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Application of Digital Simulation-Based Gamification to Improve Learning Outcomes of Grade IV Students in Natural and Social Sciences Subjects

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Abstract
This study aims to improve the learning outcomes and active participation of fourth-grade students at Kebonsari 2 Public Elementary School in Natural and Social Sciences learning through the implementation of gamification strategies. The background of this research is the low student motivation and learning achievement caused by the predominance of conventional teaching methods that lack appeal and fail to engage students actively. The research employed a classroom action research model based on the spiral framework developed by Kemmis and McTaggart, conducted over two cycles. Data were collected through diagnostic tests, observations, interviews, and documentation, and analyzed quantitatively using descriptive statistics and N-Gain analysis to measure improvement. The intervention included the integration of gamification elements such as buying and selling simulation games for economic activity topics, augmented reality-based media to explore the surrounding environment, and a tiered challenge system in student worksheets to enhance motivation and engagement. The findings revealed an increase in the average score of student learning outcomes from 61.15 in the pre-cycle to 84.81 in the second cycle. The percentage of students achieving mastery learning rose from 30.77 percent to 92.31 percent. The average N-Gain score of 0.66 indicates a moderate to high level of improvement, affirming the effectiveness of gamification strategies. Theoretically, the study supports the application of gamification as a pedagogical approach aligned with the learning preferences of the digital-native generation.

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Introduction

Education in the digital era faces complex challenges in preparing students for the 21st century, where critical thinking skills, collaboration, creativity, and technological literacy are the main demands (OECD, 2019). The UNESCO report (2021) emphasizes that the global education system needs to transform from conventional methods to a more participatory and digital technology-based learning model to respond to the character of Generation Z who are familiar with the digital environment. The results of the latest Programme for International Student Assessment (PISA) study show that Indonesia is still below the OECD average in terms of science literacy and student involvement in the active learning process (OECD, 2019). This condition encourages the importance of innovative learning methods that are adaptive and in accordance with the character of students in the digital era.

In Indonesia, the learning process in elementary schools is generally still dominated by a teacher-centered approach that uses lecture methods without variations in media and activities (Zubaidah, 2016). This method is less effectively applied to generation Z who prefer challenge-based, visualization, and interactive learning activities (Srimulyani, 2023). Based on the results of initial observations at SDN Kebonsari 2 Malang City, data was obtained that the average learning outcome score of grade IVB students in the Natural and Social Sciences (IPAS) subject has only reached 61.15, with learning completeness of only 30.77%, far below the school's Minimum Completeness Criteria (KKM) of 75. In addition, students are less active in the learning process because the IPAS material is abstract and has minimal visualization, making it difficult for students to understand (Darmawiguna et al., 2019). As a result, students tend to be passive recipients of information rather than actively involved in the learning process (Hidayat et al., 2021).

One of the potential learning innovations to answer this problem is the application of gamification strategies. Gamification is a learning strategy that adopts game elements such as points, challenges, badges, leaderboards, and reward systems into teaching and learning activities to increase student motivation, engagement, and learning outcomes (Kapp, 2012). These game elements are proven to be able to create a competitive and fun learning atmosphere, thus encouraging students to actively participate and strive to achieve learning targets. Srimulyani (2023) in his research shows that the application of gamification in learning can significantly increase motivation, active participation, and learning outcomes of elementary school students. Similarly, Pratama and Yuliana (2022) found that Quizizz application-based gamification can improve the learning outcomes of elementary school students, although the research is still limited to digital question media without the integration of contextual activities.

In fact, Kuron and Pakpahan (2023) emphasized that specifically for social studies learning in elementary school, economic activity materials such as trade should be delivered through direct experience-based learning and visualization so that abstract concepts can be easier for students to understand. Therefore, this study combines gamification strategies based on simulation of buying and selling games and augmented reality (AR) media in learning IPAS. Simulations of buying and selling games were chosen because they provide a hands-on experience of the concept of economic activity, while AR media is used to present an interesting and contextual visualization of the environment. The combination of these two media is

believed to be able to create an interactive, meaningful learning atmosphere, while fostering student learning motivation.

Although various studies on the application of gamification in learning have been conducted, there have not been many studies that have specifically examined the implementation of gamification based on contextual simulations and augmented reality in science science learning at the elementary school level. This research gap is important to fill because IPAS is a subject that contains many abstract concepts that require concrete visualization for elementary school students to understand optimally. In addition, the integration of hands-on and digital experience-based game elements is still rarely implemented simultaneously in elementary school settings. Therefore, this study aims to improve learning outcomes and active involvement of grade IV students of SDN Kebonsari 2 Malang City in social studies learning through the application of gamification-based learning strategies.

