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EXPERIMENTAL VALIDATION OF THE EFFECTIVENESS OF TEACHING 7TH GRADE PHYSICS IN A GAMIFIED DIGITAL ENVIRONMENT

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ABSTRACT

This article examines the effectiveness of using a gamified digital environment in teaching 7th grade physics. In the modern education system, the integration of digital technologies is aimed not only at improving the quality of education but also at developing students' learning motivation and cognitive activity. In this context, the use of digital platforms based on game elements is considered one of the effective ways to improve the learning process.

Within the framework of the study, a survey was conducted among students, and their interest in physics, experience in using digital platforms, and attitudes toward gamified learning were analyzed. The results showed that most students have insufficient experience with gamified digital environments. At the same time, it was observed that interactive tasks and game elements increase learning interest and promote active participation in lessons.

During the study, an experimental lesson on the topic “Mechanical Work” was organized using the Kahoot and Quizizz platforms. As a result of the lesson, an increase in students' cognitive activity and an improvement in the level of mastering the learning material were observed. In addition, group work and game elements contributed to the development of students' collaboration skills.

In general, it was found that the use of a gamified digital environment in teaching physics contributes to increasing students' interest, enhancing learning activity, and improving the effectiveness of knowledge acquisition.

Keywords: Gamification, Digital Environment, Physics Teaching, Kahoot, Quizizz, Learning Motivation, Cognitive Activity.

1 INTRODUCTION

Teaching 7th-grade physics in a gamified digital environment is one of the scientifically and methodologically grounded approaches aimed at reorganizing traditional methods of structuring educational content through modern digital technologies and game mechanics. At present, the digitalization of the education system has been identified as a strategic priority at the national level. This process is being implemented through the renewal of educational content, the introduction of interactive platforms, and the systematic integration of digital solutions into the learning process.

Regulatory and legal documents place particular emphasis on the importance of introducing digital technologies into education. The development of a digital educational environment and the use of virtual and interactive resources enable students not only to acquire theoretical knowledge but also to develop practical skills. These requirements are particularly relevant to the teaching of complex and abstract subjects such as physics.

A distinctive feature of physics is the theoretical and formalized nature of its concepts. In the 7th grade, students are introduced systematically for the first time to fundamental physical concepts such as motion, speed, mass, density, and force. At this stage, developing students' interest in the subject and maintaining their learning motivation play a decisive role. Traditional teaching methods may, in some cases, reduce students' engagement. Therefore, a digital environment incorporating interactive and game-based elements is considered an alternative approach to improving teaching effectiveness.

Gamification is a technology aimed at enhancing learning motivation by incorporating game mechanics into the educational process, including points, levels, rewards, competitive elements, and feedback. Game elements facilitate the emotional engagement of learners with educational materials and encourage their active participation. Digital platforms make it possible to implement gamification in an expanded interactive format: online tests, simulations, virtual laboratories, quest-based lessons, and interactive tasks are becoming effective tools for knowledge acquisition.

The use of digital simulations and virtual models in physics lessons provides opportunities for the visual explanation of complex concepts. Platforms such as PhET Interactive Simulations, virtual laboratories, Kahoot, Quizlet, and Minecraft Education increase students' interest in the subject and enable the learning process to be organized in an active and engaging format. Teaching in such an environment contributes not only to the development of students' subject-specific knowledge but also to their digital competence, research skills, and critical thinking.

Among the researchers who have systematized the concept of gamification and established its theoretical foundations are S. Deterding, K. Werbach and D. Hunter, and K. Kapp. They describe gamification as the process of using game elements in non-game contexts and identify its key structural components, including points, levels, rewards, leaderboards, and feedback [1–3].

Self-Determination Theory, proposed by R. M. Ryan and E. L. Deci, plays an important role in explaining the motivational foundations of gamification. This theory establishes that intrinsic motivation develops through the satisfaction of three basic psychological needs: autonomy, competence, and relatedness [4]. Subsequent studies have provided experimental evidence that gamification elements can influence learning engagement by satisfying these psychological needs [5].

A number of studies have provided empirical evidence of the effectiveness of gamification in education. A systematic review conducted by Hamari J., Koivisto J., and Sarsa H. indicates that gamification produces positive outcomes in enhancing learning engagement and motivation [6]. Domínguez A. and colleagues identified the impact of gamified learning on academic achievement [7]. Lee J.J. and Hammer J. describe gamification as a pedagogical tool that strengthens learners' engagement in the learning process [8]. Koivisto J. and Hamari J. analyze the mechanisms underlying the effects of gamification from the perspective of motivational information systems [9].

The use of game-based technologies in teaching natural sciences and physics has also been investigated. Papastergiou M. demonstrates that digital game-based learning positively influences students' academic performance and motivation [10]. Papastergiou M., Natsis A., Vernadakis N., Antoniou P., and colleagues provide evidence that the use of game-based technologies in science education improves learning outcomes [11]. Rodríguez G. and Martínez A. substantiate that incorporating gamification elements into physics lessons increases students' interest and academic achievement [12]. Brom C. and colleagues have investigated the influence of digital gaming environments on the acquisition of educational content [13].

Kazakhstani researchers have also examined the potential of gamification in the learning process. Otarbayeva L.L., Utepbergenova G.K., and Mukhanova A.S. analyze approaches to enhancing learning engagement through gamification [14]. Niyazova G.Zh. and Alkhanov S.F. describe the motivational and cognitive effects of gamification models within the education system [15].

