The Pedagogical Effectiveness of Integrating Gamification and AI Tools in Teaching Physics

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The European Conference on Education 2026
Official Conference Proceedings

Abstract

The study is aimed at evaluating the impact of the integration of gamification elements and artificial intelligence tools into the teaching process of the secondary school physics course on students' learning motivation, cognitive engagement, and the quality of mastering the learning material. The main hypothesis of the study is that the systematic use of gamification and AI tools in the educational process contributes to increasing students' interest in the subject and improving their learning outcomes.The research work is based on a quantitative methodology, and the descriptive and cross-sectional research design made it possible to analyze the views and experiences of the research participants within a certain period of time. The obtained results were processed using the Jamovi statistical program and analyzed using a t-test. Along with scientific works published in the last five years, publications from reputable academic databases such as ScienceDirect, Scopus, Web of Science, SpringerLink, and JSTOR were also analyzed. The study describes the scientific and theoretical foundations of gamification technology and analyzes foreign and domestic educational platforms. The work proposes a methodology for creating a digital environment based on gamification technology for teaching physics. The results of the conducted pedagogical research have practical value in creating an innovative educational environment aimed at introducing new teaching methods into the learning process.

Keywords: gamification, digital learning environment, game-based learning, motivation, science education

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Introduction

The education sector needs renewal, and countries aspiring to become global economic leaders must begin by building a forward-looking education system. According to the Concept for the Development of Education and Science of the Republic of Kazakhstan for 2023–2029: "The use of digital technologies and artificial intelligence will primarily aim to improve the quality of content, enable personalized learning and assessment tailored to the needs of each student, teacher, and institution, and enhance the educational process" (Government of the Republic of Kazakhstan, 2023).

The ongoing digital transformation in education brings both advantages and challenges. The integration of technology into the sector requires not only technical readiness but also a reconsideration of pedagogical approaches and strategies.

Today, the rapid development and widespread adoption of digital technologies have compelled educational institutions to adapt their teaching methods accordingly. Examples of such adaptation include the use of cloud services, online educational resources, and videoconferencing in the learning process. A core requirement in education is to update learning content while applying effective teaching methods and enhancing their efficiency.

Previous studies have noted that teaching scientific concepts – particularly in science subjects – presents considerable challenges for younger students (Bilal & Erol, 2010). In many countries, including Kazakhstan, science education in general secondary schools relies on traditional textbooks and research materials, which do little to spark students' interest. Although traditional textbooks combine text with visual materials, they often depict static events, and certain scientific concepts cannot be effectively visualized without movement.

For a 7th-grade student who is just beginning to study science subjects, the ability to observe a phenomenon in action and manipulate its parameters increases the interactivity of learning. It has been proven that interactive learning is six times more effective than passive learning (Bayraktar, 2009).

Another challenge in digital education is maintaining students' motivation. For example, global MOOCs (Massive Open Online Courses) provide unrestricted access to educational content at any time and from anywhere in the world. However, research shows that only 7–13% of MOOC users complete their courses, primarily due to a decline in internal motivation during the learning process (Koedinger et al., 2015).

Prior studies indicate that gamification can serve as an effective solution to the issues of motivation and learning efficiency (Ahmed & Asiksoy, 2021; Morales et al., 2014). In education, the term "gamification" refers to the use of game-based technologies in non-game contexts, and scholars consider it a pedagogical technology (Katanosaka et al., 2023). Within the educational context, gamification is widely applied (Zhakupova et al., 2022).

Recent studies demonstrate that pedagogical games enhance students' motivation to learn, as well as their problem-solving skills and creativity. This is largely because games allow students to explore various scenarios and simulate realities that are otherwise impossible to replicate in the real world. Additionally, games enable teachers to monitor student progress. For these reasons, gamification is an invaluable method for allowing students to make mistakes, correct

them, and reinforce learning through diverse scenarios. This is particularly effective for teaching science subjects, which are often perceived as difficult.

