaluation of the changes or effects following the intervention. Due to the use of a single group in this design, qualitative data were also incorporated to control for potential confounding variables and to enhance the validity of the findings. Additionally, to improve the reliability and validity of the results, students' views regarding the educational games they developed were gathered. This qualitative feedback was used to provide a deeper understanding of the impact of the intervention, offering insights into students' experiences and perceptions, which helped strengthen the overall conclusions of the study.

2.1. Participants

The study involved 29 sixth-grade students attending a boarding regional elementary school in the central district of Bartin province during the 2023-2024 academic year. Of the students who participated in the study, 15 were female (51.72%) and 14 were male (48.28%). The students' ages ranged from 11 to 12 years old. Data collection tools were administered to the participants both before and after the intervention. This approach employed a single-group pre-test and post-test design, which is considered a weak experimental design, to assess whether there was a significant difference between the pre-test and post-test results. The objective was to evaluate the impact of the intervention on the students by comparing the measurements taken prior to and following the application.

Instruments

Both quantitative and qualitative data-collecting tools were used in this current study. Three quantitative scales were used to collect data to assess students' critical thinking skills, motivation to learn science and academic achievement on the Force and Motion unit.

The Marmara Critical Thinking Tendencies Scale (MCTTC) was developed by Özgenel and Çetin (2018) to assess students' critical thinking skills. The validity and reliability of the scale were tested by the researchers who developed it, and based on the results from the scale development studies, it was determined to be both valid and reliable. The scale consists of 28 items considering six factors and utilizes a five-point Likert-type scaleat. Participants are asked to rate their behaviours related to critical thinking skills by selecting response options, from never to always. The Cronbach's alpha coefficients for the scale range from r = 0.35 to r = 0.65, indicating a reasonable level of internal consistency. A higher score in each factor reflects more substantial characteristics associated with that specific dimension. On the other hand, for practical reasons and due to the limited sample size, the analysis was conducted based on the total scores and average values of participants' responses for a more straightforward interpretation of the scores.

The Science Motivation Questionnaire (SMQ), developed by Glynn and Koballa (2006), aims to assess students' motivation for learning science. The scale was translated and adapted into Turkish by Cetin-Dindar and Geban (2015). The SMQ consists of 30 items and uses a 5-point Likert-type scale. Participants are asked to respond to each item by selecting response options, from never to always. When considering all the items of the scale, the Cronbach's Alpha coefficient for internal consistency, indicating the scale's reliability, was found to be 0.913. This scale, applied before and after the intervention, aims to measure students' motivation to learn science.

The Force and Motion Achievement Test (AT) was used to evaluate students' learning outcomes related to the sixth-grade Force and Motion unit. The test consists of 12 multiple-choice questions designed explicitly for the sixth-grade Force and Motion unit. It was prepared by science education experts, measurement and evaluation specialists, and teachers from the Ministry of National Education. The test is publicly available on the official website of the General Directorate of Measurement, Evaluation, and Examination Services (ODSGM, 2024). These science assessment tests were developed by 150 teachers from various provinces and subsequently reviewed by 34 teachers and 37 academicians to ensure the validity, reliability, and overall quality of the questions before publication. The finalized version was published and made accessible for free download via the ODSGM online platform.

Two qualitative data-collecting tools were utilized in this research. One of them was a self-evaluation form, throughwhich written reflections were gathered from each student involved in designing an educational game. At the end of the implementation, students were asked to reflect on their experiences throughout the design process. Specifically, they were prompted to describe their feelings during game development, the challenges they encountered, and the strategies they used to overcome those challenges. The second qualitative data-collecting tool involved peer feedback on the educational games developed by classmates. After all the educational game development processes were completed, the students had the opportunity to play all of the games in a classroom setting. Following this activity, students were asked to provide feedback on the games they played. For this purpose, they were given a set of eight open-ended questions developed by the researchers. These questions were designed to elicit students' perspectives on the educational, visual, and functional aspects of the games. The questions included: "How do you think the game looks visually?", "Do you find the game easy or difficult to play?", "What did you learn while playing the game? Do you think the game was educational?", "Were the questions in the game easy or difficult? Was the number of questions sufficient?", "Did you enjoy playing the game?", "Do you find the game visually appealing and easy to understand? Were there any features of the game you found lacking?", "Would you want to play this game again?", and "If you could modify this game, what changes would you like to make?".

