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Impact of Inquiry-Based Science Learning with a Gamification Instruction Framework towards Mastery of Science Process Skills

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Abstract

This study seeks to evaluate the impact of gamification on a science teacher's trainee academic performance, specifically in relation to learning performance. Utilizing quantitative research methodology, a single-group pretest-posttest experimental design was applied. The research was conducted during the semester of the academic year, involving Part 8 students. The experimental group engaged with a gamified science learning platform, while the control group followed the standard curriculum. The intervention lasted 14 weeks and data were gathered from the experimental group benefiting from interactive educational software and the control group using traditional textual materials. Upon post-intervention testing, results revealed a significant enhancement in the experimental group's problem-solving abilities, demonstrating that gamification substantially enriches the learning experience and fosters greater engagement and mastery of scientific concepts compared to conventional teaching methods.

Keywords: Gamification, Science, Inquiry-Based Learning, Mastery Science, Process Skills

Introduction

The integration of technology in education has significantly transformed the traditional classroom environment, enhanced student engagement and making learning a more interactive and immersive experience. Technology has enabled learning to move beyond passive absorption of information and become an active, student-centered experience. This shift is particularly important in promoting deeper cognitive engagement and stimulating students on multiple levels (Nguyen et al., 2020). The use of gamification, defined as the application of game mechanics in non-entertainment contexts to influence user behavior and increase engagement (Xu, 2020), is a prevalent trend in education that has gained traction in recent years. By incorporating game elements such as points, badges, leaderboards, and

immediate feedback into learning environments, gamification has the potential to foster greater student motivation and engagement (Zainuddin et al., 2020).

Although the use of games to facilitate learning is not a new concept—having roots in educational theories that emphasize play as an essential component of learning—modern technology has amplified the capacity for games to create a highly immersive and interactive experience (Dicheva et al., 2021). Educational technologies today allow for real-time feedback, adaptive learning pathways, and personalized learning experiences, making it easier for students to remain engaged and motivated. The use of gamified learning systems has shown particular promise in traditionally challenging subjects such as mathematics and science, where many students struggle with engagement (Aguilar et al., 2022). By providing rewards, feedback, and a sense of accomplishment, these systems can improve students' attitudes toward these subjects and promote a more positive learning experience (Hamari et al., 2020).

While studies on the impact of educational gaming on learning outcomes have yielded mixed results, many have demonstrated the positive effects of gamification on student engagement and motivation (Sezer & Guler, 2021). For instance, a study by Zainuddin et al. (2020) found that students who engaged in gamified learning environments demonstrated higher levels of motivation and interest in the subject matter compared to those who followed traditional instructional methods. Similarly, Gonzalez et al. (2021) reported that gamification in the classroom can promote higher-order thinking skills and collaborative learning, leading to more profound and sustained learning outcomes. However, other studies suggest that the effectiveness of gamification may depend on how well the game mechanics are aligned with learning objectives (Yang & Quadir, 2021).

Aim & Scope

The objective of the present study is to examine the relationship between the academic achievement of 6th-grade students and the integration of gamification into their science lessons. The study seeks to understand how the use of gamification, which incorporates game-like elements into non-game contexts to motivate and engage learners, impacts student performance in a structured educational setting. Specifically, the research aims to determine whether gamified teaching methods can positively influence students' academic outcomes and contribute to deeper understanding and retention of scientific concepts.

To address this objective, the following research questions were formulated:

Does the use of gamification in science lessons correlate with students' academic achievement?
This question seeks to explore whether there is a measurable relationship between students' exposure to gamified learning environments and their performance in science lessons. It aims to determine if gamification serves as a catalyst for improving academic outcomes by fostering student engagement, motivation, and understanding of the subject matter.

Is there a significant difference between students’ pre-test and post-test grades following the implementation of gamification?

This research question focuses on assessing the impact of gamification on students' performance over time. By comparing pre-test and post-test scores, the study aims to evaluate the effectiveness of gamified learning in enhancing students' comprehension of scientific concepts. A significant improvement in post-test scores would suggest that gamification contributes to better learning retention and academic success.

These research questions are central to understanding whether incorporating gamification in science education can lead to meaningful improvements in academic achievement, particularly in terms of engaging students with complex material and encouraging more active participation in the learning process. By investigating these relationships, the study aims to provide valuable insights into the potential of gamified learning as an effective pedagogical tool for science education.