Research also indicates that the global gamification market is growing each year. According to Metaari, the use of game technologies in higher education increased by 15.4% between 2019 and 2024 (Ansar & George, 2022). The combination of gamification and group discussion in teaching promotes long-term knowledge retention (Metaari, n.d.).

The core motivational mechanisms of gamification are points, badges, and leaderboards (PBL). Points record a learner's level of engagement and track progress during gameplay. Badges signify a learner's achievements and serve as a primary motivator. Leaderboards display the ranking of individual players or teams (ProProfs Training, n.d.). Gamification is defined as "the use of game mechanics, aesthetics, and game-like thinking to engage people, increase motivation, facilitate learning, and solve problems" (Kononova, 2017). This concept has been applied not only in education but also across various other sectors and educational tools.

Despite the growing research interest and the expansion of practical applications, the concept of gamification remains theoretically underdeveloped, and standardized rules and procedures for its implementation in organizational activities have not yet been established. Gamification is one of the essential functions of any learning management system. In the field of education, challenge-based gamification increases students' academic performance by 34.75%. Students who participate in challenge-based gamified learning improve their performance to 89.45% compared to those who receive only traditional lecture-based instruction (Spinify, n.d.).

Gamification in education, implemented through practical activities, gamified tasks, and group discussions, leads to greater knowledge retention (ProProfs Training, n.d.). Gamification employs active learning principles and spaced repetition, which have been proven to enhance knowledge retention. Gamification technology is being actively integrated into the global education system. Online learning platforms use gamification to attract users and encourage active learning, such as Duolingo, Noon Academy, Kahoot, Quizlet, Memrise, CodeCombat, and EdApp.

In science education, game technologies should be applied not only to simplify complex phenomena but also to help students grasp basic concepts and terms, and to facilitate the memorization of quantities and formulas. Therefore, it is crucial to select games that are aligned with the intended learning objectives.

Methods and Materials

The purpose of this study is to conduct a comparative analysis of methodologies that incorporate gamification elements in teaching science subjects in domestic and international secondary education institutions. The analysis focuses on the distinctive features of educational models in different countries, teaching formats, the extent of digital resources and interactive tool usage, and aims to identify and present effective practices and innovative solutions. In addition, the study examines the impact of gamification technology on students' motivation and academic performance. The study aims to identify the need for a national gamified digital platform in the Kazakh language designed to enhance learners' motivation and cognitive engagement in natural science subjects, as well as to determine the pedagogical requirements for such a platform.

The conducted study is an exploratory research aimed at determining the scientific and pedagogical justification of the gamified digital platform that the authors plan to develop in the future. That is, the research was carried out as an initial stage that determines what the structure of the future digital platform should be, which functions would be effective to include, and which pedagogical principles and requirements it should comply with.

The main research question of the conducted study is the following: can the pedagogical effectiveness of the digital platform based on gamification technology to be developed in the future be substantiated, and can the existing gamification tools and methods increase the interest of secondary school students in natural science subjects, their activity in class, and their learning outcomes? In addition, the study aims to determine the necessity of a national gamified digital platform in the Kazakh language that increases secondary school students' interest and cognitive activity in natural science subjects, as well as the pedagogical requirements and principles for such a platform.

This research work was carried out as the initial stage of a large-scale scientific and practical project aimed at creating and implementing a gamification-based digital educational platform intended for use in teaching natural science subjects in secondary schools in the future.

The research design is based on quantitative description and cross-sectional reporting. In addition, it is aimed at obtaining objective data about the current potential and pedagogical effectiveness of using gamification technologies in the process of teaching natural science subjects in secondary school.

The methodology of the research is oriented toward obtaining basic information necessary for determining the pedagogical requirements, principles, functional characteristics, and structure of the future gamified and personalized digital educational environment. This approach makes it possible to effectively identify the main patterns in the use of gamification and interactive digital tools in the process of teaching natural science subjects.The platforms ScienceDirect, Scopus, Web of Science, SpringerLink, and JSTOR, among others, were used to search for relevant articles required for the comparative analysis. Various search strategies were applied when investigating methodologies that integrate gamification into the teaching of science subjects in domestic and international secondary education institutions. The main search strategy involved combinations of keywords, which were used to construct advanced searches.