2.2. Implementation

All preliminary preparations were completed before the implementation process began. In the first stage, the researcher identified the topic for the educational game development by exploring which science unit students perceived as most challenging. Informal feedback from the students through the daily classroom conversations revealed that they had a reluctance and negative attitudes toward the Force and Motion unit, which they frequently considered difficult. This feedback highlighted the need to develop an educational game specifically for this unit. Additionally, several factors were found to contribute to students' difficulties with this unit. These included the presence of numerous abstract concepts, the frequent use of graphs, students' limited skills in graph interpretation and construction, the integration of mathematical operations, and a lack of hands-on activities in the science textbooks. These challenges, combined with insights from the daily classroom discourse and the teaching

experience of the science teacher (one of the researchers in this study), led to the decision to focus the game design on the Force and Motion unit.

Following the identification of the target topic, a formal application was submitted to the relevant authorities, and the ethical approval and administrative permissions for the implementation and use of data collection tools were obtained. Before the game design phase began, all curriculum-basedlearning outcomes related to the Force and Motion unit were delivered over a four-week period, ensuring that students had completed the unit prior to the intervention.

In the 2022-2023 academic year, the learning outcomes related to the Force and Motion unit were delivered to the sixth-grade students in alignment with the national science curriculum, using various techniques including video presentations and problem-solving activities. Once all the relevant content was covered, a six-week educational game design process was launched within the scope of the elective course titled "Science Applications." The course met for two hours per week over approximately six weeks. In this phase, the students were tasked with designing an educational game related to the Force and Motion unit. The teacher acted as a facilitator throughout this process, providing guidance, answering students' questions, and offering support where necessary. The role of the teacher was to ensure that students were on track, encouraging them to apply the knowledge gained from the lessons while fostering their creativity and problem-solving skills in the game design process.

Pre-tests (MCTTC, SMQ, and AT) were administered to the students to assess the effects of the developed educational games on students' critical thinking skills, motivation to learn science, and force and motion concepts. Afterwards the pre-tests, the students were asked to develop games based on the targeted learning outcomes of the Force and Motion unit Throughout this process, the teacher closely monitored students' progress and provided formative feedback as needed. A total of 18 educational games were developed, each accompanied by instructional materials such as rule cards and explanatory notes. After the completion of the game design phase, the post-tests (MCTTC, SMQ, and AT) were administered to the students (Figure 1). Additionally, qualitative data were collected through student self-evaluation forms and peer feedback to gain insights into their experiences during the game design process.

Figure 1.

The stages of the study

During the educational game design process, students followed a structured set of stages, each aimed at promoting creativity, critical thinking, and content integration. The steps were as follows:

- *Initial Stage*: The students were first asked to examine the learning outcomes related to the Force and Motion unit and select the outcome they wanted to design a game around.
- *Research and Idea Generation*: After selecting the learning outcome, the students conducted preliminary research and generated ideas for the rules and materials required for their game. They were encouraged to draw inspiration from existing games they were familiar with (e.g., board games like Ludo, Bingo, or card games) or to create entirely original concepts. Students were also told that they could incorporate the learning outcomes either explicitly (e.g., through information or question cards) or implicitly (e.g., by embedding problems to be solved during gameplay).
- *Game Concept and Material Planning*: No liminations were imposed regarding the types of materials or games format. Students were encouraged to design games that were both educationally meaningful and engaging. Emphasis was placed on the importance of playability with peers and alignment with the selected learning outcomes.
- *Game Rules and Scoring System*: Students were asked to clearly define the rules of the game and determine the criteria for winning or losing. It was suggested that they include a scoring system that would align with the rules and dynamics of the game. Additionally, students were encouraged to incorporate levels or stages in the game to increase its difficulty and sustain player interest.
- *Material Selection:* Students were advised to use low-cost and easily accessible materials. The use of recycled materials was also recommended to promote sustainability,

highlighting the potential to create cost-effective and environmentally friendly educational games.