Overall, although the scientific literature provides evidence that gamification contributes to increased learning motivation and improved academic outcomes, comprehensive investigations into the effectiveness of teaching 7th-grade physics in a gamified digital environment based on a specially designed pedagogical experiment have not yet been sufficiently systematized. Accordingly, this issue remains relevant from a scientific and pedagogical perspective.

In this regard, experimentally substantiating the effectiveness of teaching 7th-grade physics through the use of a gamified digital environment constitutes a relevant issue in scientific and pedagogical research.

Aim of the Study

To scientifically substantiate and experimentally verify the effectiveness of teaching 7th-grade physics in a gamified digital environment.

Research Questions

Main Research Question

To what extent does teaching 7th-grade physics in a gamified digital environment influence students' academic achievement?

Specific Research Questions

- Which types of gamification elements contribute to increasing students' learning motivation?
- How do lessons conducted in a digital environment affect the quality of students' acquisition of learning material?
- Are there statistically significant differences between the outcomes of gamified learning and those of traditional teaching methods?

Research Objectives

- To analyze the theoretical foundations of teaching 7th-grade physics in a gamified digital environment.
- To determine the content and organizational structure of the gamified digital environment.
- To conduct a pedagogical experiment using a gamified digital environment.
- To determine the impact of gamified learning on students' academic achievement through a comprehensive analysis of the experimental results.

Research Hypothesis

If a gamified digital environment is systematically implemented in the teaching of 7th-grade physics on a sound scientific basis, students' academic achievement will improve in both qualitative and quantitative terms, and their sustained intrinsic motivation to learn physics will develop. This is because an interactive digital environment based on game mechanics stimulates cognitive engagement and enables students to develop a deeper and more conscious understanding of the learning material.

2 MATERIAL AND METHODS

2.1 Research Methods

Pedagogical and scientific-methodological research methods were employed to determine the effectiveness of using a gamified digital environment in teaching physics to 7th-grade students.

First, a review of scientific and methodological literature was conducted to identify issues related to the use of digital and gamified resources in teaching physics topics. The bibliographic sources included articles published in international and national scientific journals, as well as pedagogical research studies. The following keywords were used in the search: "gamification," "digital educational resources," "physics teaching," "interactive platforms," and "7th-grade physics." The abstracts and content of the selected publications were analyzed, and the pedagogical potential of using a gamified digital environment in physics lessons was examined.

During the practical stage, a methodology for using a gamified digital environment in physics lessons for 7th-grade students was developed and implemented through a pedagogical experiment. The experiment was conducted with the participation of 7th-grade students at a general education school.

During the study, a pre-intervention questionnaire (pre-survey) was administered to determine students' initial level of knowledge and their attitudes toward the gamified digital environment. During the experimental teaching stage, game elements, interactive tasks, and tests available on the digital platform were used to explain physics topics.

Table 1: Pre-Intervention Questionnaire for Assessing Students' Attitudes toward Physics and Gamified Digital Learning.

No.	Question	Response options
1	How interested are you in physics?	1 – Not interested at all; 2 – Moderately interested; 3 – Interested
2	How well do you understand physics topics (mechanics, heat, electricity, etc.)?	1 – Do not understand at all; 2 – Understand to some extent; 3 – Understand well
3	Have you previously used digital or gaming platforms in physics lessons?	1 – Used Kahoot; 2 – Used Quizizz; 3 – Used PhET; 4 – Have never used any
4	Have you heard of or used a gamified digital environment?	1 – Have not heard of it; 2 – Have heard of it but have not used it; 3 – Have used it once; 4 – Use it frequently
5	How effective do you think the use of game elements and interactive tasks is in physics lessons?	1 – Not effective at all; 2 – Moderately effective; 3 – Effective
6	Are there any topics that you find difficult during lessons?	1 – Mechanics; 2 – Electrical circuits; 3 – Heat and energy; 4 – No difficulties
7	Do you think that interactive tasks and game elements help you understand topics during lessons?	1 – Yes; 2 – No; 3 – Not sure
8	Do group games and competitions in physics lessons increase your interest in the subject?	1 – Do not increase my interest at all; 2 – Increase my interest moderately; 3 – Increase my interest
9	Do you consider yourself an active learner when digital platforms are used?	1 – Not active at all; 2 – Moderately active; 3 – Active
10	Does a gamified digital environment increase your motivation to participate in lessons?	1 – Does not increase my motivation at all; 2 – Increases my motivation moderately; 3 – Increases my motivation

During the study, a preliminary survey was conducted to determine the effectiveness of using a gamified digital environment in teaching physics to 7th-grade students. The survey was administered via Google Forms and involved 22 7th-grade students.

The survey questions were designed to identify students' level of interest in physics, their patterns of learning and understanding educational content, their experience with digital platforms, and their attitudes toward gamified teaching methods. In addition, information was collected regarding students' classroom engagement, learning motivation, and the topics they found difficult.

The survey results made it possible to assess students' level of understanding of physics, establish the need for using a gamified digital environment, and facilitate the effective organization of the pedagogical experiment.

The question "How interested are you in physics?" was used to determine students' level of interest in the subject. The results are presented in Figure 1. According to the results, 59.1% of the students reported being interested in physics, while 36.4% indicated a moderate level of interest. In addition, 4.5% of the students reported having no interest in physics.

