Research Article

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Twenty-First Century Learning Technology Innovation: Teachers' Perceptions of Gamification in Science Education in Elementary Schools

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Abstract: In the digital era, the application of technology in education is increasingly important to enhance student engagement and learning effectiveness. The aim of this study is to explore teachers' perceptions of twenty-first century learning technology innovations, specifically the implementation of gamification in elementary science education. Using interviews, this research involves teachers from various socioeconomic backgrounds (low, middle, and high) to gain diverse perspectives on the definition of gamification, its classroom implementation, as well as the challenges and solutions in applying gamification. In addition to interviews, this study also employs questionnaires to assess teachers' initial knowledge of the gamification concept prior to classroom implementation. The findings indicate that teachers' understanding and perceptions of gamification vary, influenced by socioeconomic factors and access to technology. The identified challenges include infrastructure limitations, technical knowledge, and curriculum adaptation, while the proposed solutions encompass intensive training and infrastructure support. These findings are expected to provide insights for developing policies and training programs that support gamification as a technological innovation in elementary science education.

Keywords: gamification, elementary school, science learning, perspective teacher

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1 Introduction

Technological, information, and communication (ICT) advancements have driven the application of gamification in education (Lampropoulos, Keramopoulos, Diamantaras, & Evangelidis, 2022; Ofosu-Ampong, 2020; Saleem, Noori, & Ozdamli, 2022), a highly relevant innovation within the context of twenty-first century science learning (Kalogiannakis, Papadakis, & Zourmpakis, 2021; Papadakis, Zourmpakis, & Kalogiannakis, 2022). In science education, gamification serves as an effective approach to introduce concepts that may be abstract or challenging to understand in an engaging and interactive manner. Game elements such as points, levels, challenges, and rewards are integrated to create a motivating and enjoyable learning experience for students, particularly at the elementary level (Alsawaier, 2018; Dichev, Dicheva, Angelova, & Agre, 2015). Through gamification, students become more actively involved in the science learning process, increasing their motivation, interest, and concentration while studying scientific phenomena (Chans & Portuguez Castro, 2021; Kirillov, Vinichenko,

Melnichuk, Melnichuk, & Vinogradova, 2016). This technological innovation also enables real-time feedback, allowing students to track their learning progress, creating a more meaningful, relevant, and competitive learning experience aligned with twenty-first century needs (Figueroa-Flores, 2016; Kingsley & Grabner-Hagen, 2015).

In twenty-first century science education, gamification becomes a suitable tool for children growing up in the digital era. As a natural learning instrument, gamification supports the development of twenty-first century skills such as critical thinking, problem-solving, and creativity – key skills essential for understanding and exploring scientific concepts (Figueroa-Flores, 2016). Teachers play a crucial role in selecting game activities relevant to science learning objectives, ensuring that the applied gamification approach is effective and supports technological innovation. In this way, science learning becomes more practical and enjoyable, encouraging students to experiment and practice scientific concepts in a safe environment.

Moreover, technology in gamification facilitates creative science teaching practices. Research shows that gamification provides challenges that promote authentic learning and enhance students' intrinsic satisfaction, in line with twenty-first century educational standards that emphasize practical skills (Lampropoulos et al., 2022). Gamified e-learning, which is gaining popularity, allows science learning materials to be organized into games to create an immersive virtual learning environment. This environment enables students to learn independently, interact with science materials, and receive continuous feedback that boosts their motivation and understanding of scientific concepts.

In twenty-first century education, science learning materials relevant to everyday life are increasingly important. Gamification enables students to connect scientific concepts to real-life situations, helping them see the relevance of the knowledge acquired to their daily lives. Teachers who understand the importance of gamification as a teaching method can design creative and relevant game-based activities, enriching science learning and making it more inclusive. In a supportive learning environment, students are encouraged to think critically, collaborate, and innovate while learning science.

In the application of gamification to twenty-first century science education, five main dimensions contribute to learning effectiveness: Learning environment, learners, pedagogy, context, and teachers (González-Pérez & Ramírez-Montoya, 2022; Karan & Brown, 2022; Koyunlu Ünlü & Dökme, 2022). This effectiveness encompasses affective, cognitive, and psychomotor aspects, which are essential in modern learning approaches. With gamification designed through innovative technology, students can develop relevant experiential learning, thus becoming more engaged and motivated in understanding scientific concepts. Through this approach, gamification in science learning becomes an effective and innovative tool to enhance student engagement in the twenty-first century technology era (Al Ghozali, Mustoip, & Sulkhah, 2024; Alahmari et al., 2023).

Based on the above description, this study aims to analyze elementary school teachers' perceptions of the application of gamification in science learning in the twenty-first century learning technology era. This study will also assess the extent to which gamification can increase student engagement and motivation in elementary science learning according to teachers' perspectives. Based on these findings, this research is expected to provide relevant recommendations for the effective application of gamification in science learning, tailored to the needs and characteristics of twenty-first century learning, thus supporting the achievement of more interactive and meaningful learning objectives.