According to statistical data, a 2023 study (Li et al., 2023) conducted a meta-analysis of 41 research papers published between 2010 and 2022 on the use of gamification in education. The results confirmed the effectiveness of gamification in the educational field and identified factors influencing the relationship between gamification and student learning outcomes. Notably, the studies found that gamification proved more effective for middle school students than for high school students, and was particularly successful in teaching science and technical subjects. One of the key works in this area (Sailer & Homner, 2020) carried out an extensive meta-analysis, demonstrating that gamification has the potential to serve as an effective teaching method for activities targeting cognitive, motivational, and behavioral learning outcomes.

Digital simulations are among the most effective gamification tools for mastering educational content. One of the widely used gamification-based systems in science education is PhET Interactive Simulations, developed at the University of Colorado, USA (Wieman et al., 2008). Through interactive simulations in physics, chemistry, biology, and mathematics, this platform

helps students understand complex scientific concepts visually and experientially. It is used in many countries worldwide, including by teachers in Kazakhstan. Another example is Exploration, a "social learning laboratory" well known for its educational projects. By 2024, it had conducted 79 workshops, directly or indirectly reaching 1,591 teachers and over 3 million students (Exploratorium. Impact Report FY24, 2024).

Denmark's Aarhus University developed the nationally recognized ScienceAtHome platform, which includes science-based games and projects (AVID Open Access, 2024). In Japan, the gamified Human Resource Development Game platform, applied in biology and ecology education, is aimed at developing students' logical thinking and systematic decision-making skills. In the UK, MyGCSEScience, adapted for secondary schools, provides video lessons and quizzes in biology, chemistry, and physics, increasing student engagement during lessons (My GCSE Science, 2025). Globally popular resources such as LearningApps.org and Genially are widely used by teachers and students due to their simplicity and the ability to create tasks in the Kazakh language.

At the global level, empirical studies on the use of gamified digital environments in education – particularly in the context of teaching natural science subjects in Central Asian countries – remain limited. Most existing studies focus on the digitalization of education or the use of individual digital tools. Previous research has not considered gamification as a comprehensive pedagogical technology serving as the foundation for designing a dedicated digital educational platform.

Existing educational resources are often insufficiently interactive, especially training simulators that should consist of complex interactive tasks with feedback and analytics. Many current tasks are limited to multiple-choice tests or single-answer questions and demonstrate weak adaptability to students' individual learning potential. As a result, such resources do not adequately support teachers in simplifying routine assessment tasks, nor do they effectively enable learners' self-education, self-directed learning, and self-monitoring. In addition, most of these resources – or at least the most advanced solutions are commercial and require paid access.

The study revealed that most existing educational resources and platforms primarily offer ready-made learning materials and test-based tasks (Meng et al., 2024). However, these approaches fail to ensure full interactivity of the learning process, rapid feedback, and sustained growth in learners' motivation. In this regard, the present study aims to address the identified limitations and to provide an exploratory (diagnostic) rationale prior to the development of a gamified digital educational platform.

Thus, during the theoretical analysis it was determined that at the global level there is a lack of empirical research on the use of gamified digital environments in education, including their application in the context of teaching natural science subjects in Central Asia. The majority of modern studies mainly provide recommendations on the digitalization of education or on the use of individual digital tools. Previous studies have not considered gamification technology as a full-fledged pedagogical technology forming the basis for designing a digital educational platform.

Existing digital interactive educational resources are mostly in the form of simulators, that is, sets of interactive tasks with feedback and analytics (Meng et al., 2024). In most cases, tasks are presented in the form of multiple-choice tests or problems with a single correct answer.

Such tools have a weak potential for increasing students' adaptation and their interest in learning. In such cases, the teacher cannot significantly simplify the daily task of checking the results of students' completed assignments. In addition, most of such resources or advanced solutions are usually paid. Such limitations cannot ensure the full interactivity of the learning process, effective and rapid feedback, and a stable increase in students' interest. Our research complements the limitations identified above and is aimed at creating a preliminary justification for the development of a future gamified digital platform.