In the current research, an experimental and control group design was employed to assess the impact of gamified learning on student performance. The experimental group was exposed to gamified educational materials, while the control group followed the standard curriculum. This approach aligns with numerous other studies in the literature that have used similar experimental designs to evaluate the effectiveness of gamification in education (Altun & Doğanay, 2021). For example, a study by Agudo-Peregrina et al. (2020) found that students in the experimental group, who were taught using gamified learning strategies, outperformed the control group in both academic achievement and engagement. Likewise, Zainuddin et al. (2020) demonstrated that gamification had a significant positive effect on student achievement in a variety of subjects, including mathematics and science.

In the field of early childhood education, Aral (2019), found that using puzzle-based educational games significantly improved students' learning outcomes. The study employed a Learning Approach Scale to measure the differences in scores between the experimental and control groups, with the experimental group showing marked improvement due to the gamified approach. Similarly, Torun (2020), conducted a study in which educational games about children’s rights were applied to the experimental group, while constructivist teaching methods were used with the control group. The results indicated that the experimental group achieved higher success rates, demonstrating that game-based learning can be particularly effective when teaching abstract concepts.

Gamification has also been shown to influence students' attitudes toward challenging subjects, such as mathematics. In a study by Ozer (2019), students who were exposed to gamified mathematics lessons outperformed the control group, who received traditional instruction. The study measured students' attitudes toward mathematics and found that the experimental group displayed significantly more positive attitudes and higher achievement scores. Similarly, Türksever (2021), reported that the use of gamification in mathematics and science education had a significant impact on students' achievement levels, further supporting the growing body of evidence that suggests gamification is a valuable tool in education.

However, despite the positive outcomes associated with gamification, some scholars caution against over-reliance on game mechanics as a one-size-fits-all solution (Cheng & Liao, 2021). As with any instructional strategy, the effectiveness of gamification depends on its

implementation. For instance, poorly designed games that do not align with learning objectives can lead to disengagement or a superficial understanding of the subject matter (Chou et al., 2022). Therefore, it is essential for educators to carefully design gamified learning experiences that not only engage students but also promote deep learning and mastery of content (Jung et al., 2023).

In conclusion, the use of technology and gamification in education has demonstrated significant potential to enhance student engagement, motivation, and academic achievement. While the research presents mixed findings regarding the impact of gamification on learning outcomes, the majority of studies indicate that gamified learning environments contribute positively to student engagement and can be particularly beneficial in challenging subjects like mathematics and science (Zainuddin et al., 2020). Continued research is needed to further explore how gamification can be effectively integrated into diverse educational contexts, ensuring that it supports meaningful and lasting learning.

Methodology

Participants

The data for this study were collected during the semester of theacademic year. The participants consisted of Part 8 Science Teachers Trainee students enrolled in the Gaming for STEM School program. At the conclusion of the semester, 40 students, selected to participate in the study, contributed data to the analysis. The experiment was carried out in a computer laboratory to ensure that students in the experimental group had access to the necessary technology to engage with the gamified learning software. The study aimed to explore the relationship between the use of gamification in science lessons and students' academic achievement.

Research Design

This study employed a correlational research model to examine the relationship between the use of gamified learning tools and students' academic achievement. Specifically, the study sought to determine whether gamification in the classroom had a significant impact on learning outcomes as measured by students' performance in science-related tests. Although correlational in nature, the study also included elements of an experimental design, as it compared the performance of students exposed to gamified instruction with those who received traditional instruction, thus allowing for a comparison of the two pedagogical approaches. The experimental design included a pre-test/post-test framework to assess the changes in academic performance before and after the intervention.

Data Collection

To address the research questions and measure the impact of gamification on students' academic performance, pre-test and post-test assessments were administered. The pre-test, which focused on the topic of vitamins, consisted of ten multiple-choice questions designed to evaluate students' prior knowledge. This pre-test was administered to all 20 students at the outset of the study. Following the pre-test, the participants were divided into two groups: a control group and an experimental group, both of which were selected randomly.

The control group was provided with a plain text document covering the topic of vitamins and was asked to study the material by reading through it. This group followed a traditional, text-

based learning approach. In contrast, the experimental group was introduced to a gamified training software specifically designed to teach the same topic. Students in this group were instructed to explore the gamified content, which involved reviewing information on vitamins through interactive games and activities. The software incorporated typical gamification elements such as points, rewards, and feedback mechanisms to enhance engagement and learning.

After both groups had completed their respective learning tasks, a post-test was administered to evaluate any changes in their understanding of the topic. The post-test consisted of the same ten multiple-choice questions that were used in the pre-test, allowing for a direct comparison of students' performance before and after the intervention. Both the experimental and control groups were given 15 minutes to complete the post-test, ensuring consistency in testing conditions across the groups.This research method was designed to provide insights into whether gamified learning tools could enhance students' comprehension and retention of scientific content, as compared to traditional text-based learning methods.