2 Literature Review

Nick Pelling first coined the term "gamification" in 2002 during a presentation at TED (Technology, Entertainment, Design). Gamification is a learning approach that uses elements from games or video games to motivate students in the learning process and maximize enjoyment and engagement, capturing students' interests and inspiring them to keep learning. Gamification involves using game mechanics to provide practical solutions by building interest within specific groups (Bencsik, Mezeiova, & Samu, 2021; Patricio, Moreira, & Zurlo, 2022). In more detail, gamification is defined as a concept that uses game-based mechanics, aesthetics, and game-thinking to engage people, motivate action, promote learning, and solve problems. Glover concluded that gamification provides additional motivation to ensure that learners fully participate in learning activities (Ekici, 2021). Engagement can be defined as the willingness to participate; Frederick describes student engagement as a metaconstruct that includes students' behavioral, emotional, and cognitive involvement in learning. Just as games allow players to restart or replay, make mistakes, and learn from them, gamification reduces the fear of failure and increases players' attachment to the game. Gamification works by making technology more appealing, encouraging users to engage in desirable behaviors, providing pathways to mastery and autonomy, solving problems rather than causing distractions, and taking

advantage of human psychology's natural tendency to engage with games. According to Zichermann, gamification is the process of using game-thinking and game mechanics to engage users and solve problems. In general terms, gamification is the use of game design elements in non-game contexts.

2.1 Science Education in Elementary Schools

Science education in elementary schools aims to introduce basic scientific concepts to students, foster curiosity, and develop critical thinking and problem-solving skills (Leasa, Corebima, & Batlolona, 2020; Sutiani et al., 2021). At this level, engaging, interactive, and experiential approaches are often chosen to help students understand scientific concepts that may be abstract or challenging to grasp. Research shows that approaches such as direct experimentation, simulations, and visual models can help students more easily understand science material and relate it to everyday phenomena (Idris, Talib, & Razali, 2022; Kizilaslan, Zorluoglu, & Sozbilir, 2021). Experiential approaches also play an essential role in increasing students' engagement, so they not only learn passively but also actively explore and observe. Thus, elementary science education forms a critical foundation for building a basic understanding of science, which will be further developed in higher levels of education.

In the twenty-first century technology era, elementary science education is increasingly enriched by technology applications, such as multimedia, educational games, and virtual tools, that enhance students' engagement in understanding scientific concepts. Gamification, for example, has become a popular method in science education as it combines engaging game elements with educational content, increasing students' motivation and interest in science. Additionally, this method helps students to collaborate, think critically, and develop other cognitive skills through enjoyable activities. The use of technology in science education also allows students to learn independently and receive real-time feedback, supporting a more meaningful and adaptive learning experience tailored to each student's learning needs (Aleven, McLaughlin, Glenn, & Koedinger, 2016; Matuk, Linn, & Eylon, 2015).

2.2 Gamification in Science Education

Gamification in science education is an approach that integrates game elements, such as points, levels, challenges, and rewards, into an educational context to enhance students' engagement and motivation (Rivera & Garden, 2021). In science education, gamification is effective because it can transform potentially abstract scientific concepts into more concrete and engaging learning experiences. Research shows that gamification increases students' interest and helps them become more involved in the learning process, creating an interactive, student-centered learning environment. Additionally, game elements provide students with measurable short-term goals, encouraging them to continue learning and overcome challenges in an enjoyable way. Through this approach, students also have the opportunity to develop critical thinking skills, problem-solving abilities, and strengthen their understanding of scientific concepts.

Furthermore, gamification in science education enables continuous, immediate feedback, which is crucial in supporting the learning process. This feedback helps students identify errors or gaps in understanding in real-time, allowing them to improve their grasp of the material. Gamification also allows teachers to personalize learning according to each student's abilities and comprehension level (Oliveira et al., 2022; Roosta, Taghiyareh, & Mosharraf, 2016; Tenório, Dermeval, Monteiro, Peixoto, & Silva, 2022), making it an adaptive and suitable method for twenty-first century learning characteristics. For example, in science-based games, students can interact with virtual simulations that replicate scientific phenomena, helping them understand more complex concepts in a tangible and practical manner. Thus, gamification serves not only as an effective teaching method but also as a means of deepening students' understanding and developing skills relevant to the real world.

2.3 Teachers' Perceptions of Gamification in Science Education

Teachers' perceptions of gamification in science education tend to vary but are generally positive, as the method is seen as capable of increasing student interest and engagement (Gómez-Carrasco, Monteagudo-Fernández, Moreno-Vera, & Sainz-Gómez, 2019; Khan, Ahmad, & Malik, 2017). Many teachers consider gamification an effective tool for making science education more interactive and enjoyable, especially for elementary students who need practical and visual approaches to understand scientific concepts. According to research, teachers see gamification as helpful in developing students' cognitive skills such as critical thinking, problem-solving, and analytical abilities, which

are essential in science education. Teachers also feel that the game elements in gamification, such as awarding points, challenges, and rewards, provide additional motivation for students to continue learning and exploring science material independently.

On the other hand, although teachers generally support the use of gamification, they identify some challenges in its application (Sánchez-Mena & Martí-Parreño, 2017). Some teachers feel that gamification requires a good understanding of technology, both from the teachers and the students, which can be a barrier in environments with limited technological facilities. Additionally, some teachers worry that excessive use of gamification may reduce students' focus on understanding the material and actual learning objectives. However, teachers' positive perceptions of gamification's potential to enhance science learning suggest that the method remains relevant, as long as it is applied in balance and tailored to students' needs and characteristics. For teachers, gamification is an innovation with significant potential, particularly in creating a deeper, more interactive science learning environment aligned with twenty-first century learning characteristics.