These findings indicate that most 7th-grade students have a positive attitude toward physics. However, the relatively high proportion of students who reported only a moderate level of interest highlights the need to introduce additional motivational approaches to physics teaching.

In this regard, the use of a gamified digital environment may help increase students' interest in the subject and enhance their learning engagement.

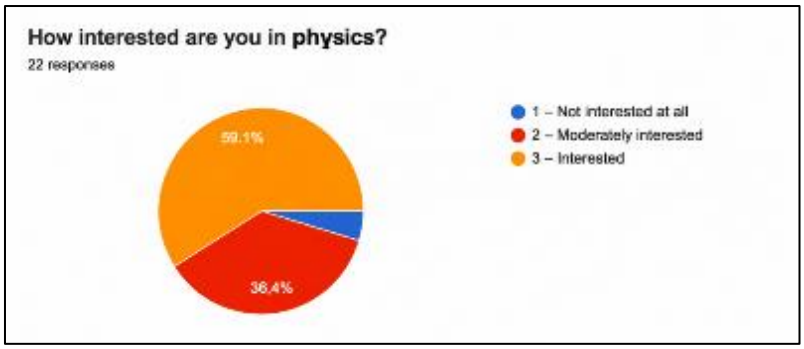


Figure 1: Level of Interest in Physics among 7th-Grade Students

The question "How well do you understand physics topics (mechanics, heat, electricity, etc.)?" was used to assess students' level of understanding of physics content.According to the survey results, 50% of the students reported that they understood physics topics well. Meanwhile, 45.5% indicated that they understood the topics at a moderate level. In addition, 4.5% of the students reported experiencing difficulties in understanding physics topics.

The results indicate that the majority of students do not experience significant difficulties in learning physics topics. However, given the relatively high proportion of students who understand the material only at a moderate level, the need to incorporate additional teaching methods and innovative technologies into the learning process becomes evident.

In this regard, the use of a gamified digital environment can facilitate the visual explanation of complex physical concepts, enhance students' cognitive engagement, and promote more effective acquisition of learning material. These findings highlight the relevance of introducing a gamified digital environment and its importance in improving the quality of teaching.

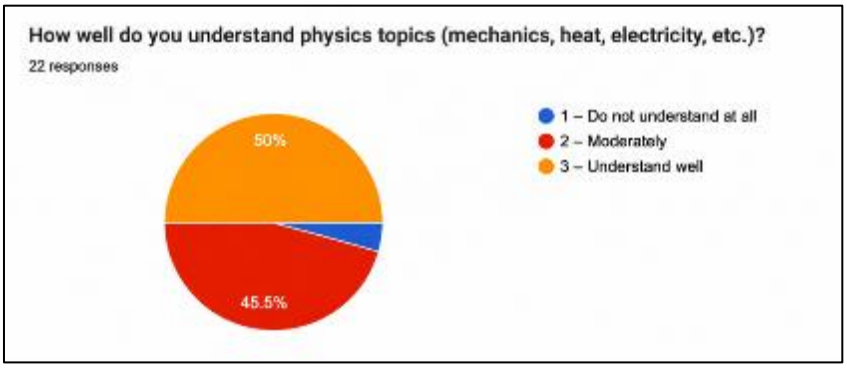


Figure 2: Students' Level of Understanding of Physics Topics

The question "Have you previously used digital or gaming platforms in physics lessons?" was designed to identify students' experience with gamified digital resources.

According to the survey results, 59.1% (13 students) reported that they had never used digital or gaming platforms in physics lessons. This finding indicates that gamified teaching methods are not sufficiently implemented in school practice.

Meanwhile, 31.8% (7 students) reported having used the Quizizz platform. In addition, 18.2% (4 students) indicated that they had used the PhET virtual laboratory, while 9.1% (2 students) had used the Kahoot platform.

These results indicate that most students have limited experience working with gamified digital platforms. At the same time, the fact that some students have used Quizizz and PhET suggests that digital learning tools are already familiar to certain learners.

The findings highlight the need for the systematic implementation of a gamified digital environment in teaching 7th-grade physics. Such platforms can increase students' interest in the subject and facilitate more effective acquisition of learning material.

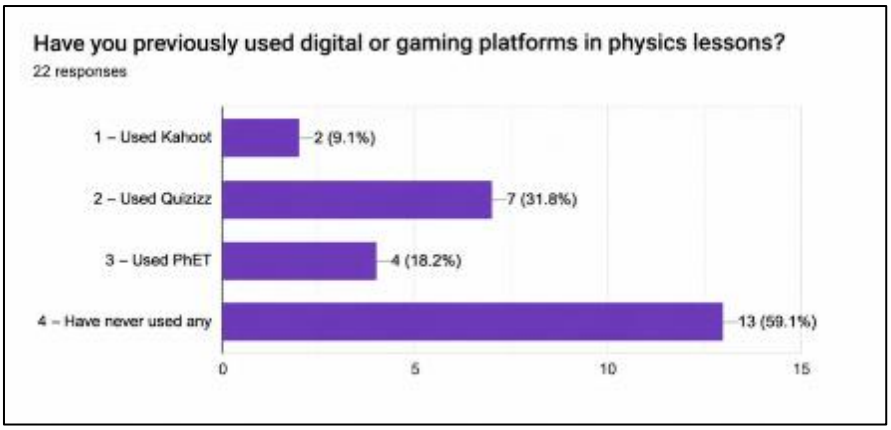


Figure 3: Students' Experience with Using Digital Platforms in Physics Lessons

The question "Have you heard of or used a gamified digital environment?" was designed to determine students' level of awareness of gamified digital environments.