Practically, this research is expected to contribute to the development of gamification-based learning models that are in accordance with the characteristics of Generation Z in elementary schools. Meanwhile, theoretically, this research is expected to enrich the study of the effectiveness of simulation-based and augmented reality-based gamification strategies in increasing active involvement and student learning outcomes in science science subjects at the elementary school level (Hendri & Feliks, 2021). Thus, the results of this research can be used as a reference for teachers and curriculum developers in designing interactive learning that is adaptive to the challenges of 21st century learning.

Method

This study employed a classroom action research design using the spiral model developed by Stephen Kemmis and Robyn McTaggart, which consists of four interrelated stages: planning, action, observation, and reflection. The research was conducted at Kebonsari 2 Public Elementary School in Malang during the even semester of the 2024/2025 academic year, involving 26 fourth-grade students from class IVB who were selected based on initial evaluations indicating low academic achievement and minimal active participation in Natural and Social Sciences learning, particularly in the topic of Cultural Diversity and Local Wisdom. Data were collected through multiple methods, including learning outcome tests, observations, interviews, and documentation. The learning outcome test comprised multiple-choice and short essay questions validated by two subject matter experts and one learning evaluation expert; the validity was assessed using expert judgment techniques, while reliability was measured using the Kuder-Richardson formula (KR-20) for multiple-choice items and Cronbach's Alpha for descriptive questions. Observations were conducted to document students' engagement using structured observation sheets, while interviews with teachers and selected students were used to explore perceptions and responses toward gamification-based learning. Documentation in the form of photographs, videos, and students' work supported the observational data. The intervention was implemented over two cycles, each consisting of planning, implementation, observation, and reflection phases. During the planning phase, the researchers collaborated with the class teacher to prepare lesson plans, student worksheets, assessment instruments, and gamification media, including trading simulation games and

augmented reality applications. The trading simulation involved role-play with props, play money, and transaction cards, while the augmented reality component utilized school tablets and smartphones to display three-dimensional representations of local cultural elements. In the implementation phase, the teacher facilitated gamified learning, and the researcher observed student engagement, interactions, and reactions to the learning media. The reflection phase involved analysis of data from tests, observations, interviews, and documentation to evaluate the effectiveness of the intervention and make necessary adjustments for the next cycle. Research success was measured by two criteria: at least 85 percent of students achieving a score above the minimum competency standard of 75, and at least 85 percent demonstrating active engagement as indicated by observation results. Learning outcomes were analyzed using percentage-based mastery criteria, and improvement was measured using the N-Gain formula with interpretation categories based on Hake's classification: high ($g > 0.7$), moderate ($0.3 < g \leq 0.7$), and low ($g \leq 0.3$).

Results and Discussion

Results

This Classroom Action Research (PTK) activity begins with the initial observation stage which is carried out through diagnostic assessment, aiming to identify learning needs and understand the characteristics of students directly and thoroughly. This diagnostic assessment serves to analyze the level of abilities, strengths, and weaknesses that students have, so that teachers can design learning interventions that are right on target and in accordance with real conditions in the classroom. Identifying learning problems or difficulties needs to be done accurately before determining the learning strategy to be implemented. In this case, diagnostic tests are used as the primary instrument to detect learning barriers that students may experience, which are analyzed based on the results of previous formative tests. Through this test, teachers can trace the factors that cause the expected lack of achievement of learning outcomes (Septyana et al., 2024).

In addition to relying on diagnostic tests, the study also collected supporting data from interviews and previous recordings of academic grades obtained from classroom teachers. The interviews were conducted to dig deeper into information about learning obstacles and challenges from the teacher's perspective, as well as to understand the social and pedagogical context that affects the learning process in the classroom. Previous score data was analyzed to trace students' academic development historically, so as to provide an overview of their learning achievement patterns. The three types of data, namely diagnostic tests, interviews, and previous academic scores, were used triangulatively to form a complete understanding of students' learning needs, potentials, and problems before gamification-based interventions were carried out. Based on the analysis of the three data sources, it was found that the main problem faced by students in grade IVB of SDN Kebonsari 2 is the low learning outcomes in the subject of Natural and Social Sciences (IPAS). To overcome these problems, this PTK implements a gamification-based learning strategy in science subjects, the results of which are presented in full in Table 1.