2.4 Conceptual and Theoretical Framework of Study

This study is based on the concept of twenty-first century learning technology innovation and the gamification approach in elementary science education. In the twenty-first century context, technology plays a key role in creating more interactive, adaptive learning experiences tailored to students' needs. Gamification, as part of this technological innovation, combines game elements such as challenges, rewards, and levels to motivate students and increase their engagement in learning. This conceptual framework proposes that teachers' understanding and perception of gamification are essential for effectively implementing this method in science education. Teachers act as facilitators and innovators who can select or adapt appropriate gamification approaches in line with the curriculum and students' learning characteristics. Thus, teachers' perceptions of gamification significantly influence the success of implementing this technological innovation in science education.

Theoretically, this study uses constructivist learning theory, which emphasizes that learning occurs effectively when students actively engage in the learning process through exploration and hands-on experience. Gamification supports this theory by creating an immersive and experiential learning environment. Furthermore, this study considers self-determination motivation theory, which suggests that individuals are driven to feel competent, autonomous, and connected to their environment. Gamification serves as a means to fulfill these needs, as it provides students with achievable challenges and goals, along with immediate feedback that helps them feel more motivated and engaged. Therefore, this framework illustrates that teachers' understanding of these theories and their perceptions of gamification's benefits and challenges can influence how gamification is implemented in science education, ultimately impacting students' motivation and engagement.

3 Research Methods and Methodology

This study employs a mixed-methods approach to explore elementary school teachers' perceptions and views regarding the application of gamification in science education. This approach was chosen because it allows the researcher to examine various aspects related to individual experiences, beliefs, values, knowledge, and perceptions of gamification, as well as its implementation in an educational context. Primary data were collected through semi-structured interviews and a 5-point Likert scale questionnaire, offering flexibility for the researcher to ask open-ended, in-depth questions. Through these interviews, teachers were able to openly express their subjective views on the benefits, challenges, and impacts of gamification on students' motivation and engagement in the learning process.

The participants consisted of 34 elementary school teachers from diverse regions, including Jakarta, Depok, Bogor, Tangerang, and Bekasi. Participants were selected using purposive sampling with a maximum variation approach to ensure diversity in characteristics such as teaching experience and socio-economic background, spanning areas with low, middle, and high economic conditions. This strategy aimed to capture a wide range of perspectives that reflect the varying experiences and challenges teachers face when applying gamification in elementary-level science education.

Research data were collected through semi-structured interviews and questionnaires designed to gather in-depth information on teachers' perceptions of gamification in science education. The interview and questionnaire forms were carefully prepared by the researchers to align with the research objectives, and draft versions were reviewed by experts in education and gamification to ensure validity and relevance. After incorporating expert recommendations,

Table 1: Aspects of the instrument of interviews with teachers

No.	Interview aspect
1	Definition of gamification according to elementary school teachers
2	Elementary school teachers' opinions on gamification as a learning method
3	Teachers' opinions on the implementation of gamification methods in the learning process
4	Teachers' perspectives on the problems faced in the implementation of gamification methods in elementary schools
5	Teachers' suggestions regarding the issues faced in the implementation of gamification methods in elementary school education

the instruments were finalized. Interview questions were based on the aspects shown in Table 1.

Data collection was conducted gradually during the 2024–2025 academic year with a flexible schedule to accommodate teachers' availability. Before starting data collection, the researchers explained the study's purpose and procedures to each participant to ensure informed consent. Willing teachers signed consent forms prior to the interview sessions and questionnaire completion.

The questionnaire and interview guidelines were carefully developed to align with the research objectives. Draft versions of these instruments were reviewed by experts in education and gamification to ensure validity and relevance. After incorporating expert feedback, the instruments were finalized.

The interview instrument covered several aspects designed to explore teachers' perceptions of gamification in elementary science education. Tables 3–6 provide an overview of key dimensions analyzed in the study, including definitions of gamification, teachers' perspectives, its implementation, and the challenges encountered.

In addition to interviews, the study employed a questionnaire to gather quantitative data on teachers' perceptions of gamification. The questionnaire included 20 items measuring various gamification elements applied in science education. Items were structured using a Likert scale to explore teachers' attitudes and beliefs toward different facets of gamification.

Following reviewer suggestions, we clarified that the quantitative data obtained through the questionnaire served as exploratory support for qualitative analysis rather than a primary dataset warranting inferential statistical tests. Thus, the quantitative analysis is descriptive in nature, providing an overview of teachers' perceptions of gamification. Questionnaire results will be compared with interview findings to offer a comprehensive understanding of teachers' views on gamification in science education.