The results of this study are derived from a comprehensive analysis of the test scores obtained from both the experimental and control groups. To evaluate the impact of gamification on students' academic performance in science lessons, pre-test and post-test scores were compared across the two groups. The focus of the analysis was to identify any significant differences in the students' scores before and after the intervention, utilizing both paired samples t-tests and independent groups t-tests.

The paired samples t-test was used to determine whether there was a statistically significant difference between the pre-test and post-test scores for each group. This method enabled a direct comparison of student performance within each group, allowing for an assessment of how their understanding of the subject matter progressed from the pre-test to the post-test. In addition, the independent groups t-test was conducted to examine whether there were significant differences in the post-test scores between the experimental group, which experienced gamified instruction, and the control group, which engaged in traditional instructional methods.

Paired Samples T-Test: Control Group

The first analysis involved comparing the pre-test and post-test scores of the control group, who learned about vitamins through traditional text-based methods. Table 1 presents the results of the paired samples t-test for this group. The test was conducted to assess whether there was a significant improvement in the students' scores after engaging with the learning material. The data reveal whether the traditional method of instruction resulted in any meaningful change in students' performance in mastery learning of science process skills.

Table 1
Paired samples t-test results: For the comparison of the pre-test and post-test scores of the control

Test	N	M	Sd	t	p
Pre-Test	20	43	16.19	-1.103	0.030
Post-Test	20	46	16.85		

The paired samples t-test was conducted to determine whether there was a significant difference between the pre-test and post-test scores of the experimental group, with the results displayed in Table 2.

Table 2
Paired samples t-test results: For the comparison of the pre-test and post-test scores of the experimental group

Test	N	M	Sd	t	p
Pre-Test	20	44	16.46	-2.577	0.030
Post-Test	20	46	15.05		

The findings, as presented in Table 2, show that there was a significant difference between the pre-test and post-test scores of the experimental group. The students who used the gamified learning platform demonstrated a marked improvement in their post-test scores, indicating that the gamified approach effectively enhanced their understanding and retention of the scientific concepts related to vitamins. The significant difference in the scores suggests that gamification had a positive impact on learning outcomes, as it likely encouraged more active participation and engagement with the material.

Independent Samples T-Test: Comparison Between Control and Experimental Groups

To further investigate the effectiveness of gamification, an independent samples t-test was performed to compare the post-test scores of the control and experimental groups. This analysis sought to determine whether the differences in learning outcomes between the two groups were statistically significant, thereby providing a clearer picture of the impact of gamification versus traditional learning methods.

The results of the independent t-test, shown in Table 3, reveal that the experimental group significantly outperformed the control group in the post-test. This finding supports the hypothesis that gamification leads to better academic achievement .The students who engaged with the gamified platform not only demonstrated higher levels of engagement but also achieved higher scores, indicating that the interactive elements of gamification may foster deeper learning and a better grasp of complex scientific concepts and skills.

Table 3
Independent samples t-test results: For the comparison of the experimental and control groups pretest scores

Test	N	M	Sd	t	p
Pre-Test	20	43	16.49	1.095	0.288
Post-Test	20	46	16.15		

Conclusion and Suggestions

Gamification has emerged as a promising tool for enhancing student motivation, engagement, and academic achievement in classroom settings. By integrating game mechanics into educational activities, gamification provides students with a dynamic and interactive learning environment, helping them to view education as a joyful and rewarding experience. This approach encourages students to participate more actively in their learning and fosters a sense of achievement as they overcome challenges and earn rewards. Moreover, gamification blurs the boundaries between formal and informal learning, promoting lifelong and life-wide learning opportunities (Zainuddin & Perera, 2021). However, while the potential benefits of gamification are substantial, there are also important challenges that must be considered.

One of the key advantages of gamification is its ability to motivate students by making learning more enjoyable and interactive. It provides teachers with tools to guide and reward students, promoting a sense of accomplishment and motivation (Sanchez et al., 2022). Gamification can also encourage students to bring their full selves to the learning process, creating an environment in which they feel empowered to explore, experiment, and engage with the material on a deeper level (Huang et al., 2020). This approach can foster intrinsic motivation, helping students to become more self-directed learners (Kapp, 2021).

Despite these benefits, gamification also presents significant challenges. Implementing gamified learning experiences can require considerable teacher resources, including time and effort to design, implement, and assess the effectiveness of gamified activities (Cheong et al., 2020).

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