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Students' Views on the Use of Cryptology Methods Education Contexts[1]

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Abstract

This study aimed to gather middle school students' opinions on the utilization of cryptologic methods in education. Using a case study approach, data were collected through a semi-structured interview form developed with expert input. The focus was on the effects of integrating cryptologic methods within the Information Technologies and Software course. The study involved approximately 105 middle school students. Data analysis revealed that students generally viewed cryptologic methods positively, highlighting benefits such as enhanced long-term and rapid learning, improved problem-solving skills, and increased interest and motivation through diverse teaching techniques. However, some students reported difficulties in learning cryptologic methods and a lack of interest. The findings suggest that engaging, sustainable, and rapid learning captures students' attention and enhances their focus. Integrating cryptologic methods into the curriculum holds significant potential for developing 21st-century skills, including critical thinking, research, and problem-solving abilities, enabling students to connect clues and formulate solutions. The further integration of cryptologic methods promises to foster enjoyable and enduring cognitive gains in students' learning activities.

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Introduction

The increasing ease provided by digital technologies in people's lives (Giacomo et al., 2017) has paved the way for the reassessment and development of previously used but gradually overlooked methods and technologies. This process has encouraged the emergence of new applications based on old knowledge and technologies. In light of these technological advancements, the science of cryptology, which dates back to ancient times and is based on the foundations of mathematics, has regained importance (Arora et al., 2015; Massey, 1988). Cryptology has established a foundation for meeting societies' needs to protect information and deencrypt texts for desired purposes (Çeşmeci, 2009). The evolution of cryptology has been shaped particularly by the need for private communication in diplomatic and military fields (Buluş, 2006), gradually contributing to the resolution of such needs for societies and individuals.

After understanding the historical and theoretical background of cryptology, it is essential to focus on its applications in education and the benefits it offers to students. There are numerous advantages to using cryptology methods in educational settings (Rocca, 2005). Especially in today's rapidly advancing digital transformation, skills related to securely storing, using, and transmitting information can be enhanced through cryptology-based education. These trainings help students develop 21st-century skills such as problem-solving, computational thinking, and critical thinking (Patterson, 2020). Integrating cryptology into mathematics and information technology courses makes the content more effective, allowing students to gain deeper knowledge in these areas (Simms & Chi, 2011). Although the use of traditional cryptology methods has decreased today, these methods have been found to play a significant role in developing students' 21st-century skills (RathiDevi et al., 2017). Cryptology education generally prepares students to adapt to the new digital world (Sakalli et al., 2004). Moreover, it has the potential to equip students with the skills to use and protect personal data, learn secure data transmission in online environments, and effectively utilize digital technologies (Arınmış-Uzun, 2021).

The rise of digital technologies in education not only increases the need for security and data protection but also transforms learning methods. In this context, digital games serving educational purposes have become an innovative tool that enriches students' learning experiences. Research has shown that such games increase students' motivation by capturing their interest (Lin et al., 2010). Additionally, gaming experiences support students in achieving various learning objectives, thus ensuring more active participation and in-depth knowledge acquisition (Minović et al., 2015). Digital games have the potential to significantly contribute to the development of students' creativity, critical thinking, problem-solving, and collaboration skills. These skills are crucial not only in the educational process but also in professional life (Yang & Chang, 2013). Game-based education offers students greater independence, allowing them to set their own learning pace and take more responsibility in the process. This encourages students to play a more active role and makes the learning experience

enjoyable (Prensky, 2001). Furthermore, digital games, by presenting tasks at varying levels of difficulty, have the potential to boost students' confidence and enthusiasm for learning (Oti, 2012; Sadera et al., 2014).

The integration of cryptology methods from ancient applications with contemporary technologies creates an innovative and transformative approach in education (Adamovic et al., 2018). Within this framework, the integration of cryptology methods from past to present with modern technology has the potential to offer students engaging and enjoyable learning environments (Bergner et al., 2012). Especially the combination of cryptology methods with the fast-paced and engaging features of digital games can enhance students' problem-solving abilities. This multifaceted approach holds significant potential for effectively imparting both problem-solving and information processing skills to students (Percival et al., 2022). This strategy not only provides students with an interesting and enjoyable learning experience but also allows them to deeply understand cryptology methods in a historical context and how these methods addressed past problems (Rubin, 1997). Furthermore, students can apply cryptology methods to their real lives, gaining important skills such as analytical thinking, logical reasoning, and data analysis. In this regard, it is crucial to evaluate the potential contributions of integrating the science of cryptology and digital games into educational environments. This study aims to deeply examine students' perspectives on the integration of cryptology methods into digital game-based learning environments and their use in education and teaching.