Table 2: Questionnaire questions for teachers' perceptions of gamification

Item	Questions
1	Teachers use points or scores as a form of reward for each task completed by students
2	Teachers implement a leveling system to motivate students in learning
3	Teachers award badges as recognition for students' achievements
4	Teachers use leaderboards to encourage healthy competition among students
5	The use of gamification makes students more engaged in the learning process
6	Gamification elements applied increase students' motivation to learn
7	Students are more enthusiastic about completing tasks when gamification elements are included
8	Gamification helps students feel more challenged and motivated to achieve learning objectives
9	Learning with gamification helps students understand the material better
10	Teachers use gamification to provide immediate feedback to students
11	Students find it easier to remember the material taught through gamification methods
12	Gamification helps students connect theory with practice
13	Teachers use digital applications or platforms to implement gamification in learning
14	Teachers utilize multimedia (videos, audio, etc.) in the gamification process
15	The technology used in gamification is easily accessible to students
16	Teachers guide students in using technology for gamified learning
17	Teachers use the results from gamification elements to evaluate students' learning progress
18	Assessment through gamification provides a clear picture of students' abilities
19	Teachers provide constructive feedback based on gamification results
20	Teachers use data from gamification to design subsequent learning strategies

Table 3: Definition of gamification according to elementary school teachers

Aspect	Respondent category	Responses
Definition of gamification according to elementary school teachers	Teachers with low socioeconomic levels	• Use of play elements in learning • Makes learning more enjoyable • Increase student engagement in learning
	Teachers with moderate socioeconomic level	• Interactive learning methods • Learning that can motivate and actively engage students • Learning using technology
	Teachers with high socioeconomic levels	• Integration of technology in learning • Increase motivation with a point system and challenges • Student-centered approach to learning

The qualitative data from semi-structured interviews were analyzed using thematic analysis, involving coding, categorizing, and identifying key response patterns. Insights emerged regarding factors supporting gamification's effectiveness, including increased student motivation, learning engagement, and concept comprehension. Challenges such as technological limitations and gaps in digital skills were also identified.

Questionnaire data, collected via Likert scale, were analyzed descriptively to summarize teachers' attitudes and beliefs about gamification. Descriptive statistics detailed response distributions and provided an overview of general views on gamification implementation. Although inferential statistical tests were not applied, descriptive analysis added valuable support to interview findings. The questions for the questionnaire are shown in Table 2.

Through this integrated approach, the study combines qualitative and quantitative findings to provide a comprehensive view of teachers' perceptions of gamification in science education. By merging in-depth interviews with descriptive statistics, the research captures both individual insights and broader trends, offering a well-rounded understanding of the benefits and challenges of gamification. This method enhances the study's validity and clarity, ensuring that the findings are grounded in a robust, coherent research design while addressing key methodological considerations.

4 Results and Discussion Data

In this section, the results of the study on teachers' perceptions of the implementation of gamification in science education at the elementary school level in the twenty-first century will be discussed. The primary objective of this research is to explore the extent to which teachers perceive

Table 4: Elementary school teachers' opinions on gamification as a learning method

Aspect	Respondent category	Responses
Elementary school teachers' opinions on gamification as a learning method	Teachers with low socioeconomic levels	• Focus on challenges in accessing devices or technology infrastructure • Assume gamification can be of interest to students, but may be difficult to implement due to resource limitations • Prefer an accessible method at no additional cost
	Teachers with moderate socioeconomic level	• Consider gamification as an interesting additional tool to increase learning motivation • See it as a way to help students engage more actively, yet consider the cost and time required
	Teachers with high socioeconomic levels	• Have a positive view of gamification and be ready to adopt the latest technologies to enhance learning • See it as a means to provide an interactive and creative learning experience • Tends to support investment in gamification applications and teacher training for optimal use in the classroom

gamification as an effective pedagogical innovation to enhance student engagement and understanding of science concepts. Based on comprehensive data obtained from interviews and surveys, the presented findings offer critical insights into the multifaceted challenges, distinct benefits, and overall impacts of gamification on the classroom learning experience. Furthermore, this section elaborates on the key factors that influence the successful implementation of gamification, including technological readiness, teacher preparedness, and institutional support, alongside teachers' perspectives on the integration of digital technologies in elementary science education.

Based on the interviews analyzed through six main dimensions, elementary school teachers' perceptions regarding gamification in science education are described in detail. Teachers' perceptions were evaluated based on their comprehension of the fundamental gamification concepts, recognition of its potential to enhance student motivation and engagement, practical application of gamification elements within the learning process, perceived barriers and challenges, and the degree of readiness and interest among teachers in adopting gamification strategies in their classrooms. The results of this in-depth analysis provide a nuanced understanding of both the cognitive grasp teachers have of gamification and their evaluative judgments regarding its potential impact on science learning outcomes at the elementary level.

Table 3 illustrates the variation in teachers' conceptualizations of gamification. Teachers from lower and middle socioeconomic backgrounds predominantly define gamification as a learning approach designed to increase student engagement by embedding game elements. Meanwhile, educators across all socioeconomic categories consistently emphasize that gamification aligns with student-centered learning principles, which make science education more interactive and dynamic by integrating game and technology elements into traditional curricula.