According to the survey results, the majority of students, namely 90.9% (20 students), reported that they had never heard of a gamified digital environment. This finding indicates that gamified teaching methods are unfamiliar to most students.

Meanwhile, 4.5% (1 student) reported having heard of a gamified digital environment but had never used it. Another 4.5% (1 student) indicated that they had used this approach once. No students selected the option "Use it frequently."

The findings indicate that gamified digital environments are not sufficiently implemented in school practice. Furthermore, these results highlight the relevance of introducing a gamified digital environment as part of the present study.

Accordingly, using a gamified digital environment in physics teaching would represent a new learning experience for students and could provide opportunities to increase their interest in the subject.

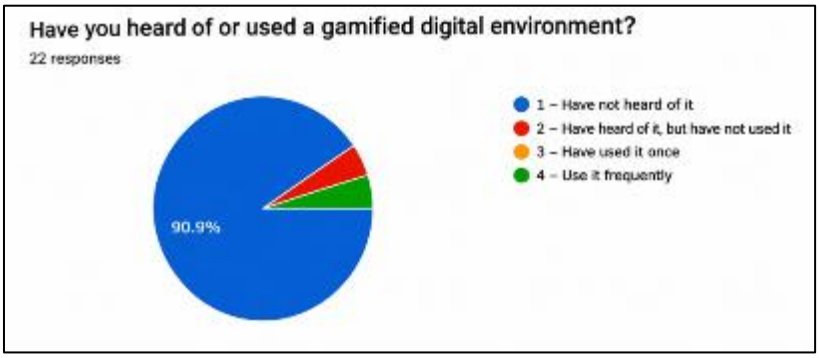


Figure 4: Level of Awareness of Gamified Digital Environments

The question "How effective do you think the use of game elements and interactive tasks is in physics lessons?" was designed to assess students' perceptions of the effectiveness of these teaching methods.

According to the survey results, 54.5% (12 students) considered game elements and interactive tasks effective. Meanwhile, 45.5% (10 students) rated these methods as moderately effective. No students selected the response "Not effective at all."

The findings indicate that the majority of students have a positive attitude toward gamified learning elements. These results suggest that game elements and interactive tasks can contribute to increasing students' interest in the subject and enhancing their learning engagement.

However, since some students rated these methods as only moderately effective, the need to implement a gamified digital environment systematically and appropriately becomes evident.

Overall, the results indicate that incorporating game elements and interactive tasks into physics lessons can improve teaching effectiveness.

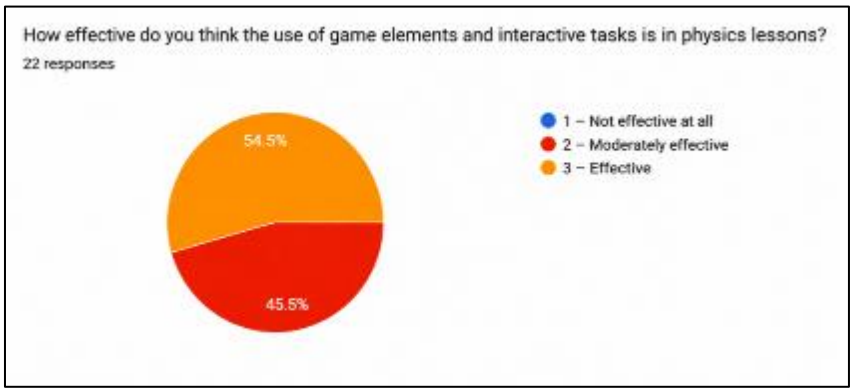


Figure 5: Effectiveness of Game Elements in Physics Lessons

The question "Are there any topics that you find difficult during lessons?" was used to identify the areas of physics that students find challenging.

According to the survey results, 54.5% (12 students) reported that they did not experience any particular difficulties in physics. This indicates that, overall, these students have a satisfactory level of understanding of physics topics.

Meanwhile, 22.7% (5 students) indicated that they experienced difficulties with mechanics. Another 22.7% (5 students) reported difficulties in understanding topics related to heat and energy. In addition, 9.1% (2 students) identified electrical circuits as a challenging topic.

The results indicate that mechanics and thermal phenomena are challenging areas for some students. Since these topics often involve abstract concepts and problem-solving tasks, students may experience difficulties in understanding them.

In this regard, the use of a gamified digital environment provides opportunities to explain challenging topics through visual models, interactive tasks, and virtual experiments. This can facilitate students' acquisition of learning material and contribute to improving the quality of their knowledge in physics.