- *Design and Content Development*: Once the game concept was finalized, the students began the content develeopment and sketching process. They were encouraged to utilize various resources, such as the internet, books, and encyclopedias, to research and refine their content. The students were informed that they could base the content and questions for the game on textbooks or other supporting materials.
- *Prototyping and Feedback*: Students developed initial prototypes of their games and then obtained feedback from the teacher and classmates to refine their designs. Based on the feedback, they revised the game components, materials, or visuals to improve clarity, educational value, and playability. Collaboration, creativity, and peer support were strongly encouraged during this iterative stage.
- *Testing and Iteration*: In this stage, students tested their educational games by creating prototypes and observing their flow and interaction to identify areas requiring refinement. The games were tested in small peer groups to evaluate gameplay, rules, and educational content. Students received feedback from their peers, observed the test sessions, and made further improvements in response to this formative evaluation.
- *Finalization and Presentation*: In the final stage, students completed the final versions of their games, incorporating revisions based on prior testing. Once completed, the students presented their educational games to the class, explaining the learning objectives, materials used, game rules, and instructions. They also shared their design experiences, discussing the challenges they faced during the design process and the suggestions they received. Classmates provided written feedback using structured peer review forms.
- *Final Product*: A total of 18 educational games were developed on the *Force and Motion* topic. Throughout the design process, the teacher worked closely with the students, offering guidance, motivation, and feedback. Upon completion, the educational games were then tested in the classroom to assess their usability and effectiveness. During this process, students completed self-evaluation forms to reflect on their design experiences and the learning outcomes associated with their games.

2.3. Data analysis

Both quantitative and qualitative data were collected in this study. Quantitative data were analyzed using the SPSS 22 software package. Prior to analysis, the dataset was examined for missing values, data entry errors, and outliers. Next, the normality assumption was assessed to determine the suitability of parametric tests. Since the sample size was below 50, measures of central tendency and the Shapiro-Wilk test statistics were used for the normality (Pallant, 2016). As the significance levels for all variables in the normality test exceed 0.05, it was concluded that the data were normally distributed ($p > .05$).

In this study, repeated measures tests were used to analyze the data and determine whether the dependent variables showed a significant difference between different groups or conditions. This test is appropriate for examining whether the differences between measurements taken from the same group under two different conditions or time points are statistically significant (Pallant, 2016). Pre-test and post-test scores were used to compare students' critical thinking skills, motivation to learn science, and academic achievement. For each scale, total scores were computed by averaging item responses. The means of the two measurements were analyzed, and the significance of the differences was evaluated at a 95% confidence interval ($p < 0.05$). The results were used to test and interpret the study's hypotheses by highlighting the differences between the pre-test and post-test scores of the dependent variables.

Qualitative data were analyzed using content analysis procedures (Marshall & Rossman, 2006). Categories and codes were generated based on the students' responses to the open-ended questions. In the initial stage of data analysis, each researcher independently reviewed and coded the responses. Following this, the researchers compared their coded categories, identifying similarities and discrepancies. Cross-checks were conducted to ensure inter-coder reliability. Through discussion and consensus, the the final coding scheme was established and used to interpret the qualitative findings.

3. Results

Descriptive statistics were calculated for the study variables, and their normality distributions were checked. The results are presented in Table 1, the skewness and kurtosis values for all variables fell within acceptable ranges, indicating that the data were approximately normally distributed. As a result of the variables demonstrating normal distribution, parametric statistical tests were applied to the analyses of the three research sub-problems.

Table 1.

Descriptive Statistics of the implemented tools

Variables	N	Min.	Max.	Mean	SD	Skewness	Kurtosis
MCTTC (pre-test)	29	1.89	4.32	2.7635	0.60	1.066	.639
MCTTC (post-test)	29	2.93	4.61	3.8214	0.47	-.179	-.967
SMQ (pre-test)	29	1.43	4.43	3.0448	0.66	-1.28	.630
SMQ (post-test)	29	2.13	4.70	3.7552	0.54	-1.107	2.096
AT (pre-test)	29	1.00	11.00	5.0345	2.38	.620	.368
AT (post-test)	29	4.00	12.00	8.8276	2.99	-.175	-1.665

The first sub-research question of this research was formulated as: "Does designing educational games in sixth-grade science courses have a significant effect on students' critical thinking skills?" The null hypothesis developed to address this research question is as follows: "Designing educational games in sixth-grade science courses has no significant effect on students' critical thinking skills." To test this hypothesis, the MCTTC, consisting of 28 items, was administered to the sixth-grade students as both a pre-test and a post-test before and after the intervention. These tests were used to analyze whether students' critical thinking skills changed as a result of the educational game design process. The data were analyzed using the SPSS software, and the results are presented in Table 2. A paired-sample t-test was applied to evaluate the differences. When examining Table 2, it is evident that there was a 1.06-point increase in students' critical thinking skills after the application. This difference was found to be statistically significant according to the paired-sample t-test analysis, $t(28) = -10.905$, $p < 0.05$. Since the significance value is less than 0.05, it indicates that the difference between the pre-test ($M = 2.76$, $SD = 0.60$) and post-test ($M = 3.82$, $SD = 0.47$) critical thinking scores are statistically significant (see Table 3). The 95% confidence interval for the mean difference ranges from -1.26

to -0.86. Additionally, the eta squared value was calculated as 0.81, indicating a medium effect size (Pallant, 2016).