Table 4 shows how the perceptions of gamification as a learning methodology are influenced by teachers' socioeconomic contexts. Those from lower socioeconomic backgrounds express skepticism about the effectiveness of gamification, largely due to limited access to digital devices and technological infrastructure, though they acknowledge its potential to captivate students' interest. Middle socioeconomic groups view gamification increasingly as a motivational tool but remain cautious about costs and affordability. Teachers from higher socioeconomic backgrounds demonstrate strong support for gamification, recognizing its capacity to boost engagement and expressing readiness to invest in technological resources. These findings highlight that disparities in access and resources are critical factors affecting the acceptance and practical implementation of gamified learning, advocating for educational policies that address equity in technology distribution.

Table 5 highlights differing implementation patterns of gamification linked to socioeconomic variations. Teachers at lower socioeconomic levels face considerable challenges due to inadequate device availability and unreliable

Table 5: Teachers' opinions on the implementation of gamification methods in the learning process

Aspect	Respondent category	Responses
Teachers' opinions on the implementation of gamification methods in the learning process	Teachers with low socioeconomic levels	• Faced major obstacles in accessing devices and internet networks to implement gamification • Feeling that this method is difficult to implement without adequate funding and technology support • Prefer simple methods that do not cost much
	Teachers with moderate socioeconomic level	• Seek to find ways to implement gamification using an affordable app or device • Considering that gamification can increase students' interest in learning, but requires more preparation in terms of time and cost • Looking for alternative solutions such as manual gamification or educational games that are less reliant on technology
	Teachers with high socioeconomic levels	• Tend to be enthusiastic in implementing gamification by using the latest applications and technologies • See it as an effective way to make learning more interactive and fun • Support the provision of training for teachers to maximize the implementation of gamification in learning

networks, hindering gamification deployment without sufficient technological backing. Those in middle socioeconomic tiers have adopted more cost-effective or manual gamification techniques to circumvent funding limitations. Conversely, higher socioeconomic teachers are more enthusiastic and equipped, leveraging modern technology and professional development opportunities to enhance gamification efficacy. The data underscore the importance of equitable technological support and targeted training to maximize gamification's benefits in diverse school settings.

Table 6 identifies that implementation challenges vary by socioeconomic status (SES). Lower SES teachers report fundamental barriers such as device shortages, poor internet connectivity, and constrained budgets, complicating gamification adoption. Middle SES educators highlight costs associated with software subscriptions and insufficient training, alongside infrastructural shortcomings. Meanwhile, higher SES teachers experience challenges primarily related to time constraints, curricular alignment, and maintaining student focus amid the potentially distracting nature of game elements. This suggests that successful gamification requires infrastructure investment, inclusive teacher training programs, and curricular reforms that holistically incorporate technology across socioeconomic strata.

Table 7 presents teacher recommendations to ameliorate gamification challenges, differentiated by socioeconomic context. Lower SES teachers advocate for simple, low-cost gamification techniques and governmental support or subsidies to facilitate technology access. Middle SES teachers call for affordable, ongoing training and shared resource acquisition to enable broader gamification usage. In contrast, higher SES teachers emphasize the necessity of curriculum alignment and comprehensive training to optimize gamification's pedagogical value. These insights collectively argue for inclusive policy measures, equitable access to technology and professional development, and strategic curriculum design to bridge implementation gaps and ensure all elementary schools can effectively deploy gamification.

Based on the interview results, teachers' perceptions of gamification in science education at the elementary level vary according to SES, influencing their understanding and acceptance of the definitions and benefits of gamification. Teachers from lower socioeconomic levels generally define gamification as a simple game-based learning method without high-tech elements due to limited access to devices and budgets. They view gamification as a way to engage students, but with a focus on no additional costs. Teachers from middle socioeconomic backgrounds have a broader understanding, seeing gamification as a method that can utilize simple applications, assuming that game-based learning can foster student interest and engagement. Among teachers from higher socioeconomic backgrounds, gamification is understood more comprehensively,

Table 6: Teachers' perspectives on the problems faced in the implementation of gamification methods in elementary schools

Aspect	Respondent category	Responses
Teachers' perspectives on the problems faced in the implementation of gamification methods in elementary schools	Teachers with low socioeconomic levels	• Facing major constraints in device limitations and internet access, which hinder the implementation of gamification • Limited school budgets to provide the technology needed • Concerns about how to make gamification methods simple and still attractive to students at no additional cost
	Teachers with moderate socioeconomic level	• The biggest challenge is the subscription fee of the application or gamification program which may still be a burden on the school's budget • Limitations in teacher training on how to effectively use gamification in learning • There are technical obstacles related to the readiness of school infrastructure, such as uneven internet access in each classroom
	Teachers with high socioeconomic levels	• The main challenge is time and curriculum, which sometimes does not align with the development of gamified content • There needs to be in-depth training for teachers to design interactive learning experiences • Although technology support is available, it takes effort to keep students focused from being distracted by the game aspect alone

Table 7: Teachers' suggestions regarding the issues faced in the implementation of gamification methods in elementary school education

Aspect	Respondent category	Responses
Teachers' suggestions regarding the issues faced in the implementation of gamification methods in elementary school education	Teachers with low socioeconomic levels	• Propose the use of gamification methods that do not require expensive devices, such as manual educational games • Encourage schools or governments to provide basic equipment assistance or internet subsidies • Suggest simple gamification training that can be applied with limited resources
	Teachers with moderate socioeconomic level	• Recommend periodic training for teachers on the use of gamification applications on an affordable budget • Propose the procurement of a joint device or simple gamification support tool in schools • Encourage schools to seek sponsors or grants to subscribe to more budget-friendly gamification apps
	Teachers with high socioeconomic levels	• Suggest aligning the curriculum with gamified content to make learning time more efficient • Support in-depth training for teachers to design structured and effective gamification • Encourage the use of applications that prioritize the educational aspect so that students stay focused on learning

viewed as a modern method involving technology and advanced applications that can make science learning more interactive and engaging through simulations or application-based experiments.