In this study, the application of gamification technology in teaching science subjects considered the following requirements: the topic must be based on a learning objective, the expected outcome must be clearly defined, and the activity must correspond to the time allocated for the learning process; the features of gamification technology should be aimed at increasing students' motivation to study the subject and deepening their understanding of the material.

Accordingly, several key features of gamification in teaching science subjects were taken into account:

1. Interactivity of learning materials – Use of simulations and virtual experiments allows students to explore complex phenomena interactively, conduct experiments, and gain a deeper understanding.
2. Group-based gamification – Dividing students into teams to encourage joint decision-making, problem-solving, and practical application of scientific laws, thereby developing communication skills.
3. Increased motivation and introduction of competitive elements – Creating competition among students through gamification to stimulate motivation.
4. Opportunities for research and development – Project-based learning enables students to conduct experiments, apply principles and laws, and analyze results (Tsirulnikov et al., 2023).
5. Development of creativity and thinking skills – Role-playing activities allow students to analyze certain natural processes or unresolved global issues by taking on specific roles, thus fostering creativity.
6. Formation of technical skills – Using gamification technologies and applications improves students' digital literacy and skills in working with IT tools.
7. Visualization of the learning process – Use of infographics, animations, and other visual elements to simplify the explanation of learning material.
8. Assessment and feedback – Interactive quizzes and tests with gamification elements provide instant feedback, making assessment easier and contributing to improved learning quality (Meng, 2024).

In this study, the proposed methods were primarily based on gamification-driven interactive learning applications such as Kahoot, Quizizz, WordWall, and Learning Apps, as well as the integration of riddles and crosswords into the learning process. These applications not only increase student motivation and active participation but are also effective for knowledge consolidation and assessment. The Kahoot platform, for instance, enables teachers to create their own quizzes, present them to students in an engaging format, and assess their knowledge.

The main advantage of the proposed methodology is the consideration of students' individual abilities and characteristics, as well as the use of personalized approaches in the teaching process. When designing the game structure, each student's interests and cognitive abilities are taken into account in advance. This approach encourages independent action, develops critical thinking skills, and consequently increases motivation to master the subject. Thus, the

methodology presented in this study makes the learning process in natural sciences more engaging and effective, while fostering students' subject-specific skills and encouraging active participation.

The research was conducted among 9th-grade students at M. Poshanov Secondary School No. 21 in Turkistan city, Turkistan Region. The study involved two classes from grades 7, 8, and 9 (7A, 7B, 8A, 8B, 9A, and 9B). Specifically, the "A" classes were taught according to the standard curriculum using traditional teaching methods, while the "B" classes used educational games and digital applications in the learning process. The study lasted for one academic quarter, after which the students' level of content mastery, interest in the subject, and class participation were assessed.

In class "A," lessons were conducted in a traditional format: teacher explanations, problem solving, laboratory work, and written assignments. Students listened to the teacher's explanations of new material, took notes using the textbook, and completed exercises at the end of each topic. In class "B," various game-based applications were used in every lesson to complete assignments, review homework, and consolidate new topics.

The practical implementation of the methodology began by integrating gamification elements into traditional teaching. During lessons, students used a specially developed (author's) booklet, which included theoretical materials on the topic "Direct Current," as well as tasks of varying difficulty levels and laboratory work enhanced with gamification elements. The teaching process involved competitive tasks using educational platforms, physics riddles, logical problems, tiered assignments, role-playing activities, group competitions, interactive online quizzes, and quest-based challenges.

As an example, let us consider the topic "Curvilinear motion; uniform circular motion of a material point" taught in Grade 9.

Learning objective: 9.2.1.13 – Describe the uniform circular motion of a body in terms of linear and angular quantities.

For lesson consolidation, a matching task was created in Learning Apps. This activity's advantage is that the teacher can send a link to students for independent review at home, while also monitoring their performance online.

The following lesson was Practical Work No. 1.

In this practical session, before solving problems, students first recalled physical quantities and formulas by playing a game in the Wordwall application. In this activity, students "popped" balloons while recalling the names and symbols of physical quantities. To review formulas, they played the Quiz Show game.