Table 2.

A paired-sample t-test results of critical thinking skills

	Paired Differences					t	df	Sig.(2-tailed)
	Mean	SD	Standard Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
pre-MCTTC–post-MCTTC	-1.058	.522	.0970	-1.257	-.859	-10.905	28	.000

The second sub-research question of the research was framed as: "Does designing an educational game in sixth-grade science courses have a significant effect on students' motivation to learn science?" The null hypothesis created to address this question is as follows: "Designing educational games in sixth-grade science courses has no significant effect on students' motivation to learn science." To test this hypothesis, the Science Motivation Questionnaire (SMQ), which consists of 30 items, was administered to the sixth-grade students as both a pre-test and a post-test before and after the educational game design application. The objective was to assess whether there was any change in the students' motivation to learn science as a result of the intervention. The data obtained from these tests were analyzed using the SPSS package program. For this analysis, a paired-sample t-test was used, and the results are presented in Table 3. It is observed that there is an increase of 0.71 points in students' learning motivation after the application of educational game design. This difference was found to be statistically significant, with the results of the related samples t-test analysis showing $t(28) = -10.900$, $p<0.05$. Since the p-value is less than 0.05, it indicates that the difference between the pre-test ($M = 3.05$; $SD = 0.66$) and post-test ($M = 3.76$; $SD = 0.54$) scores for learning motivation is statistically significant. The 95% confidence interval for the mean difference lies between -0.86 and -0.57, confirming the reliability of the result. Additionally, the eta squared value of 0.81 suggests a medium effect size, indicating a substantial impact of the educational game design intervention on students' motivation to learn science (Pallant, 2016).

Table 3.

A paired-sample t-test results of motivation to learn science

	Paired Differences							
				95% Confidence Interval of the Difference				
	Mean	SD	Standard Error Mean	Lower	Upper	t	df	Sig.(2-tailed)
pre-SMQ–post-SMQ	-.710	.379	.070	-.855	-.566	-10.090	28	.000

To test the third sub-research question of the research, which focuses on whether designing educational games in sixth-grade science courses has a significant effect on students' academic achievement in the Force and Motion unit, the hypothesis was stated as follows: "Designing educational games in sixth-grade science courses has no significant effect on students' science assessment in the Force and Motion unit." The AT, consisting of 12 questions focused on the Force and Motion unit, was administered to the students as both a pre-test and post-test. This allowed for an evaluation of whether students' academic achievement test scores changed due to the application of educational game design. The data collected from the pre-test and post-test results were analyzed using the SPSS package program. For testing the hypothesis, a paired-sample t-test was conducted. The results, including statistical findings, will be presented in Table 4. The analysis will provide insights into whether there was a significant difference in students' assessment test scores before and after the intervention, helping to determine the impact of educational game design on students' academic achievement. When examining Table 4, a significant improvement is observed in students' academic achievement in the Force and Motion unit after the application of educational game design. Specifically, there is a 3.79-point increase in students' scores on the AT. The results of the paired-sample t-test analysis showed that there is a statistically significant difference, with a test statistic of $t(28) = -9.53$, $p < 0.05$. This indicates that the difference between the pre-test ($M = 5.03$; $SD = 2.38$) and post-test ($M = 8.83$; $SD = 2.99$) scores is significant. The 95% confidence interval for the mean difference is between -4.61 and -2.98, confirming that the increase in achievement scores is both statistically significant and meaningful. Additionally, the eta squared value was calculated as 0.76, which indicates a medium effect size, suggesting that the educational game design had a notable impact on students' achievement in the unit. This analysis supports the hypothesis that

designing educational games in the sixth-grade science course positively affects students' academic achievement in the Force and Motion unit.

Table 4.