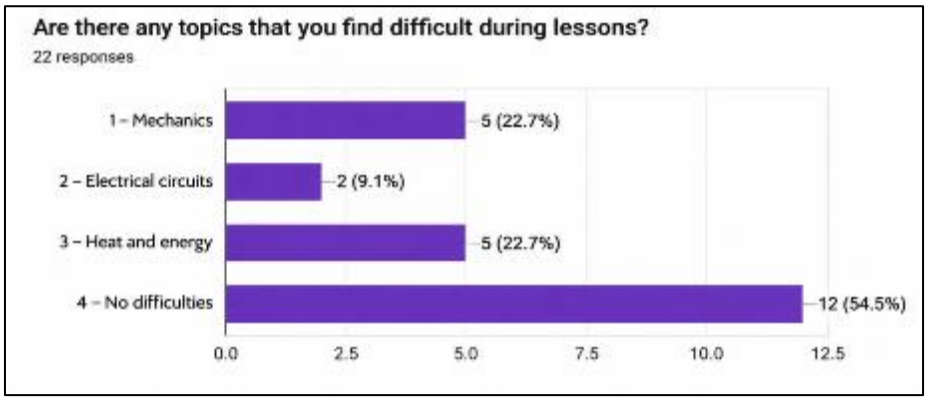


Figure 6: Topics in Physics That Students Find Difficult

The question "Do you think that interactive tasks and game elements help you understand topics during lessons?" was designed to identify students' perceptions of the impact of gamified teaching methods on their understanding of learning material.

According to the survey results, 68.2% (15 students) believed that interactive tasks and game elements help them understand topics. Meanwhile, 31.8% (7 students) expressed uncertainty and selected the response "Not sure." No students selected the response "No."

The findings indicate that the majority of students recognize the positive impact of gamified tasks on their understanding of learning material. This suggests that interactive tasks and game elements can enhance students' cognitive engagement and facilitate the acquisition of complex physical concepts.

However, since a certain proportion of students expressed uncertainty about the effectiveness of this approach, there is a need to increase their interest and confidence through the systematic use of a gamified digital environment.

Overall, the results indicate that using a gamified digital environment can contribute to improving students' understanding of physics topics.

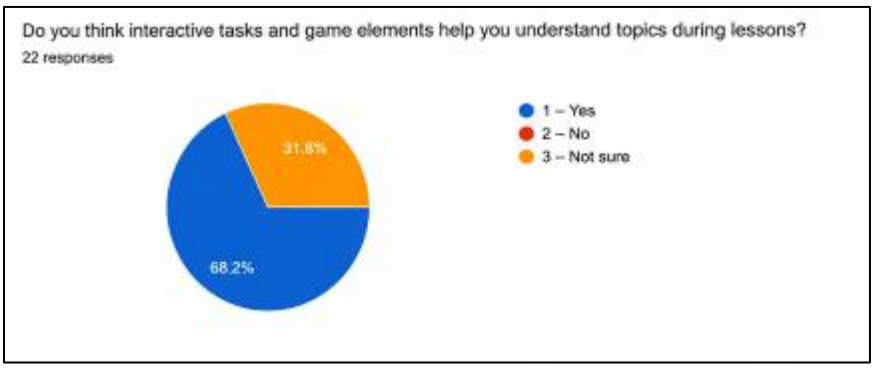


Figure 7: The Impact of Interactive Tasks on Topic Comprehension

The question "Do group games and competitions in physics lessons increase your interest?" was designed to identify students' attitudes toward group games and competitive activities.

According to the survey results, 63.6% (14 students) reported that group games and competitions increased their interest. In addition, 9.1% (2 students) indicated that their interest increased significantly. Meanwhile, 27.3% (6 students) stated that these activities had a moderate effect on their interest. No students selected the option "Do not increase my interest at all."

The findings indicate that the majority of students have a positive attitude toward group games and competitions. This suggests that gamified learning elements can contribute to increasing student engagement, developing collaborative skills, and enhancing learning motivation.

Overall, the results demonstrate that incorporating group games and competitive activities into physics lessons plays an important role in increasing students' interest in the subject.

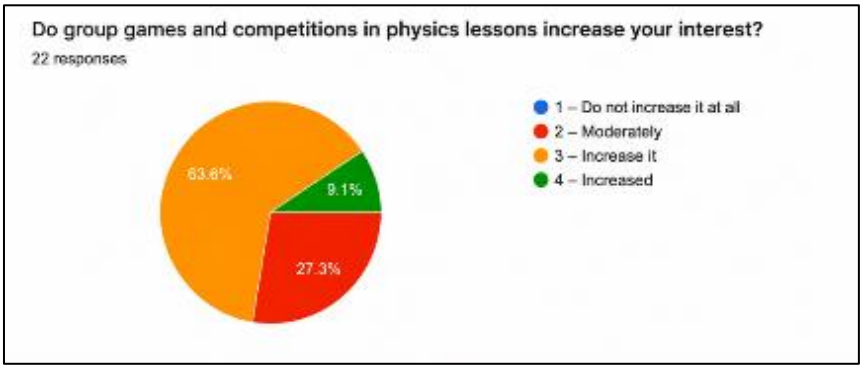


Figure 8: The Impact of Group Games and Competitions on Students' Interest

The question "Do you consider yourself an active student when using digital platforms?" was designed to assess students' learning engagement in a digital environment.

According to the survey results, 54.5% (12 students) reported that they considered themselves active learners when using digital platforms. Meanwhile, 45.5% (10 students) rated their level of engagement as moderate. No students selected the response "Not active at all."

The findings indicate that the majority of students demonstrate active engagement when using digital platforms. This suggests that digital learning tools can increase students' participation in lessons and encourage more active involvement in the learning process.