Method

Research Design

This research utilized qualitative research methods, an approach that aims to collect descriptive data in natural settings and focuses on the perspectives of research subjects, employing an inductive methodology (Bogdan & Biklen, 2006). A case study method was adopted in the research, aiming to examine existing application examples through the question of 'how' (Yıldırım & Şimşek, 2008). This approach allowed the research to be conducted in a detailed and focused manner. Additionally, expert opinions were consulted during data collection and evaluation processes to enhance the methodological reliability and validity of the research.

Participants

The study included a total of 105 sixth-grade students, selected through random sampling and based on voluntary participation. Necessary permissions were obtained from both students and their parents, with detailed information provided to parents through consent forms. This careful process ensured the study's compliance with ethical standards and the protection of participants' rights, significantly contributing to the reliability and validity of the research.

Implementation Phase

Development of the Digital Game-Based Cryptology Application

The research model synthesizes the ADDIE model with the experiential game model. In planning the five stages of the game model, the Analysis, Design, and Development stages were developed according to the ADDIE model. The choice of the ADDIE model was influenced by its practicality and purposefulness compared to other instructional design models in the literature (Arkün et al., 2009). The Implementation and Evaluation stages were based on the experiential game model, which is grounded in "Experiential Learning Theory." This model progresses from concrete to abstract experiences, expecting students to derive conclusions from concrete experiences such as data collection and observation and to use these conclusions purposefully (Kiili, 2005).

The necessary scenarios, graphics, and content for the game were developed with the support of experts. The game includes problems related to classical encryption methods, each containing the keys required to solve them. The designed game consists of eight rooms, each containing one encryption problem that needs to be solved. Students are expected to find clues hidden in each room and solve the encryption to earn the eight keys. Some rooms require students to encrypt texts, while others require them to decrypt encrypted texts. Figure 1 provides visuals of the general overview of the game.