A paired-sample t-test results of the assessment test

	Paired Differences							
				95% Confidence Interval of the Difference				
	Mean	SD	Standard Error Mean	Lower	Upper	t	df	Sig.(2-tailed)
pre-AT–post-AT	-3,793	2,144	,398	-4,609	-2,977	-9,525	28	,000

For the fourth sub-research question of the research, which aimed to explore sixth-grade students' views on the educational games they designed, students were asked to provide their reflections through open-ended written responses. The analysis of the students' written responses revealed that all students expressed positive feelings toward the educational game design process. This finding indicates a high level of engagement and enjoyment, suggesting that the activity was both motivating and enriching for the students. The students' enjoyment could be attributed to their active involvement in a creative, hands-on learning experience that allowed them to apply scientific knowledge in an innovative and meaningful context. Further examination of the students' reflections (as shown in Table 5) would provide more detailed insights into their feelings about various aspects of the game design process, such as their perceptions of creativity, challenge, and learning outcomes.

Table 5.

The students' self-evaluation reflections on developing educational games

Category	Students' Quotations
Cognitive effect	I learned science subjects faster by designing games.
Affective effect	I loved science class. I started to love it more.
	I enjoyed designing games.
	The lesson is great and fun.
	I liked it.
	It was good.
	We are very happy thanks to our teacher; the lessons are going perfectly
Designing	I have a hard time designing games.

When students presented the educational games, they had developed to their peers and received feedback, the qualitative analysis of their responses revealed three distinct thematic

categories. These categories, which reflect students' perceptions of the games and the feedback process, are summarized in Table 6.

Table 6.
The students' evaluation feedback about the games designed by their classmates

Category	Students' Quotations
Educational Value	It helped me remember topics we had forgotten.
	It helped me understand and reinforce the subject matter.
	There were no flaws in the game.
	The game was very short. It would have been better if the questions were more challenging.
	The game was short, and there were few questions.
	The game was very entertaining and helped me recall old topics.
	The game was entertaining and allowed us to review the topic.
	Someone unfamiliar with science could learn a few things thanks to this game.
	I learned about the concept of speed through this game.
	I did not enjoy it very much because it ended quickly and had few questions.
	The game had very few questions. Adding more difficult ones would improve it.
	I learned questions related to force. We played it and liked it a lot.
	It helped me learn science.
	There were a few questions, and the game was easy.
	The game was very entertaining, and the questions were excellent.
Enjoyment and Fun	I played it with great pleasure.
	The game was very nice.
	A very nice game; I liked it very much.
	It was fun.
	I liked the game very much.
	It was a different game, and I enjoyed it.
	It was very difficult and made me a little bored; I did not like the game.
	It was very enjoyable. I loved it.
	Among all the games, this was my favorite. Even though I got bored waiting at times, it was very fun and beautiful.
	In a word, it was great. It was a big surprise for us.
	I did not like it very much.
	We competed as Boys versus Girls, and it was very fun.
Design Aspect	There are no negative aspects.
	The design is nice.
	I did not like the design; the questions were few, but the creativity was good.
	I got a little bored because the game went on for too long.
	The game was very nice, but the design was poor.
	A great game! The fun design was nice, and I liked it.
	The logical aspect of the game was very enjoyable.
	I did not like it much. I disliked the black coloring of the questions and the glass. The questions were too easy.
	The cards were prepared too small, so I did not like it much, though the questions were nice.

Category	Students' Quotations
	The game was perfect, except for the question cards being small. The game was very nice, but there were too few cards. It was a nice touch to have different colored cards based on the difficulty level of the game.

The feedback provided by the students regarding the peer-designed educational games centered around three main themes:

Educational Value: Students assessed the extent to which the games facilitated learning, particularly in reinforcing key concepts from the Force and Motion unit. Many students emphasized that they were able to understand and retain important scientific content while engaging with the games.

Enjoyment and Engagement: A common thread across responses was the high level of enjoyment experienced during gameplay. Students frequently described the games as "fun" and expressed appreciation for the opportunity to learn in an interactive and entertaining format, highlighting the successful integration of learning and play.

Design Features: Students commented on various aspects of the games' design, including visual appeal, clarity, and usability. While many praised specific elements such as layout or creativity, some also provided constructive criticism, offering suggestions for improvement to enhance clarity and user experience.

In summary, the feedback from students reflected a positive overall reception of the educational games. They found the educational games to be both enjoyable and educational, and they appreciated the design elements that contributed to the overall experience. The quantitative data collected during the study demonstrated that the educational game design process had a positive impact on students' critical thinking skills, motivation to learn science, and academic achievement in the Force and Motion unit. These improvements were statistically significant, indicating that the game design process was an effective educational tool. Furthermore, the qualitative data aligned with the quantitative findings and provided more richer insights into the students' experiences. The students not only enjoyed the game design process but also reported that they learned through play. The games were not viewed as mere entertainment; they served as cognitive tools that encouraged deep learning, making the process both

enjoyable and educational. The teacher, who was also one of the researchers, observed several positive outcomes during the process. According to the teacher's reflections:

- Students' interest in science lessons increased.
- Students actively participated in lessons and were more engaged with the subject.
- The concept of force and motion was reinforced as students repeated it through the games.
- The educational games played a key role in helping students learn new information.
- Passive students became more involved in the lessons, contributing to a more dynamic classroom environment.