However, since a proportion of students rated their engagement as moderate, there is a need to further enhance learning motivation through the use of a gamified digital environment. Overall, the results indicate that digital platforms can serve as an effective tool for increasing students' learning engagement.

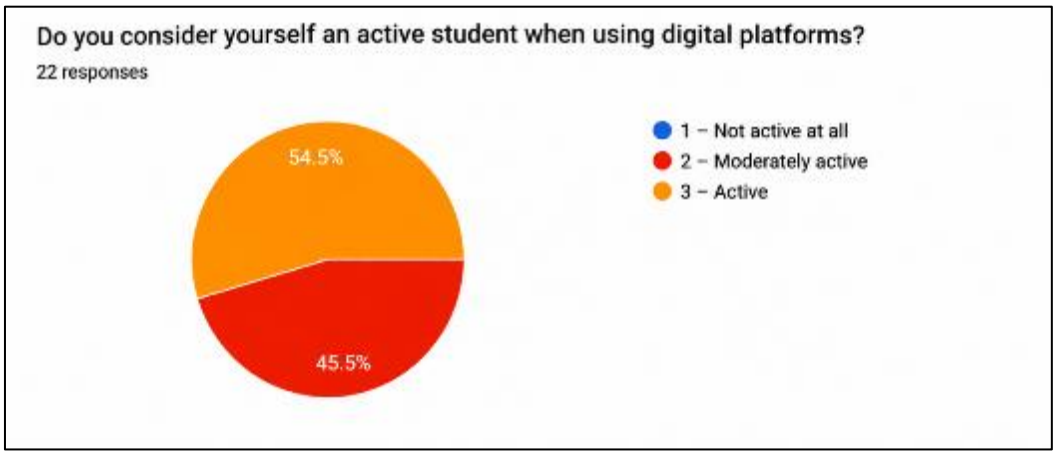


Figure 9: Students' Engagement Levels When Using Digital Platforms

The question "Does a gamified digital environment increase your motivation to participate in lessons?" was designed to assess students' motivation toward gamified learning.

According to the survey results, 50% (11 students) reported that a gamified digital environment increased their motivation to participate in lessons. In addition, 9.1% (2 students) indicated that their motivation increased significantly. Meanwhile, 40.9% (9 students) stated that this approach had a moderate effect on their motivation. No students selected the option "Does not increase my motivation at all."

The findings indicate that the majority of students have a positive attitude toward a gamified digital environment. This suggests that gamification elements can increase students' interest in lessons and encourage their active participation in the learning process.

However, since a proportion of students rated the effect of this approach as moderate, it is necessary to organize gamified tasks effectively and integrate them appropriately into lesson content.

Overall, the results indicate that using a gamified digital environment can enhance students' motivation and increase their engagement in Grade 7 physics lessons.

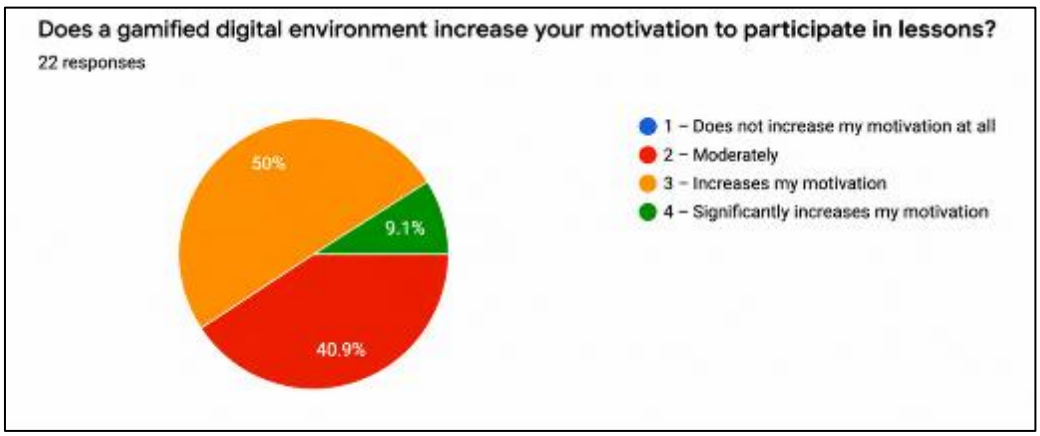


Figure 10: The Impact of a Gamified Digital Environment on Motivation to Participate in Lessons

3 RESULTS

The survey results revealed that the majority of students were interested in physics and demonstrated a moderate to good understanding of the learning material. However, most students had not previously used digital and game-based platforms and were unfamiliar with gamified digital learning environments.

Specifically, 59.1% of students had not used digital platforms, while 90.9% were unfamiliar with gamified digital environments. These findings indicate that gamified digital learning environments are not yet widely implemented in school practice. Therefore, introducing such an environment represents a new and potentially effective teaching approach for students.

An analysis of topics that students found challenging showed that 22.7% experienced difficulties with mechanics, 22.7% with heat and energy, and 9.1% with electrical circuits. These findings highlight the need to incorporate digital and interactive tools into the teaching of these topics.

Furthermore, 63.6% of students reported that group games and competitions increased their interest, while 50% indicated that a gamified digital environment increased their motivation to participate in lessons. The students' responses suggest that interactive tasks and game elements can facilitate understanding of physics concepts and increase interest in lessons.