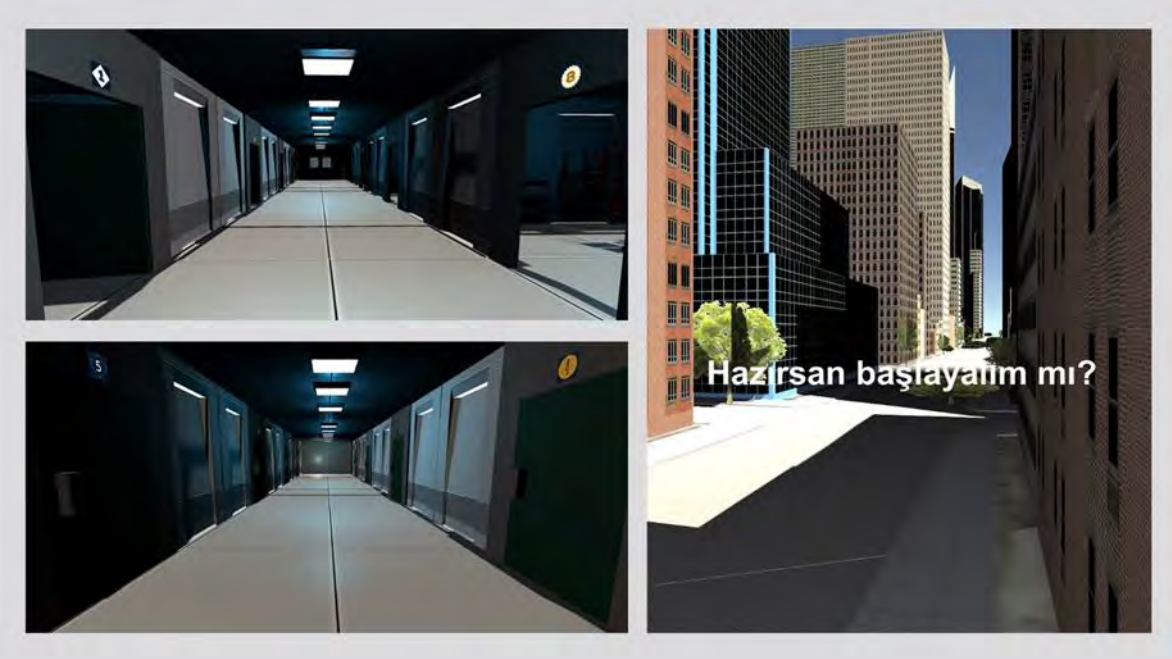

Figure 1. General Overview of the Digital Game-Based Cryptology Application

Experience Phase of the Digital Game-Based Cryptology Application by Students

Before the data collection process began, necessary permissions were obtained from the Ethics Committee of the Graduate School of Educational Sciences at ÇOMÜ to ensure the research adhered to ethical norms and standards. The schools where the research would be conducted were identified. Prior to data collection, students were taught outcomes involving cryptology methods as part of the sixth-grade Information Technology and Software course curriculum. Classical encryption methods were utilized in teaching these outcomes. Activities were conducted based on the Caesar encryption method to create and decrypt ciphers. Following this, students began playing the digital game-based cryptology game. The game consists of eight rooms, each containing problems related to eight different encryption methods, each requiring specific keys. Students were expected to find and solve the ciphers composed of eight separate keys. These methods include Caesar, Vigenere, Scytale, Pigpen, Rail Fence Cipher, and Algebraic encryption methods, as well as Semaphore and Morse alphabets. These encryption methods and special alphabets used in communication form the basis of the problems in the game rooms. Students were expected to find clues hidden in each room and solve problems prepared with different encryption methods provided in each clue. Some rooms required students to encrypt texts, while others required them to decrypt encrypted texts. All these activities were completed within a two-week period. After completing the process, an open-ended questionnaire was administered to the students for data collection.

Data Collection

Following the experience with the digital game-based cryptology application, students' opinions were collected using a comprehensive open-ended questionnaire. This questionnaire was designed to cover a broad perspective on various game experiences, preferences, and satisfaction levels. The valuable data collected from a total of 105 students were gathered over a period of 2 weeks. During this period, efforts were made to include students with different demographic characteristics, ensuring participation from various classes, age groups, and genders. This method was adopted to increase the general validity and diversity of the data obtained. The collected data are securely stored in a digital environment by the researcher, using a secure storage system. These security measures were implemented to ensure the privacy and anonymity of the students. The information obtained was used solely for analysis purposes.

Data Analysis

Following the application of the open-ended questionnaire, which constitutes the qualitative aspect of the study, the written data collected from the experimental group students were analyzed using categorical analysis and frequency analysis techniques, which are types of content analysis. The categorical analysis process involved the following stages: (1) coding the data, (2) creating categories, (3) organizing categories, and (4) identifying and interpreting the findings (Corbin & Strauss, 2007).

Frequency analysis was used to quantitatively determine the occurrence frequency of the data, thereby identifying the intensity and importance of a specific item (Ryan & Bernard, 2000). This process quantified the qualitative data, increasing the reliability of the data, reducing bias, and enabling comparison among the data (Yıldırım & Şimşek, 2008). Moreover, this approach allowed for a deeper understanding and the acquisition of a broad perspective on the research findings.

Findings and Discussion

Findings and Comments on the Digital Game-Based Cryptology Application

Students were asked about the topics they learned and the aspects they found interesting regarding the digital game-based cryptology application. The data collected through the open-ended form were analyzed using categorical analysis and frequency analysis techniques. The analysis results revealed that all students provided positive feedback. The categories determined based on the students' responses and the frequency and percentage values related to these categories are shown in Table 1.

Table 1. Students' Opinions on the Topics Learned and Interesting Aspects of the Digital Game-Based Cryptology Application

Positive	f	%
Learning with enjoyment	52	49,52
Contribution to mathematics learning	47	44,76
Awareness of information security	14	13,33
Intelligence development	9	8,57
Logical thinking	3	2,86

All students participating in the study expressed positive opinions. Some of the students' views on the topics learned and interesting aspects of the digital game-based cryptology application are as follows. S18 stated, "Learning cryptology through games is really fun," while S21 mentioned, "Cryptology in digital games is not only for fun but also useful in daily life. Thanks to my knowledge of encryption, I can keep my online accounts more secure." S38 added, "Cryptology in games makes learning enjoyable." These views suggest that the digital game-based cryptology application contributes to learning with enjoyment. Additionally, S55 noted, "Thanks to cryptology games, some topics in math class have become more memorable and clear," S73 commented, "I think solving ciphers in the game improves my math skills," and S82 mentioned, "I learned math-related topics better." These statements indicate that the digital game-based cryptology application contributes to mathematics learning. On the other hand, S57's comment, "Dealing with cryptology in games made me think about real-world security measures," and S101's view, "Cryptology games increased the importance of securing information," suggest that the digital game-based cryptology application raises awareness about information security.