In conclusion, the integration of educational game design into the science curriculum not only enhanced students' conceptual understanding but also promoted the development of critical cognitive and social skills. he approach fostered a more interactive, engaging, and effective learning environment, demonstrating its potential as a powerful instructional tool in science education.

4. Discussion and Suggestions

The first sub-research question of the study aimed to investigate whether designing educational games in the sixth-grade science course has a significant effect on students' critical thinking skills. To test this hypothesis, the Marmara Critical Thinking Tendencies Scale was applied to the students as both a pre-test and post-test. The analysis revealed a 1.06-point increase in students' critical thinking skills scores after the educational game design process. The difference was found to be statistically significant, confirming that the educational game design process had a positive impact on the development of students' critical thinking skills. This finding aligns with the existing literature that emphasizes the importance of using diverse teaching methods to develop critical thinking. Researchers have pointed out that critical thinking skills can be nurtured through innovative teaching strategies (Akkocaoğlu Çayır & Akkoyunlu, 2016; Karadağ & Demirtaş, 2018; Papadopoulos & Bisiri, 2020). For instance, Papadopoulos and Bisiri (2020) aimed to enhance students' critical thinking skills through a training program that incorporated game-based activities. The program made learning more interactive and collaborative, fostering both individual and group work, which were crucial for developing critical thinking. Thus, the results of this study contribute to the growing body of research

supporting the idea that integrating educational games into the curriculum can be an effective method for enhancing students' critical thinking abilities. While much of the current literature on educational games involves researcher-designed or digital game environments, there is a noticeable scarcity of studies exploring student-designed physical (non-digital) games, particularly at the middle school level. This study contributes to a growing body of research that highlights the educational potential of student-driven, hands-on game design, offering a compelling alternative to more technology-centered approaches.. In research where educational game design is conducted by pre-service teachers, several important conclusions have been drawn. First, it has been found that educational games are not only enjoyable but also demanding processes requiring significant effort and creativity (Küçükşen Öner, Cetin-Dindar, & Sarı, 2024). These games provide students with opportunities to learn through hands-on experience and active participation, fostering deeper understanding and retention of the subject matter. Additionally, the game design process itself can promote essential 21st-century skills such as critical thinking, problem-solving, collaboration, and creativity.

For the game design process to be successful, certain key factors must be considered. The game designer should align the design with the intended educational objectives, ensuring that the game serves as an effective learning tool. Additionally, the knowledge level and needs of the target audience should be carefully analyzed to make the game accessible and engaging. Lastly, the game must integrate an enjoyable and interactive learning experience, balancing educational content with elements of fun to maintain students' motivation and interest throughout the activity. These findings emphasize the importance of strategic planning and intentional instructional design when implementing educational game activities in science education. By integrating theoretical knowledge with practical applicationgame design transforms traditional classrooms into student-centered, experiential learning environments that promote deep engagement (Korkmaz, Cetin-Dindar, & Oner, 2023). Future studies could explore additional dimensions, such as the long-term effects of educational game design on students' academic achievement and the development of skills, as well as the potential benefits of incorporating diverse cultural and disciplinary perspectives into the game creation process.

The holistic approach adopted by the Turkiye Century Education Model (2024) aligns with the objective of cultivating well-rounded individuals who not only excel academically but also demonstrate critical thinking, problem-solving abilities, and a strong sense of ethical

responsibility. This educational approach emphasizes the importance of developing higher-level thinking skills, particularly critical thinking, to prepare students to engage with the world in a responsible and ethical manner. One of the central goals of this model is to nurture students who are capable of questioning information, conducting independent research to identify accurate knowledge, and evaluating their inferences with reflective reasoning. In this regard, the model goes beyond content delivery, aiming instead to foster individuals who are equipped to solve problems, think critically, and contribute constructively to their communities and society at large. This study, which investigates the impact of educational game design on students' critical thinking skills, directly contributes to the literature surrounding this new educational model. By demonstrating how engaging students in hands-on, creative processes like game design can enhance their cognitive abilities, particularly critical thinking, the research supports the implementation of such innovative methods within the broader educational reforms in Turkiye.