In terms of views on gamification as a learning method, teachers from lower socioeconomic levels tend to be skeptical about the widespread application of gamification in science education due to technological resource limitations and lack of support for device access. Conversely, teachers from middle socioeconomic backgrounds see the potential of gamification as an effective method for science learning, although they are aware of budgetary challenges. They tend to look for more economical solutions, such as free applications or paper-based games and simple tools to engage students. Teachers with higher socioeconomic backgrounds, on the other hand, strongly support gamification and argue that this method can make science learning more dynamic, helping students understand abstract concepts through visual experiences and simulations. However, they also suggest that the curriculum should be more flexible to incorporate more gamification content.

Teachers' perspectives on the challenges in implementing gamification also reflect economic differences. Teachers from lower socioeconomic levels mention the main constraints of limited devices and internet access, along with limited school budgets, and suggest government support to expand technology access. Teachers from middle socioeconomic levels focus on budget limitations for subscribing to gamification applications and a lack of training, proposing periodic training and grant access for technology procurement. Teachers from higher socioeconomic backgrounds, while having access to technology, face challenges in curriculum adjustments and time management, as well as ensuring students remain focused on learning without being distracted by game elements. Overall, this study shows that the implementation of gamification in science education can be effective with supportive policies targeting the provision of technological infrastructure, training, and inclusive curricula, enabling teachers at every socioeconomic level to experience the benefits of gamification in elementary science learning.

In addition to conducting interviews to explore teachers' perceptions of gamification in science education at the elementary level, a survey was also conducted to assess teachers' initial knowledge of gamification. The data obtained are shown in Figure 1.

The result of the questionnaire indicates that teachers' initial knowledge of gamification reveal high numbers, suggesting that many teachers have a good understanding of the concepts, benefits, and basic applications of gamification in learning. This high score indicates that teachers generally have a theoretical knowledge of gamification, including its definition and how it can enhance student

motivation and engagement in learning. This serves as a strong foundation in preparing teachers to implement gamification, as a deep understanding of this concept allows them to design more effective and relevant learning experiences for students.

However, although the questionnaire results show a good understanding, high initial knowledge does not always align with practical implementation skills. The study indicates that other factors, such as the availability of resources, access to technology, and practical skills in using gamification applications, may still pose challenges in the field. High theoretical knowledge needs to be complemented by training focused on the direct application of gamification, especially for teachers in areas with limited access. If only relying on initial understanding without adequate implementation skills, the application of gamification may remain limited in practice, thus failing to fully realize its potential benefits in learning.

Overall, these results underscore the importance of a continuous training approach that focuses on practice to maximize the initial knowledge that teachers already possess. The study indicates that additional support in the form of practice-based training, technology procurement, and the development of comprehensive implementation guides is essential. This approach will help bridge the gap between theoretical knowledge and practical skills, ensuring that high initial knowledge can be optimized and applied effectively in daily learning, particularly to enhance the quality of learning through gamification in elementary schools.

5 Discussion

The findings of this study offer critical insights into elementary school teachers' perceptions of gamification in science education, particularly highlighting the significant disparities across SES groups. The three SES categories – high, medium, and low – are defined based on school funding levels and neighborhood income data, which serve as reliable indicators of the resources available to teachers and students. School funding levels are determined by factors such as local tax revenues, government grants, and educational policies that allocate resources to schools, directly influencing the quality of infrastructure, learning materials, and access to technology. In parallel, neighborhood income data reflect the socio-economic standing of the communities surrounding the schools, which often correlates with household income levels, parental education, and access to external resources that can enhance student learning, such as tutoring or extracurricular opportunities. These SES indicators provide a nuanced understanding of the disparities in educational resources, highlighting the multifaceted ways in which socio-economic conditions shape both the teaching environment and students' educational experiences. By using these data points, we can more accurately gauge how access to resources, both inside and outside the classroom, influences educational practices, particularly in relation to innovative teaching approaches like gamification.