Table 1. Learning Outcomes

Cycle	Number of Students	Number of Students Completed	% Completeness	Mean
Pre-cycle	27	7	30.77%	61,15
Cycle 1	27	19	72%	78,08
Cycle 2	27	22	92,31%	84,81

Figure 1. Application of Gamification in Grade 4

Based on the data presented in Table 1, the application of gamification in the learning process has been proven to have a very significant positive impact on improving student learning outcomes. Quantitative data obtained systematically showed a consistent increase in both the average score and the level of learning completeness of students, which can be seen from the initial stage of the pretest to the second cycle of learning using gamification elements. In the pretest stage, before the application of gamification elements in the learning process, the average score of students only reached 61.15, while the overall level of learning completeness was still very low, which was only 30.77%. This condition clearly indicates that the learning methods used previously are still not effective in attracting students' attention or facilitating their understanding optimally. This is a strong signal that the conventional learning approach that is teacher-centered and predominantly one-way, has not been able to answer the needs and characteristics of 21st century students that are very different from the previous generation.

The phenomenon of low motivation and student involvement in learning is in line with various literature that states that traditional learning methods tend to be less relevant in the context of the native digital generation, or better known as generation Z. This generation has unique characteristics, namely learning preferences that are very prominent in visual, interactive, and digital technology-based aspects. They are accustomed to fast stimulation, dynamic content, and learning experiences that involve a variety of interactive media. Therefore, learning methods that rely only on lectures, textbooks, and conventional exercises are not able to meet their cognitive and affective needs to the maximum. Furthermore, learning methods that are completely teacher-centered without the active involvement of students often make students feel bored, unmotivated, and ultimately negatively impact learning outcomes. These findings are reinforced by recent research from Uluum et al. (2025), which explicitly states that traditional learning methods, which lack the use of technology and two-way interactions, are often incompatible with the learning styles of the native digital generation that demand a more dynamic, contextual, and technology-based approach.

Responding to these problems, in the first cycle, the implementation of gamification was carried out through a learning strategy that utilizes Augmented Reality (AR) technology and trading game simulations as innovative learning media. In this strategy, teachers take the role of sellers of learning materials that provide all the needs of students to complete the Student Worksheet (LKPD). This method is designed in such a way that learners play the role of buyers who must actively choose and use the right materials to complete their tasks. As a result, the average score of students increased significantly to 78.08 with the level of learning completeness also rising to 72%. The application of gamification in the form of simulation not only succeeds in attracting the interest of students, but also simultaneously

encourages them to be actively involved both socially and cognitively during the learning process. The concept of role-playing as sellers and buyers in this simulation is very effective in fostering the conceptual understanding of learners through hands-on experience, which is in accordance with the principles of constructivist theory from Vygotsky. The theory of constructivism emphasizes that social interaction is a crucial factor in the formation of knowledge, so learning that involves dialogue, cooperation, and active roles will strengthen the transfer of knowledge and understanding in a more profound way.

In this context, learning is no longer one-way or passive, but rather transforms into a dynamic and fun collaborative experience, where learners can interact, discuss, and learn from each other through simulation. This approach emphasizes relevant and contextual experiential learning, so that material that is considered abstract becomes more concrete and easy to understand. Empirical support for these findings also comes from research conducted by Fitriyana & Indriyani (2024), which shows that the application of gamification with a meaningful game context and integrated with subject matter can significantly improve students' critical thinking skills. The study emphasizes that the use of carefully designed game elements is not only entertainment, but also able to stimulate the ability to actively analyze, evaluate, and solve problems.

Furthermore, in the second cycle, the learning strategy was further developed by adding a tiered approach in the Student Worksheet (LKPD). In this approach, learners must complete each level of learning sequentially and gradually before moving on to the next level. This multi-level approach provides a clear and measurable structure in the learning process, while increasing students' focus and concentration because there are stages that must be completed systematically. In addition, this level system also fosters a healthy competitive spirit and an intrinsic drive to complete the given challenges. Students not only compete with time or classmates, but also compete with themselves to reach the next level, so that the learning motivation that comes from within them is more driven.