In summary, this study offers valuable insights into how game-based learning can be effectively integrated into educational practices to meet the goals of the Turkiye Century Education Model (2024). By fostering critical thinking and problem-solving skills, the study aligns with the model's broader aim of producing responsible, ethical individuals equipped with the necessary tools to navigate and contribute to an ever-changing world. The findings of this study align with existing literature regarding the positive impact of educational game design on students' motivation to learn science. By applying the Science Motivation Questionnaire as a pre-test and post-test, the study observed a significant increase in students' motivation to learn science education after engaging with educational games. This result mirrors previous research, which supports the notion that educational games make science lessons more enjoyable, engaging, and ultimately more effective in boosting student motivation. Studies have shown that when educational games are used in teaching science, students' intrinsic motivation to learn is enhanced, as games help make learning more interactive and fun. Educational games have been shown to activate intrinsic motivation by fostering curiosity, providing challenges, and encouraging participation, which in turn increases attention, focus, and overall engagement (Yurt, 2007). Furthermore, beyond the cognitive gains, research has highlighted that educational games can enhance students' social and affective skills as well, providing a comprehensive learning experience that also nurtures emotional and social development

(Babaandaç, 2013; Bayat, Kılıçaslan & Şentürk, 2014; Karamustafaoğlu & Kaya, 2013; Yıldız, Şimşek & Ağdaş, 2017). Moreover, several studies have demostrated that educational games foster a positive attitude towards the subject matter, thereby increasing intrinsic motivation. This finding is consistent with previous research, which indicates that students who engage in educational games develop a more favorable view of the subject, as well as greater intrinsic motivation (Beker Baş & Karamustafaoğlu, 2020; Gürpınar, 2017; Korkmaz, 2018; Şentürk, 2020; Serdaroğlu & Güneş, 2019; Yazıcıoğlu, Çavuş & Güngören, 2019). Educational games introduce an element of enjoyment and curiosity into the learning process, making lessons more engaging and productive. This finding is consistent with studies (e.g., Beker Baş & Karamustafaoğlu, 2020) that show how integrating games into science education increases students' intrinsic motivation and promotes sustained engagement with the subject matter. Motivation, as a critical factor in learning, is enhanced by the interactive and competitive nature of games, as well as their ability to make abstract concepts more accessible. This is consistent with the findings of Tasgin and Tunç (2018), who observed that students with low levels of participation in conventional lessons became more active and engaged when exposed to game-based activities. In this respect, educational games serve as an inclusive instructional tool, reaching a diverse range of learners and addressing varying needs within the classroom.

In conclusion, this study contributes to the expanding body of evidence supporting the integration of educational game design into science education as a means of enhancing both academic achievement and student motivation. By making learning experiences more enjoyable, interactive, and learner-centered, educational games foster a more dynamic and supportive environment that aligns with the vision and pedagogical priorities of the Türkiye Century Education Model (2024).

The findings of this study regarding the effect of educational game design on student academic achievement in the Force and Motion unit align with research that suggests educational games can positively influence academic performance. The significant increase in assessment test scores from pre-test to post-test demonstrates that educational games, when applied appropriately, can enhance students' learning outcomes. This aligns with existing literature that emphasizes the positive impact of educational games on science achievement (Atakul, 2022). The idea that educational games can improve academic performance is well-supported in literature. Game-based learning environments tend to promote greater focus and motivation,

which in turn foster deeper engagement and improved performance. Educational games also create interactive and dynamic learning conditions that enhance content retention and conceptual understanding. However, it is also important to acknowledge that not all studies have found educational games to be effective in improving academic performance. Some researchers, including Yiğit (2007), Bayırtepe and Tüzün (2007), and Ataöver (2005), have found no significant effects on academic achievement when educational games were used. This inconsistency can be attributed to several factors, such as the design and implementation of the game, the teaching methods used, the student profile, and the content of the game. As Candan Tosun and Koçak (2021) emphasized, the effectiveness of educational games depends on their pedagogical coherence and purposeful integration into the learning environment. Therefore, while educational games hold significant potential as a learning tool, their success is not guaranteed in all contexts. Effective integration of educational games into the curriculum requires careful planning, design, and adaptation to meet the needs of the students and align with the learning objectives. When designed correctly and implemented with pedagogical expertise, educational games can serve as a powerful tool for improving student achievement.