Quantitative data reveal that teachers in higher SES schools generally perceive gamification more positively,

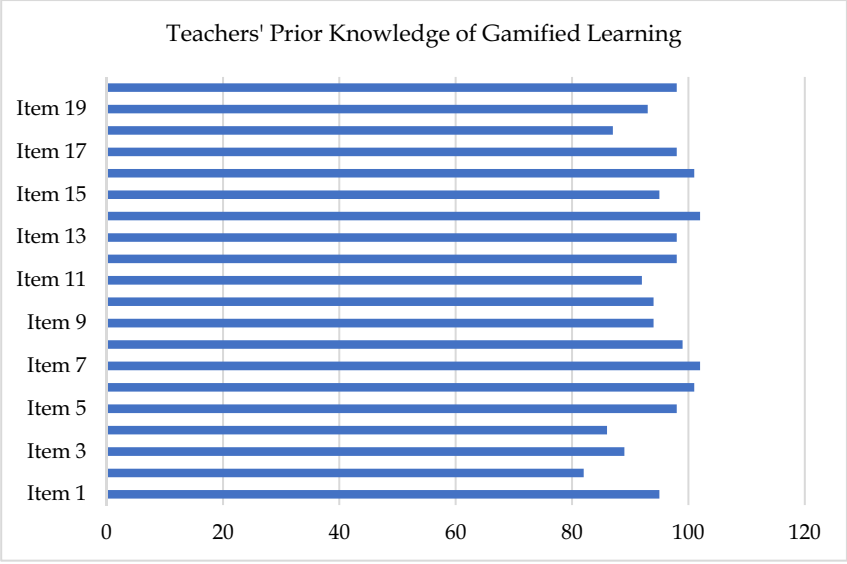

Figure 1: Teacher's prior knowledge of gamified learning.

with a notable average score of 4.4 (SD = 0.5), compared to 3.8 (SD = 0.6) for medium SES and 3.1 (SD = 0.8) for low SES schools. This pattern is consistent with existing research that links SES to perceptions of educational tools and methods, where higher SES is often associated with greater access to resources, including digital technology, and more positive attitudes toward innovative teaching practices. These differences in perceptions reflect not only variations in access to digital technology but also broader systemic inequalities in education. Specifically, 90% of high-SES teachers report access to digital devices, while only 40% of the low-SES teachers have similar resources. This stark technological divide significantly influences how gamification is perceived and implemented in classrooms. It highlights a critical barrier that prevents equitable access to educational innovations, such as gamification, which heavily relies on digital tools and platforms. Moreover, these disparities are also evident in teacher readiness scores, with high-SES teachers reporting an average readiness of 4.3 (SD = 0.4), significantly higher than the low-SES group, which scores 2.9 (SD = 0.7). These findings underscore how SES-related access to resources not only shapes teachers' perceptions but also their confidence and ability to adopt and implement gamification effectively. This aligns with studies which indicate that teachers in higher SES contexts tend to have more professional development opportunities and better access to technology, which boosts their readiness to integrate new teaching methods. Thus, SES disparities in both material and professional resources play a crucial role in shaping the adoption of educational innovations like gamification.

Qualitative data reinforce these quantitative results by providing deeper insights into teachers' attitudes toward gamification. Teachers commonly defined gamification as integrating game elements, such as points, levels, and rewards, to enhance student engagement and motivation. However, interpretations varied: some teachers emphasized gamification's potential to create a fun, dynamic learning environment, while others focused on its more structured elements, like game mechanics. This variation reflects gamification's adaptability across different teaching styles and educational contexts (Kangas, Siklander, Randolph, & Ruokamo, 2017; Ke, 2016; Nousiainen, Kangas, Rikala, & Vesisenaho, 2018), supporting the broader literature on gamification's ability to align with specific pedagogical goals and contextual needs.

In general, teachers expressed positive views on gamification, citing its ability to increase student engagement, foster interactivity, and enhance motivation, particularly in making abstract scientific concepts more accessible. These findings align with previous research, which highlights gamification's potential to make complex topics more engaging for young learners (Duarte & Cruz, 2018; Falah et al., 2021; Mora, Riera, González, & Arnedo-Moreno, 2017). Examples of effective gamification strategies included gamified quizzes, role-playing activities, and challenges that promoted active participation and sustained student interest. However, many teachers argued that gamification should complement, rather than replace, traditional methods of instruction, advocating for a balanced integration of both approaches.

Despite its benefits, technological constraints emerged as a significant barrier to widespread gamification adoption, especially in low-SES schools where digital resources are limited. This issue is indicative of broader systemic inequalities that persist in education, where teachers and students in under-resourced schools face challenges in accessing the necessary tools and professional development to effectively implement technology-driven pedagogies. These findings highlight the urgent need for targeted investments in educational infrastructure, particularly in low-SES schools, and for professional development programs to enhance digital literacy and pedagogical expertise among teachers. Addressing these disparities is essential not only for the successful implementation of gamification but also for fostering greater educational equity.

In addition to SES, other factors such as teaching experience, subject expertise, school location (urban vs rural), school type, and classroom size also play significant roles in shaping teachers' perceptions and readiness to adopt gamification. Future research should examine how these factors interact with SES to influence the adoption and effectiveness of gamification, offering a more nuanced understanding of the barriers and enablers of gamified learning. For instance, exploring how teachers' previous experiences with technology and their attitudes toward innovation contribute to their willingness to experiment with gamification could offer valuable insights into the process of technology adoption in classrooms.