Thus, gamification elements were incorporated into each part of the lesson throughout the learning process.

Results

In order to assess the level of knowledge acquisition in natural science subjects, including physics, testing was conducted in each of the compared classes. As a result, it was determined

that the classes taught with the active use of gamification elements demonstrated higher results, showed increased interest in the subject, and were more active during lessons. In particular, it was found that the level of knowledge of low-performing students also began to increase.

In addition, a survey was conducted among students in order to determine how traditional teaching and teaching based on gamification technology influence the lesson and to identify the differences in teaching approaches.

The questionnaire developed by the authors consisted of 10 main statements aimed at identifying the effectiveness of using gamification elements in teaching the secondary school physics course, as well as their impact on learning motivation, cognitive activity, and the performance of group work. The responses were evaluated according to the Likert scale: “Strongly agree,” “Agree,” “Disagree,” “Strongly disagree.”

Figure 1

The Impact of Gamification on Learning Motivation and Interest in the Subject

1.1 1.2



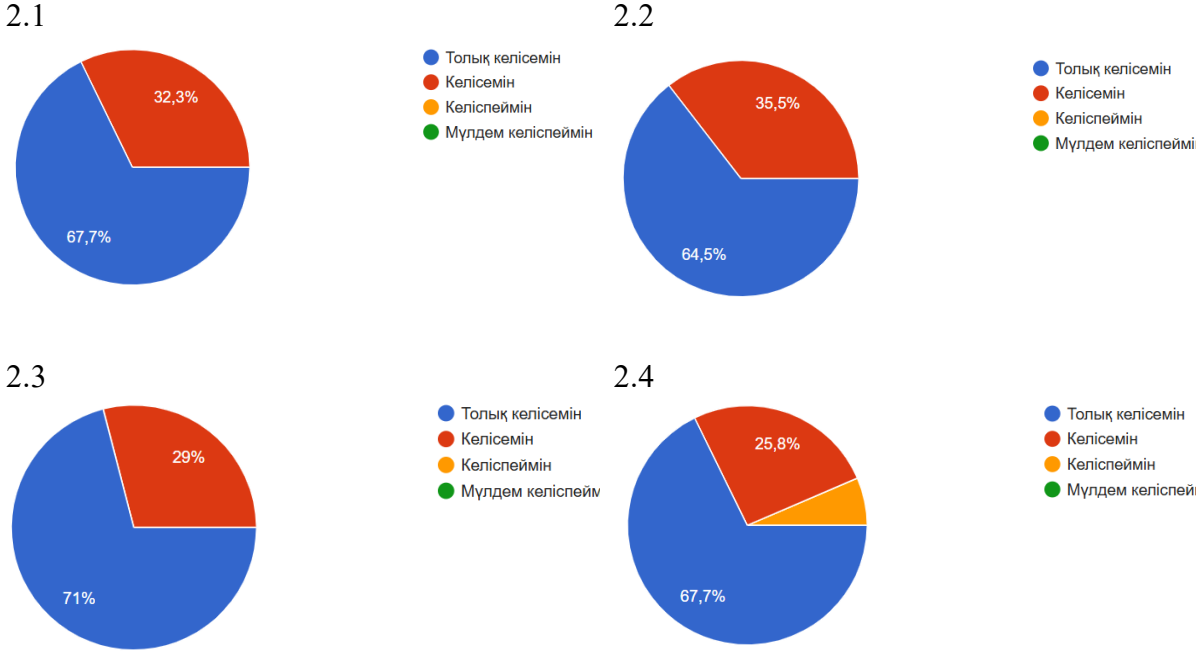
Note. 1.1 The use of game elements in physics lessons increases interest in the subject;
1.2 Gamification elements contribute to the formation of a positive attitude toward physics.

The effect of using gamification elements in lessons on learning motivation and interest in the subject is presented in Figure 1. For the two questions, it can be seen that the vast majority of respondents expressed positive opinions. More than 96% of students selected the responses “Agree” and “Strongly agree.”