S33 stated, "Solving ciphers in the games helps me develop my intelligence," and S45 mentioned, "... these games make me love math and logic even more." These views indicate that the digital game-based cryptology

Students' Difficulties and Solutions While Learning Cryptology Methods

Students were asked about the difficulties they experienced while learning cryptology methods and their views on solutions to these difficulties. The data collected through the open-ended questionnaire were analyzed, and the categories determined based on the students' responses, along with their frequency and percentage values, are shown in Table 2.

Table 2. Students' Views on Difficulties and Solutions While Learning Cryptology Methods

Difficulties	f	%
Mathematical terms and calculations	63	60,00
Step-by-step processing	39	37,14
Inappropriateness to level	13	12,38
Solutions		
Peer learning	46	43,80
Taking notes and reinforcement	43	40,95
Breaking down the topic	21	20,00

In the study conducted to deeply examine students' views on the integration of cryptology methods into a digital game-based learning environment, students were asked about the difficulties they experienced while learning cryptology methods and their views on solutions to these difficulties. S5 stated, "I felt like I wasn't very good at math. It was especially hard to understand complex encryption algorithms," S63 mentioned, "Dealing with numbers was challenging for me, especially large ones," and S47 added, "Cryptology was a topic that combined history and math, which sometimes confused me." These views suggest that the mathematical terms and calculations within cryptology methods caused difficulties for the students. Additionally, S39 stated, "The challenging part was following the steps for decryption in order. Sometimes the steps got mixed up," and S18 mentioned, "Understanding the path followed by cryptology methods to reach the goal was difficult for me," indicating that the algorithms created while developing cryptology methods were challenging for students to grasp. Furthermore, S101's comment, "Cryptology sometimes included things I didn't understand, and it was hard for me to grasp," and S92's view, "I struggled to understand some cryptology terms because they weren't suitable for my level," suggest that there might be issues with students' comprehension of cryptology applications.

Regarding the solutions proposed by students to overcome these difficulties, S67 stated, "Discussing and learning the topics with my group members helped me better understand cryptology methods," and S44 mentioned, "I asked our teacher to explain with simple examples, and working with my friends helped me understand the topics better." These statements indicate that peer learning and consulting their teachers were effective solutions for the difficulties they faced. Additionally, S88's comment, "I overcame this topic by taking notes and solving example questions," highlights that taking notes and reinforcement were helpful solutions, while S41's view, "I overcame the difficulty by breaking the topics down into small parts and proceeding step-by-step," indicates that tackling complex topics piece by piece helped to overcome the challenges.

Impact of Knowledge Learned in the Digital Game-Based Cryptology Application on Daily Life

Students were asked about their views on the impact of the knowledge learned in the digital game-based cryptology application on their daily lives. The responses collected through the open-ended questionnaire are presented in Table 3.

Table 3. Students' Views on the Impact of Knowledge Learned in the Digital Game-Based Cryptology Application on Daily Life

Positive	f	%
Ability to create secure passwords	67	63,80
Protecting personal data	44	41,90
Developing logic to solve problems	13	1238
Negative		
Methods being outdated	5	4,76

The majority of students expressed positive opinions. Some of the students' views on the impact of the knowledge learned in the digital game-based cryptology application on their daily lives are as follows. S22 stated, "By informing my family about creating passwords, we made our social media account passwords stronger," and S75 mentioned, "I use the cryptology knowledge I learned from the games to strengthen the passwords for my internet accounts." These views suggest that students have become aware of the importance of security in their online interactions with their families and can create strong passwords using cryptology methods. Additionally, S43 stated, "...I use the encryption methods I learned from the games in my diaries and personal files," and S13 mentioned, "...I use them in my 'secret notebook' to store my class notes." These statements indicate that students use cryptology methods to protect their personal data. S21 mentioned, "...I solve the ciphers in puzzle books using the encryption logic I learned from the games," suggesting that cryptology methods have contributed to their ability to solve problems they encounter.