From a methodological perspective, the study's use of both descriptive and inferential statistics provides a robust foundation for understanding trends across SES groups. However, future research could benefit from more advanced analyses, such as factor analysis, to uncover the underlying constructs influencing teachers' perceptions of gamification. Furthermore, graphical data presentation could improve the clarity and interpretability of findings. The study would also benefit from a stronger theoretical framework that more explicitly connects the empirical data to established educational theories, such as constructivism and self-determination theory. For instance, constructivist learning theory, championed by

theorists like Piaget and Vygotsky, emphasizes the importance of active, student-centered learning, where knowledge is constructed through personal experiences and interactions with the environment. This theory provides a robust theoretical basis for understanding how gamification can enhance student engagement and comprehension of scientific concepts. In a gamified learning environment, students actively participate in challenges, problem-solving, and interactive tasks, which aligns with the core principles of constructivism. By incorporating game mechanics, such as levels, rewards, and feedback loops, gamification encourages students to construct their own understanding, engage in meaningful learning, and make connections between theoretical knowledge and real-world application. This active learning process is particularly beneficial for complex subjects like science, where abstract concepts can often be difficult for young learners to grasp.

Similarly, self-determination theory (Deci & Ryan, 1985), which focuses on three core psychological needs, autonomy, competence, and relatedness, offers a valuable lens for understanding how gamification can foster intrinsic motivation in students. According to this theory, when students feel that they have control over their learning (autonomy), believe in their ability to succeed (competence), and feel connected to others in the learning environment (relatedness), they are more likely to be motivated and engaged. Gamification, by design, addresses these needs by providing opportunities for choice (e.g., selecting challenges or learning paths), offering immediate feedback and rewarding progress (competence), and creating collaborative or competitive dynamics that foster social interaction (relatedness). By meeting these psychological needs, gamification can significantly enhance students' intrinsic motivation, leading to deeper engagement, sustained effort, and improved academic outcomes.

By integrating these theories into the analysis, the study can offer deeper insights into how gamification functions as a pedagogical tool that aligns with key principles of learning and motivation. Linking observed patterns of teacher motivation and perceived student engagement to these well-established theories not only strengthens the conceptual framework of the research but also provides a more comprehensive understanding of why gamification may be effective in enhancing student learning, particularly in subjects that require higher levels of abstract thinking and critical reasoning. Furthermore, a theoretical alignment with constructivism and self-determination theory can guide future research in identifying the specific mechanisms through which gamification influences learning outcomes, offering more targeted recommendations for educators seeking to implement this approach in their classrooms.

In conclusion, this study affirms gamification's potential as a transformative pedagogical tool for elementary science education, but its successful implementation depends on addressing resource disparities, particularly those related to SES, and providing adequate support for teachers through professional development and infrastructure improvements. Future research should build on these findings by incorporating a wider range of contextual variables, applying more advanced analytical techniques, and integrating relevant theoretical frameworks to guide the effective implementation of gamification. By doing so, educators can maximize the educational benefits of gamification and ensure a more equitable and engaging learning experience for all students.

6 Conclusion

This research highlights the crucial role of technology, particularly gamification, in enhancing student engagement and learning outcomes in elementary science education. By exploring teachers' perceptions across various socioeconomic backgrounds, the study reveals significant variations in understanding and implementing gamification, driven by factors such as access to technology and technical expertise. The identified challenges ranging from infrastructure limitations to the need for curriculum adaptation underscore the importance of addressing these issues through targeted solutions, including comprehensive training and improved technological resources. Ultimately, the findings aim to inform policy development and training initiatives that can effectively support the integration of gamification as a vital educational innovation, thereby fostering a more engaging and effective learning environment for all students in the digital era.

7 Recommendations

Based on the findings of this study on teachers' perceptions of gamification in elementary science education, several key recommendations can be made to enhance the successful implementation of gamification in the classroom. First, to address the varying levels of understanding and perceptions of gamification, it is crucial to offer continuous, intensive training programs for teachers. These programs should focus on both the theoretical aspects and

practical applications of gamification in science education, helping teachers better integrate these techniques into their teaching strategies, regardless of prior experience. Additionally, the study highlighted infrastructure limitations as a significant challenge, especially in schools from lower socioeconomic areas. Policymakers must invest in upgrading technological infrastructure, ensuring that all schools have access to necessary devices and reliable internet connectivity, thereby providing equal opportunities for all students and teachers to benefit from gamified learning experiences. Another key recommendation is the adaptation of the existing curriculum to seamlessly incorporate gamification.

Educational authorities should work with teachers to revise and adapt the curriculum, providing guidelines, examples, and templates for aligning science content with game-based learning principles. Furthermore, teachers with more experience in gamification should be encouraged to collaborate with their peers by creating a community of practice where they can share best practices, lesson plans, and resources. Peer observation and mentorship programs can also help less experienced teachers. While gamification has the potential to increase student engagement, it is essential to ensure that the games and activities cater to diverse student needs and learning styles. Teachers should be trained to design inclusive, differentiated gamified activities that encourage participation from all students, including those with learning disabilities or different cultural backgrounds. To improve the effectiveness of gamification, schools should establish mechanisms for ongoing assessment and feedback, monitoring both teacher and student progress, and providing constructive feedback on the use of gamified strategies. It is also vital to evaluate the impact of gamification on student learning outcomes, engagement, and motivation. Finally, governments and educational bodies should consider developing policies that promote and support the integration of gamification into education, including funding for technology, teacher training, and curriculum development, as well as guidelines for the ethical use of gamified learning experiences. By addressing these recommendations, schools can foster an environment where gamification in science education is effectively implemented, leading to enhanced student engagement, motivation, and learning outcomes.

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