As shown in Figure 1, the majority of respondents expressed positive opinions regarding the two statements mentioned. In particular, nearly 100% of them marked the responses “Agree” and “Strongly agree.” In this regard, the absence or very small number of negative responses indicates that gamification can be an effective tool for increasing students’ learning motivation.

Figure 2

The Impact of Gamification on Cognitive Engagement and the Learning Process

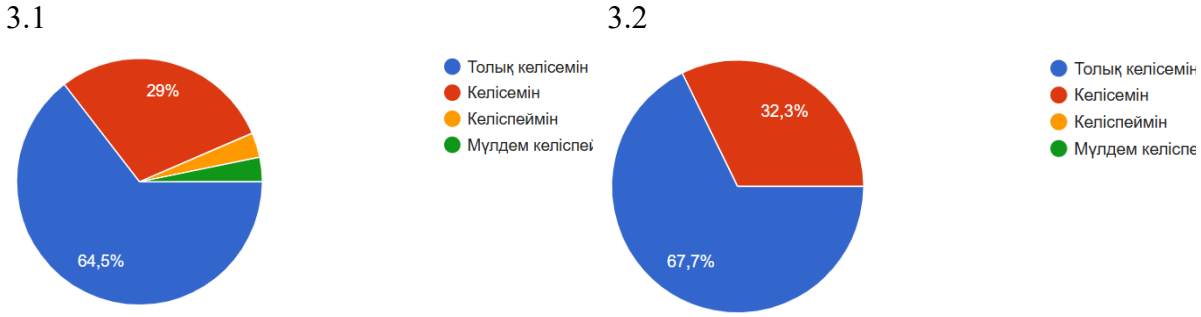


Note. 2.1 Gamification techniques such as points, levels, and rewards motivate me to participate more actively in class;
2.2 Gamification makes it easier to understand complex physics concepts;
2.3 Assessing my knowledge is more engaging in lessons that use game elements;
2.4 Gamification helps me maintain attention for a longer period during lessons.

From the diagram in Figure 2, it can be seen that 92–100% of students support the introduction of gamification mechanisms into the learning process and have noticed its positive impact. The highest indicators are related to the fact that using game elements when assessing knowledge is interesting and helps maintain attention for a longer time. The obtained results showed that gamification has a significant role in increasing students' cognitive activity.

Figure 3

The Impact of Gamification on Social and Creative Skills



Note. 3.1 Group competitions and team-based games increase collaboration and active participation during lessons;
3.2 Game-based tasks in physics lessons contribute to the development of my creative abilities.

As shown in Figure 3, according to the two given statements, all respondents 93–100% indicated that gamification elements increase cooperation when working in groups and have a significant impact on their creative abilities. These indicators show that the use of gamification technology in lessons is important not only for developing cognitive skills but also for forming communicative and social skills.

After the completion of the survey, all responses were downloaded and statistical processing of the data was carried out. The statistical analysis was conducted using the specialized Jamovi statistical software. All responses were coded and their percentage indicators were calculated. All empirical indicators were presented visually through the construction of diagrams. The statistical software allows for accurate and clear analysis of the data (Table 1).

Table 1

Statistical Results of Attitudes Toward the Use of Gamification Technology

Question N	N	Mean	Mdn	SD	Min	Max
1	62	1.36	1	0.674	1	3
2	62	1.27	1	0.467	1	2
3	62	1.27	1	0.467	1	2
4	62	1.64	1	0.924	1	4
5	62	1.36	1	0.505	1	2
6	62	1.27	1	0.467	1	2
7	62	1.45	1	0.688	1	3
8	62	1.45	1	0.688	1	3
9	62	1.27	1	0.467	1	2
10	62	1.45	1	0.934	1	4

Using the program, descriptive statistical indicators such as the mean value, median, and standard deviation (SD) based on the number of respondents (N) are determined separately for each question. In Table 1, the indicator N shows the number of students who answered a particular question. The mean value reflects the general direction of students' responses. By general direction, we mean the level of students' attitudes toward gamification elements. The median indicates the central value of the statistical data. The standard deviation characterizes the consistency of students' responses.