Overall, the survey results indicate that using a gamified digital environment can increase Grade 7 students' interest in physics, enhance their learning engagement, and support more effective acquisition of learning material. These findings establish the need to investigate the effectiveness of a gamified digital environment through an experimental study.

Experimental Stage of the Study

As part of the study, an experimental lesson on the topic of "Mechanical Work" was conducted with students in Grade 7 "A" to evaluate the effectiveness of using a gamified digital environment. The main objectives of the lesson were to enhance students' cognitive engagement, promote a deeper understanding of physical concepts, and increase their interest in learning. To achieve these objectives, digital platforms incorporating gamification elements were used during the lesson. Specifically, Kahoot was used to review previously covered material, while Quizizz was employed at the end of the lesson to consolidate learning and assess students' understanding. Each stage of the lesson was designed to connect theoretical knowledge with practical tasks and ensure students' active participation.

3.1 Theoretical Background

Mechanical work is a physical quantity that describes the work performed when a force causes an object to move. The amount of mechanical work depends on the magnitude of the force and the displacement of the object.

$$A = F \cdot s \cdot \cos \alpha \quad (1)$$

where:

A – work (J);
F – force (N);
s – displacement (m);
α – the angle between the directions of the force and displacement.

When the force and displacement are in the same direction, the formula can be expressed as follows:

$$A = F \cdot s \quad (2)$$

Mechanical work is widely encountered in everyday life. For example, lifting a load, pushing a cart, and moving an object over a certain distance are all examples of mechanical work.

Objective: To help students understand the concept of mechanical work through gamified digital platforms and enhance their learning engagement.

3.2 Experiments and Tasks

During the lesson, students completed the following tasks:

Determining the work done by forces of different magnitudes;

Solving problems using the formula for mechanical work;
Providing examples of mechanical work in everyday life;
Comparing results through group activities;
Assessing their knowledge through test questions.

For example, if a force of 10 N acts on an object and the object moves a distance of 5 m, the work done is calculated as follows:

$A = F \cdot s$

$A = 10 \cdot 5 = 50$ J

Through this problem, students determined that mechanical work depends on the force applied and the displacement of the object.

At the end of the lesson, students were also given a set of test questions through the Quizizz platform.

Task 1. Test Questions

Question 1. When is mechanical work performed?

- When no force acts on an object
- When a force acts on an object and it undergoes displacement
- When only velocity acts on an object
- When an object remains at rest

Correct answer: B

Question 2. What is the formula for mechanical work?

- A = mg
- A = Fs
- A = st
- A = Nt

Correct answer: B

Question 3. What is the SI unit of work?

- Newton
- Watt
- Joule
- Pascal

Correct answer: C

Question 4. What does one joule represent?

- The work done by a force of 1 N over a distance of 1 m in the direction of the force
- The mass of an object weighing 1 kg
- A time interval of 1 second
- A velocity of 1 m/s

Correct answer: A

Question 5. What is power?

- The velocity of an object
- The work done per unit of time
- The magnitude of a force
- The mass of an object

Correct answer: B

Question 6. What is the formula for power?

- N = Fs
- N = A/t
- N = mg
- N = st

Correct answer: B

Question 7. What is the SI unit of power?

- Joule
- Newton
- Watt
- Metre

Correct answer: C

Question 8. If an object performs the same amount of work in less time:

- Its power decreases
- Its power remains unchanged
- Its power increases
- The work disappears

Correct answer: C

Question 9. In which case is more work performed, assuming the force and displacement are in the same direction?

- A small force acts over a short distance
- A large force acts over a long distance
- No force acts
- The object does not move

Correct answer: B

Question 10. What quantities are needed to calculate power?

- Force and mass
- Work and time
- Velocity and distance
- Mass and time

Correct answer: B

Note: The correct formula for power is N = A/t, where A is the work performed and t is the time taken. This notation is used to ensure scientific accuracy.

The test tasks provided an opportunity to assess the extent to which students had mastered the topic. In addition, interactive quizzes increased students' interest and encouraged their active participation in lessons.

3.3 Data Analysis and Summary

At the introductory stage of the lesson, interactive tasks designed to review the previously studied topic were presented using the Kahoot platform. By answering game-based questions, students had the opportunity to assess their knowledge quickly. The inclusion of competitive elements increased students' interest and encouraged their active participation in the lesson. Furthermore, the immediate display of task results made it possible to assess students' knowledge levels and organize the learning process more effectively.

During the explanation of the new topic, the physical meaning of the concept of "Mechanical Work" was examined, and its formula and units of measurement were analyzed. Students provided examples of the application of mechanical work in everyday life and connected their theoretical knowledge with practical applications by solving simple problems. In addition, question-and-answer activities, pair work, and group work were incorporated into the lesson, thereby enhancing students' interaction and cognitive engagement.

During the concluding stage of the lesson, interactive tasks were organized using the Quizizz platform. While completing the assigned tasks, students consolidated their knowledge of "Mechanical Work" and had the opportunity to evaluate their own performance. The platform's ranking system and game elements increased students' interest and strengthened their motivation to complete the tasks. Furthermore, the interactive format made it possible to determine students' level of understanding and analyze the mistakes they had made.

Throughout the lesson, students' activity levels, interest in completing tasks, and participation in feedback activities were monitored. The results indicated that the majority of students actively participated in the gamified tasks and effectively mastered the topic of mechanical work. In addition, students demonstrated collaborative skills during group work and were able to express their ideas freely.