Regarding the negative views, S86 stated, "I think the passwords created with old cryptology methods wouldn't be strong," which suggests that the impact of the encryption methods used in the digital game-based cryptology application on daily life might be limited.

Student Views on Experiences with Digital Game-Based Cryptology Applications

Students were asked about their views on the impact of the knowledge learned in the digital game-based cryptology application on their daily lives. The analysis of the data collected through the open-ended questionnaire is presented in Table 4.

Table 4. Students' Views on Experiences with Digital Game-Based Cryptology Applications

	f	%
Easy learning	39	37,14
Enhancing success	28	26,67
Speeding up reading, comprehension, and understanding	25	23,81
Learning new encryption methods	22	20,95
Developing skills	20	19,05
Assisting learning	19	18,10
Enhancing intelligence	16	15,24
Fun learning	7	6,67
Acting faster and more efficiently	6	5,71
Learning without realizing	4	3,81
Permanent learning	2	1,90

All students expressed positive views in response to this open-ended question. Some of the students' views on their experiences with digital game-based cryptology applications are as follows. S84 stated, "I think it helped me learn more easily," S29 mentioned, "It had a positive effect, I can solve ciphers better now," S3 commented, "It was very useful. It made it more permanent in my mind," and S62 said, "It’s very fun, so it sticks in my mind more. I’m having fun but also learning without realizing it. It would be great if we could always learn this way." These views suggest that digital game-based cryptology applications enhance easy learning, fun learning, and retention.

Additionally, S97 stated, "I think games have a significant effect on lessons," S14 mentioned, "When I first took the exam, I had questions like 'what is this?' but the games we played were effective. I scored higher on my second exam," and S36 commented, "The activities were good, it was a game that would develop our skills." These views indicate that digital game-based cryptology applications increase academic success and develop skills.

Furthermore, S17 mentioned, "I think it added more knowledge and taught new things," S94 said, "It taught me new information. It was both fun and it developed our intelligence," S60 commented, "It was good, it taught us by making us solve ciphers, and the last game was more enjoyable," S26 mentioned, "It sped up and facilitated my reading, comprehension, and understanding," and S37 said, "I think it was very good. I learned a lot of encryption methods thanks to the games." These views suggest that digital game-based cryptology applications teach new encryption methods, develop intelligence, and speed up reading and understanding. Based on the students' feedback, it can be concluded that digital game-based cryptology applications have a predominantly positive impact on students.

Discussion, Conclusion and Recommendations

The aim of this study with middle school students is to examine the impact of integrating cryptology methods into a digital game-based learning environment on education and teaching from the perspective of student opinions. Data collected from questions asked under four different headings were analyzed, and it was found that students generally have a positive outlook on cryptology methods and that they gained various benefits from the digital game-based cryptology application developed with these methods.

Students' positive views on cryptology methods in education generally focused on the concrete applications of cryptology. In this study, when looking at students' opinions on the topics learned and interesting aspects of the digital game-based cryptology application, factors such as contributing to mathematics learning, learning with enjoyment, and raising awareness of information security came to the forefront. Griffiths' (2020) study shows that postgraduate students see cryptology not only as important but also as an exciting field, emphasizing the need for a strong mathematical foundation to be effective in this area. In this context, students' positive outlook on cryptology motivates them in the learning process. Both studies highlight the importance and necessity of mathematics education in cryptology, as expressed by the students. Additionally, the findings indicate that cryptology education creates an enjoyable learning experience and increases motivation.

Regarding the impact of the knowledge learned in the digital game-based cryptology application on daily life, students emphasized factors such as creating secure passwords, protecting personal data, and developing critical thinking to solve problems. It was found that students applied the knowledge they gained from cryptology methods to their daily lives. Sakalli's (2004) research highlights the potential of cryptology to enhance mathematics education, suggesting that students can achieve more interest and success in this area when it is associated with mathematics. This study reveals that using abstract mathematical concepts in cryptology in daily life can make students' learning experiences more concrete and impactful. When looking at these two studies, it can be said that cryptology methods can contribute to solving problems encountered in daily life when applied in different fields.