The results of the statistical data analysis showed that the mean values of all questions ranged between 1.22 and 1.56. The median value was equal to one for all questions, indicating that the majority of students selected the response "Strongly agree." The standard deviation of the statistical data varied between 0.44 and 1.01. This means that although students' opinions were generally in the same direction, there were slight variations in some individual questions.

When calculating the generalized statistical indicators of the survey results, the overall mean value for all questions was 1.37, while the median remained at 1. The standard deviation averaged 0.56. These data indicate that the results obtained during the research are reliable and stable, and that there are no significant deviations among students' responses.

The obtained research results demonstrate that the use of gamification elements in physics lessons increases students' interest in the lesson and their learning motivation. In addition, it

facilitates the understanding of complex topics and concepts, strengthens cognitive activity, and positively influences the development of creative thinking and teamwork skills.

Table 2

One-Sample Student's t-Test, Statistical Results

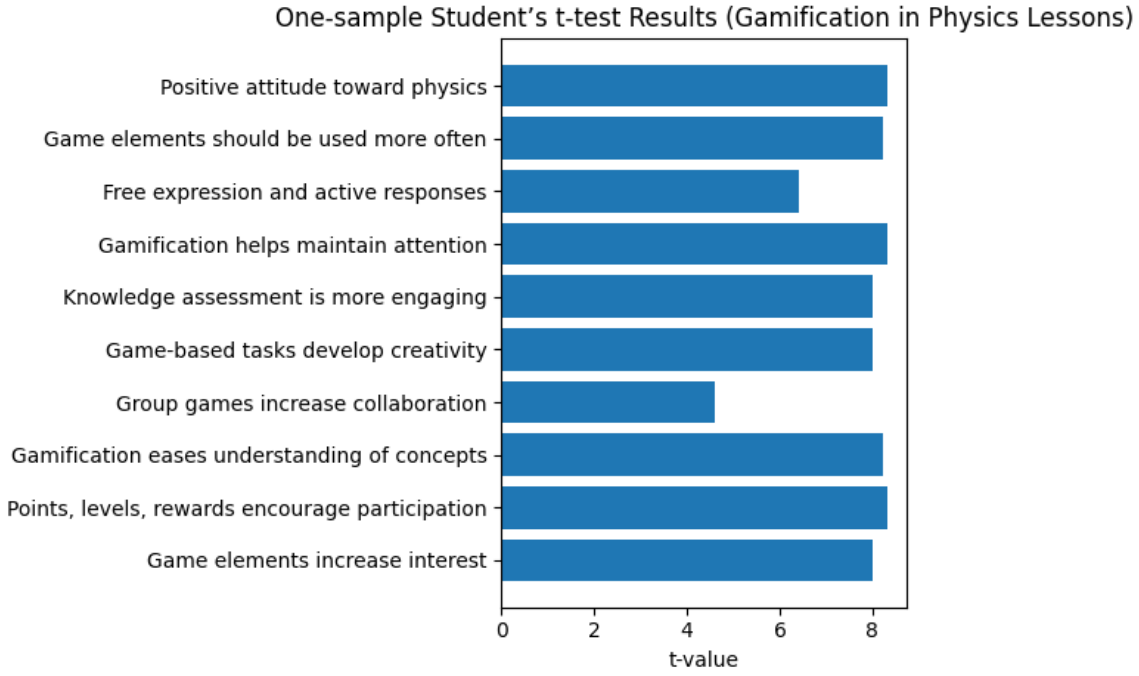
Question		Statistical data, t	df	p
The use of game elements in physics lessons increases interest in the subject.	Student's t-test	8.00	61.00	< .001
Gamification techniques such as points, levels, and rewards encourage active participation.	Student's t-test	8.32	61.00	< .001
Gamification makes it easier to understand complex physics concepts.	Student's t-test	8.22	61.00	< .001
Group competitions and team-based games increase collaboration and engagement during lessons.	Student's t-test	4.60	61.00	0.002
Game-based tasks in physics lessons develop creative abilities.	Student's t-test	8.00	61.00	< .001
Assessing knowledge is more engaging in lessons that use game elements.	Student's t-test	8.00	61.00	< .001
Gamification helps maintain attention for a longer period during lessons.	Student's t-test	8.32	61.00	< .001
In such lessons, I freely express my ideas and actively respond to questions.	Student's t-test	6.42	61.00	< .001
I believe that game and competition elements should be used more frequently in physics lessons.	Student's t-test	8.22	61.00	< .001
Gamification elements have helped form a positive attitude toward physics	Student's t-test	8.32	61.00	< .001