The research findings demonstrated that the use of digital gamification elements increased students' learning engagement and facilitated their understanding of physical concepts. Moreover, the digital environment enhanced students' interest in the subject and had a positive impact on their active participation in the learning process.

Thus, the use of the Kahoot and Quizizz platforms in teaching the topic of "Mechanical Work" to Grade 7 "A" students improved lesson effectiveness and contributed to increased learning motivation and cognitive engagement. The proposed methodology demonstrated the effectiveness of using a gamified digital environment in physics lessons and confirmed that it is one of the effective approaches to innovative organization of the learning process.

3.4 Mathematical Statistical Analysis

The Pearson chi-square (χ^2) test was used to determine the statistical significance of differences in learning outcomes between the experimental group (Grade 7A) and the control group (Grade 7B).

1. Observed Frequencies (O)

Table 2: Observed Frequencies of Students' Academic Achievement Levels in the Experimental and Control Groups

Group	High	Medium	Low	Total
Grade 7A (EG)	11	8	3	22
Grade 7B (CG)	6	10	6	22
Total	17	18	9	44

3.5 Calculation of Expected Frequencies (E)

Expected frequencies are determined using the following formula:

$$E_{ij} = (\text{Row Total} \times \text{Column Total}) / N$$

High level: E = (22 × 17) / 44 = 8.5
Medium level: E = (22 × 18) / 44 = 9
Low level: E = (22 × 9) / 44 = 4.5

Table 3: Expected Frequencies of Students' Academic Achievement Levels in the Experimental and Control Groups

Group	High	Medium	Low
Grade 7A (EG)	8.5	9	4.5
Grade 7B (CG)	8.5	9	4.5

3.6 Calculation of the Chi-Square (χ^2) Statistic

Formula:

$\chi^2 = \Sigma_{i=1}^{r} \Sigma_{j=1}^{c} (O_{ij} - E_{ij})^2 / E_{ij}$

Calculations for Grade 7A (EG):

High level: $(11 - 8.5)^2 / 8.5 = 6.25 / 8.5 = 0.735$

Medium level: $(8 - 9)^2 / 9 = 1 / 9 = 0.111$

Low level: $(3 - 4.5)^2 / 4.5 = 2.25 / 4.5 = 0.500$

Calculations for Grade 7B (CG):

High level: $(6 - 8.5)^2 / 8.5 = 0.735$

Medium level: $(10 - 9)^2 / 9 = 0.111$

Low level: $(6 - 4.5)^2 / 4.5 = 0.500$

Summary of Calculations

Table 4: Summary of Chi-Square Test Calculations for the Experimental and Control Groups

Group	Observed frequency (O)	Expected frequency (E)	$(O-E)^2/E$
Grade 7A — High	11	8.5	0.735
Grade 7A — Medium	8	9	0.111
Grade 7A — Low	3	4.5	0.500
Grade 7B — High	6	8.5	0.735
Grade 7B — Medium	10	9	0.111
Grade 7B — Low	6	4.5	0.500

$\chi^2 = 0.735 + 0.111 + 0.500 + 0.735 + 0.111 + 0.500 = 2.692$

Degrees of Freedom

$f = (r - 1)(c - 1) = (2 - 1)(3 - 1) = 2$

Critical Value

Significance level: $p = 0.05$

χ^2critical = 5.99

Comparison

2.69 < 5.99

When comparing the results of the experimental and control groups, the calculated χ^2 value was lower than the critical value. This indicates that the observed difference was not statistically significant at the $p > 0.05$ level.

Nevertheless, the increase in the number of students achieving a high performance level in the experimental group suggests a positive effect of using gamified digital technologies.

Statistical note: Since the calculated chi-square value is below the critical value, the results do not establish a statistically significant difference between the groups. Therefore, the positive effect of gamification should be interpreted as a descriptive trend rather than a statistically confirmed effect.

4 CONCLUSION

The conducted study enabled a comprehensive analysis of the effectiveness of teaching 7th-grade physics through the use of a gamified digital environment. Theoretical analysis and the results of the practical experiment demonstrated that gamification elements have a positive influence on the learning process.

The survey results obtained during the study revealed that the majority of students were interested in physics; however, their experience in using digital and game-based platforms was limited. In addition, most students indicated that a gamified digital environment increased their learning motivation and facilitated the acquisition of educational material.

During the experimental stage, lessons organized using the Kahoot and Quizizz platforms increased students' cognitive engagement and encouraged their active participation in the learning process. Interactive tasks and game elements strengthened students' interest in the subject and enabled them to connect theoretical knowledge with practical applications.

The mathematical statistical analysis revealed differences between the results of the experimental group (Grade 7A) and the control group (Grade 7B). However, according to Pearson's chi-square test, these differences were not statistically significant ($\chi^2 = 2.69 < \chi^2 crit = 5.99$, $p > 0.05$). Nevertheless, the increase in the number of students achieving a high performance level in the experimental group indicates a positive pedagogical effect of the gamified digital environment.

Thus, the use of a gamified digital environment in physics lessons was shown to be a promising pedagogical tool for increasing students' learning engagement, strengthening their interest in the subject, and facilitating effective mastery of educational material.

The research findings highlight the importance of systematically integrating gamified teaching methods into the educational process and substantiate the need for their wider application in school practice.

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