Spaht et al. (2002) emphasized the practical applications of cryptology, indicating that cryptology can play an important role in increasing students' interest in mathematics. Zapechnikov et al. (2015) examined the use of distance education technologies in teaching cryptology, showing that students are open to innovative approaches in this field. Distance education can provide students with learning opportunities in cryptology regardless of distances, allowing them to develop their knowledge and skills in this area. Students' positive views on cryptology suggest that they see cryptology not only as an academic subject but also as an applicable and exciting field in daily life. This can enable cryptology to be used more effectively and attractively in education.

When examining the literature on the use of cryptology in educational environments, it is revealed that students have positive views on the use of cryptology in these environments. Although cryptology has been a continuously evolving field from past to present, it can be said that it has not been adequately addressed in education. Educational studies on cryptology generally show positive results. Therefore, there is a need to include more cryptology education in current curricula. Teaching cryptology to students can develop many skills. This study concluded that adding new tools to the curriculum to enhance students' education with cryptology was positively received by students. Specifically, digital game-based cryptology applications were found to resonate more with students' interests and attitudes and contributed more effectively to skill acquisition. Thus, incorporating more innovative approaches and applications in cryptology into educational systems can allow students to develop these important skills more effectively.

Policy Implications

The findings from the study highlight several key areas where educational policies can be informed and enhanced by integrating cryptology methods and digital game-based learning environments. Below are the policy implications derived from the study:

1. Incorporation of Cryptology in Curricula:

- Mathematics and Information Technology Integration: Given the positive impact of cryptology on students' understanding and interest in mathematics, educational policies should encourage the incorporation of cryptology topics into mathematics and IT curricula. This can foster a deeper understanding of mathematical concepts and enhance students' problem-solving skills.
- Development of New Learning Modules: Policies should support the development of new, engaging learning modules that integrate cryptology methods. These modules can be designed to align with existing educational standards while introducing innovative content that appeals to students' interests.

2. Promotion of Digital Game-Based Learning:

- Support for Educational Game Development: Policies should incentivize the development and use of educational digital games that incorporate cryptology. Funding and resources can be allocated to educational technology developers to create high-quality, engaging games that can be used in classrooms.
- Teacher Training and Resources: Teachers should be provided with the necessary training and resources to effectively integrate digital game-based learning into their teaching practices. This includes professional development programs focused on the use of educational games and cryptology methods in the classroom.

3. Enhancement of Digital Literacy and Security Awareness:

- Digital Security Curriculum: Incorporating cryptology into education not only enhances mathematical and logical skills but also raises awareness about information security. Policies should mandate the inclusion of digital security and cryptology in the curriculum to equip students with the knowledge to protect personal data and understand secure data transmission.
- Critical Thinking and Problem-Solving Skills: Policies should emphasize the development of critical thinking and problem-solving skills through cryptology education. This can be achieved by integrating activities that require logical reasoning and analytical thinking, preparing students for the challenges of the digital age.

4. Encouragement of Innovative Educational Practices:

- Support for Experiential Learning Models: The positive feedback from students on the use of cryptology in digital game-based learning suggests that experiential learning models are highly effective. Policies should support the adoption of such models, encouraging hands-on, interactive learning experiences that make education more engaging and effective.
- Research and Evaluation: Continuous research and evaluation should be supported to assess the effectiveness of cryptology and digital game-based learning in education. Policies should promote ongoing studies to refine these methods and ensure they meet educational objectives.

5. Equity and Accessibility:

- Ensuring Access for All Students: Policies must ensure that all students, regardless of their socio-economic background, have access to the technologies and resources needed for digital game-based cryptology education. This includes providing devices, internet access, and software necessary for participation in such innovative learning environments.
- Inclusive Curriculum Design: The curriculum should be designed to be inclusive, addressing the diverse needs of students and ensuring that cryptology and digital game-based learning methods are accessible and beneficial to all learners.

By implementing these policy recommendations, educational systems can effectively integrate cryptology methods and digital game-based learning into their curricula, thereby enhancing students' learning experiences and preparing them for the demands of the digital world.

Conflict of Interest

The authors declare no conflict of interest.

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No funding was received for conducting this study.

Ethical Statement

This study was approved by the Ethics Commission of Çanakkale Onsekiz Mart University (approval number: 2023-YÖNP-0180) in 2023. All procedures were carried out in accordance with the relevant guidelines and regulations. Informed consent was obtained from all study participants.

Credit Author Statement

All authors contributed equally to the conceptualization, methodology, data collection, analysis, and writing of this manuscript.

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