Discussion

The results of the implementation of gamification strategies in science science learning in grade IV SDN Kebonsari 2 Malang City showed very encouraging achievements, marked by an increase in the average score of students to 84.81 and the level of learning completeness which jumped significantly to 92.31%. This increase is a clear indicator that gamification methods designed with a multi-level and systematic approach are effective in improving learning outcomes and active participation of students. These findings are in line with the view of Wardani (2023) who states that students' intrinsic motivation will increase when they are faced with challenges that are balanced with their abilities, thereby encouraging active engagement and the desire to continue participating in the learning process. In addition, Srimulyani (2023) also emphasized that the level system in gamification has been proven to increase learning achievement and engagement because it creates a clear learning flow, challenging but realistic goals, and rewards in the form of level achievements that are able to foster students' confidence.

Overall, the results of this study show that gamification designed in a structured, contextual, and tailored to the characteristics of students is able to have a positive impact on learning motivation, active engagement, and learning outcome achievement. The learning that takes place becomes more fun, interactive, and meaningful because students not only act as recipients of information, but also as active subjects who build their own understanding through simulation-based learning experiences and augmented reality. This is in line with the study of

Mulia et al. (2023) which states that gamification developed appropriately can create an interesting, sustainable learning experience, while facilitating effective formative assessments. In the context of formative assessment, gamification allows teachers to monitor students' learning progress in real time, provide immediate feedback, and quickly identify areas that need improvement, so that learning can be dynamically adjusted.

Although the results of this study show a significant positive impact, there are some limitations that need to be observed. One is the lack of long-term measurement to ascertain whether the improvement in learning outcomes and motivation achieved through gamification can be maintained over a certain period of time after the action ends. In addition, the application of gamification in this study was carried out in a school environment that relatively already has supporting facilities such as tablet devices and adequate internet connections. This is a challenge if the same method is applied in schools with limited digital infrastructure. In line with that, Pratama and Yuliana (2022) emphasized that the effectiveness of gamification in learning is greatly influenced by the availability of supporting technology and teachers' readiness to manage digital media.

In addition to infrastructure factors, another challenge in the implementation of gamification in various primary education contexts is related to teachers' digital skills. Not all educators have the technical competence to design and integrate gamification elements such as simulations, level systems, or augmented reality into learning. In fact, as revealed by Hendri and Feliks (2021), the success of the implementation of gamification is not only determined by the availability of technology, but also the ability of teachers to design learning flows that are interesting, challenging, and in accordance with the character of the material and the needs of students. Therefore, special training is needed for teachers to be able to make optimal use of gamification technology.

Thus, the results of this study confirm that gamification is not only a fun alternative learning method, but also a potential pedagogical strategy to answer the increasingly complex educational challenges of the 21st century. These challenges include the need for learning innovations that are able to accommodate various learning styles, provide appropriate learning personalization, and increase student engagement holistically, both cognitively, affectively, and socially. Gamification is one of the effective solutions that is able to integrate elements of technology, motivational psychology, and modern pedagogical approaches in one comprehensive learning strategy. Therefore, the implementation of gamification should be a concern for teachers, curriculum developers, and education policymakers so that the learning process in elementary schools can take place more effectively, relevantly, and in accordance with the character of digital-native students in the era of the industrial revolution 5.0.

Conclusion

The results of this study show that the application of gamification-based learning strategies is significantly effective in improving learning outcomes and active involvement of students in Natural and Social Sciences (IPAS) subjects in grade IV of SDN Kebonsari 2 Malang City. The strategy that integrates buying and selling game simulations, augmented reality media, level systems, and LKPD-based educational challenges is able to create an interesting, participatory, and motivating learning atmosphere for students to be active in the learning

process. There was an increase in the average score of learning outcomes from 61.15 in the pre-cycle to 84.81 in the second cycle, as well as the percentage of learning completeness from 30.77% to 92.31%. In practical terms, these results make an important contribution for primary school teachers in designing gamification-based learning models that are adaptive to the needs of Generation Z and relevant to the educational challenges of the 21st century. Teachers are expected to be able to systematically utilize elements of educational games, contextual simulations, and digital media in the teaching and learning process, while for curriculum developers and education policymakers, this finding is a reference that gamification is feasible as an alternative strategy in improving the quality of learning in elementary schools, so it needs to be supported by teacher training and the provision of adequate digital infrastructure. Academically, this study enriches references on the effectiveness of gamification in learning social studies in elementary schools, which has been minimally researched. For future development, it is recommended to conduct experimental research with the control group to obtain stronger comparative data, as well as test the application of gamification at other levels of education and different subjects to expand its potential use. In addition, follow-up research should clarify the operational definition of gamification elements used and add advanced statistical analysis, such as effect size, to determine the extent of the impact of interventions on learning outcomes more comprehensively.

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Authors' Note

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

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