**Note*. H_a represents the alternative hypothesis, where $\mu \neq 0$.

Using the Jamovi program, a one-sample t-test was conducted to perform a deeper analysis of the data obtained during the study (Table 2). The one-sample t-test makes it possible to determine the significant deviation of the mean value obtained for each question from the accepted null hypothesis (H0: $\mu = 0$). In our research, the alternative hypothesis $\mu \neq 0$ was adopted; therefore, the aim was to determine whether there is a statistically significant difference in the students' responses.

Figure 4

One-Sample Student's t-Test Results



Let us analyze the obtained results based on the p-value. In Table 2, it can be observed that the p-value is significantly lower than 0.05, which indicates that the responses were not marked randomly and that there is a clear tendency in the students' opinions. For example, in most of the questions the value was $p < .001$, and such a high level of significance shows that students clearly support gamification. All indicators produced statistically significant results. Only one question showed $p = 0.002$, but since it is also lower than 0.05, it is considered statistically significant as well.

The obtained results indicate that the students' responses were not random and demonstrate that students perceive the use of gamification elements in physics lessons as effective. Thus, the results of the statistical test confirm the overall positive results of the survey. Clear evidence was obtained showing that gamification is a factor that increases interest, communication, understanding, sustained attention, and participation in the lesson.

Discussion

These findings clearly demonstrate both the effectiveness and demand for gamification technology. The survey also confirmed that combining traditional teaching with game elements makes lessons more engaging, more understandable, and helps students absorb information more quickly and effectively.

An analysis of various domestic studies and platforms (such as Online Mektep, Bilimland.kz, BilimCenter.kz, Kitap.kz, Daryn Pro, Roqed, Kundelik.kz, twig-bilim.kz, 100ballov.kz, itest.kz, and others) revealed that, in the process of teaching natural sciences, teachers often need to independently adapt subject content to the individual level of each student, design gamification-based tasks, and effectively integrate them into lessons.

It was observed that both domestic and widely used international educational resources primarily offer ready-made learning materials. The study also found a lack of educational platforms that provide real-time responses to students' actions, deliver immediate feedback, analyze task performance, and offer comprehensive interactive training systems (simulators). Currently, most available tasks are limited to problems and tests with only one correct answer. Such an approach does not fully support the development of students' independent learning skills or allow for a comprehensive assessment of their knowledge.

In addition, many of these platforms are accessible only through paid subscriptions. The methodology for creating a gamified digital environment for teaching natural sciences proposed within this study is aimed at effectively addressing the aforementioned challenges. Future research will continue to explore solutions to this issue.

Conclusion

This study showed that the development and implementation of a domestic gamification-based digital educational platform can be important for teaching natural science subjects in secondary schools. The research results revealed the high potential of integrating gamification into the educational process through a digital platform. In general, students are ready to use these technologies, but the lack of appropriate platforms and systematic instruction prevents their full implementation in domestic secondary schools.

In conclusion, teaching natural science subjects through gamification technologies can be considered an effective method for ensuring deeper subject understanding, increased student interest, active participation in the learning process, and improved academic performance.

The empirical data obtained during the study made it possible to identify the structure, functional capabilities, and pedagogical requirements of a gamified digital platform to be developed in the future. Conducted as an exploratory study, this research establishes a solid scientific and methodological foundation for the future design and implementation of a gamified digital educational platform for natural science subjects in accordance with the national curriculum.

Acknowledgement

This research has been funded by the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan (Grant № AP 26193791).

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