Furthermore, the study highlights that the perception of educational games among educators can sometimes be negative. As Tosun (2011) pointed out, some science and technology teachers may perceive educational games as a "waste of time" or as causing confusion in the classroom. This perception may hinder the broader adoption of educational games in teaching. However, in the constructivist learning approach, which emphasizes active participation and student-centered learning, educational games are particularly valuable. They engage students, make learning more motivating and enjoyable, and help develop important skills such as problem-solving, creativity, and self-confidence. In conclusion, educational games, when carefully designed and applied, can be an effective for enhancing student achievement in science education. While their success may depend on various factors such as teacher approach and game content, they provide an engaging and interactive learning experience that benefits students' academic performance and overall development (Korkmaz, Cetin-Dindar, & Oner, 2023).

Based on both the self-evaluations of students and the peer evaluations of their classmates, it can be concluded that developing educational games is particularly effective for teaching abstract and complex scientific concepts. These games make learning more interactive and

enjoyable, thus promoting deeper engagement. Many students indicated that the educational games facilitated the reinforcement and retention of knowledge, as the repetitive nature of game-based activities allowed them to revisit and consolidate previously learned content. Additionally, students noted that the games made the lessons more enjoyable, helped them recall forgotten topics, and increased their interest in the subject matter, especially when elements of competition were incorporated. However, some students mentioned that the games were too short, which suggests that there may be a need to adjust the length of the game activities to better engage students. Despite this minor limitation, the overall consensus was that the use of educational games enriched the learning experience, making science lessons more enjoyable, efficient, and motivating. These findings are consistent with previous literature. For instance, Garvey (1990) noted that games are motivating, fun, and satisfying for students. Zhu (2012) also demonstrated that games significantly increase students' interest in the subject matter, while Demirel (2002) showed that even students who were typically less engaged can become active participants through the use of interactive educational games.

From the teacher's perspective, the application process went smoothly, with no disciplinary issues reported during the educational game design phase. The teacher observed that all students were actively engaged throughout the process, which further supports the idea that educational games can contribute to increased student participation and engagement. Moreover, the teacher highlighted notable improvements in students' social skills, particularly during collaborative group work. These observations are consistent with previous studies by Çavuş, Kulak, Berk, and Öztuna Kaplan (2011) and Boyraz and Serin (2015), science lessons that incorporate educational games improve not only academic achievement but also fosters the development of social competencies. Students exhibited improvements in important areas such as teamwork, rule adherence, and mutual respect, which are essential for social and emotional development. In conclusion, the integration of educational games in science courses proved to be an effective strategy for enhancing both academic learning and social-emotional development. The games fostered a positive learning environment where students were more motivated and engaged, making the learning process both fun and effective. These findings are in line with the existing literature and underscore the multidimensional benefits of game-based learning in fostering holistic student development.

The findings of this study indicate that designing educational games in science education significantly enhances students' critical thinking skills, motivation to learn science, and academic achievement in the Force and Motion unit. These results emphasize the potential of educational games as a multifaceted pedagogical tools that extend beyond transmission of academic knowledge, promoting a broad spectrum of social, cognitive, affective, psychomotor, communication, and creative thinking.

The findings of this study have significant implications for science education and beyond. Integrating educational games into the curriculum can provide an engaging and interactive alternative to traditional teaching methods, better addressing the diverse learning needs of students. To optimize the impact of such strategies, it is essential to provide comprehensive professional development for teachers in designing and implementing educational games. Furthermore, games must be aligned with curricular objectives, adapted to students' developmental and cognitive levels, and designed to promote active participation within a collaborative classroom culture.

While the study highlights the potential of educational games, it is important to recognize some limitations. The findings are based on a specific context (sixth-grade science course on force and motion unit) and may limit the generalizability of the findings to other subjects or grade levels. Additionally, the success of game-based learning depends heavily on the teacher's facilitation skills, the quality of the games, and the engagement of students. Future research could explore the long-term impact of educational games on learning retention and skill development, the effectiveness of game-based learning across different subjects and educational levels, and the use of digital and immersive technologies (e.g., virtual reality) in educational games to enhance student engagement and learning outcomes.

In conclusion, this study demonstrates the considerable educational value of engaging students in the design and implementation of educational games within science education. By supporting the development of both academic and non-academic competencies, educational games represent a holistic and student-centered approach to teaching and learning. When carefully designed and effectively implemented, such practices have the potential to transform traditional classrooms into dynamic learning environments that cultivate curiosity, motivation, and lifelong learning skills.

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