Development and Evaluation of a Gamified Digital Platform for Science Education in Secondary Schools

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Abstract

The integration of gamification into science education has emerged as an effective approach to enhance student engagement, motivation, and learning outcomes. This study investigates the application of gamification elements in teaching natural science subjects through the development of a specialized digital platform. The proposed platform incorporates key gamification components, including points, badges, levels, leaderboards, and instant feedback mechanisms, designed to foster interactive and student-centered learning. The research was conducted among 7th-grade students, where the developed platform was integrated into the instructional process. To evaluate its effectiveness, a quasi-experimental design was employed, including pre-test and post-test assessments, along with student motivation and engagement surveys. The evaluation framework was based on widely used educational measurement scales, such as Likert-scale questionnaires and performance-based assessment criteria, enabling both quantitative and qualitative analysis. The results demonstrated a significant improvement in students' academic performance and learning motivation compared to traditional teaching methods. Students who used the gamified platform showed higher test scores, increased participation, and greater interest in science subjects. Additionally, the platform contributed to the development of critical thinking and problem-solving skills by encouraging active involvement in the learning process. Furthermore, the findings align with existing research highlighting the positive impact of gamification in education, particularly in STEM disciplines. The use of structured evaluation scales allowed for a comprehensive assessment of both cognitive and affective learning outcomes. In conclusion, the developed gamification-based platform proved to be an effective tool for enhancing the quality of science education.

Keywords: gamification, natural science education, digital platform, student motivation, STEM education

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Introduction

One of the main tasks of education systems in the 21st century is to develop students' functional literacy and research skills through the effective use of information and communication technologies. The digitalization of education in the Republic of Kazakhstan has become a priority direction of state policy, reflecting a broad international trend towards the use of technologies in the learning environment. In accordance with this policy direction, schools in the country are increasingly introducing electronic resources, virtual laboratories, interactive platforms and gaming technologies into everyday teaching. Natural sciences—physics, chemistry and computer science—are the main focus of this modernization work, as they require students to acquire not only theoretical knowledge, but also to develop practical skills, scientific thinking and a logical-analytical approach. These competencies are important for students who intend to study or build a career in science, technology, engineering and mathematics (STEM) and are increasingly being emphasized in national curricula. However, a significant part of educational research shows that students often perceive these subjects as complex, abstract and relatively uninteresting, especially when teaching is based on lectures and memorization. Common barriers include limited access to hands-on lab experiences, lack of immediate feedback, and lack of individualized learning pace that takes into account students' varying levels of knowledge. These circumstances create a need to redesign the learning process in a more engaging, interactive, and learner-centered way. One approach that has gained significant popularity in education in recent years is the gamification approach. The gamification approach involves applying game elements and game mechanics—such as points, badges, levels, and structured feedback—to non-game contexts, including formal education, with the goal of increasing user engagement and motivation. Unlike full-scale educational games or game-based learning environments, the gamification approach does not require the creation of a completely fictional game world; instead, it overlays familiar game mechanics onto existing course content and tasks. In an educational environment, the gamification approach aims to increase student motivation by incorporating game elements into the learning material: as students progress through the course, they advance to the next level, earn rewards, and reinforce their learning by completing structured tasks. This approach aims to make the learning process more enjoyable and productive by transforming task completion into a process with visible, incremental progress and indicators of achievement.

Gamified digital platforms for science education offer a number of tangible benefits beyond increasing interest in the subject. They allow students to virtually complete lab work when access to a physical lab is limited, take quizzes in a gamified format that reduces test anxiety, and track their progress using visible progress indicators. In addition, such platforms allow teachers to automatically assess student performance, analyze results, and identify students who may need additional support, thereby reducing the administrative burden associated with manual review and progress monitoring.

This article reviews the theoretical foundations of the development of a game-based digital platform for secondary schools, presents the structure and functional architecture of the platform, and describes a system for evaluating its pedagogical effectiveness.

Literature Review

Currently, the rapid development of digital technologies in education has greatly influenced the widespread use of new pedagogical approaches based on the use of game elements in the

teaching process. Gamification in teaching natural sciences is considered an effective tool for increasing students' motivation to learn, cognitive activity and subject competence.

Indiaka et al. (2025), who studied the effectiveness of digital gamification in teaching biology in general education institutions, found that game-based digital teaching methods significantly improve students' level of mastery of biological concepts and motivation to learn. According to the author, digital games increase students' interest in the learning material, contribute to their active participation in the lesson and long-term memory of knowledge.

Moral-Sánchez et al. (2022), who studied the teaching experience of mathematics and STEM, considered that combining STEM and gamification methods in teaching geometry allows students to develop problem-solving, critical thinking and collaborative skills. This is believed to prove the importance of gaming technologies in not only increasing interest, but also in developing 21st century skills.

In their work, Ateş and Kölemen (2025), who examined the issue of teaching science through mobile devices, proved that mobile educational platforms incorporating gaming elements showed high results in developing students' self-regulated learning abilities. The authors noted that digital platforms contribute to students' self-planning of the learning process, monitoring their academic achievements, and increasing their responsibility.

In a study conducted in the field of science teacher training, Franco-Mariscal, Cebrián-Robles, and Rodríguez-Losada (2023) examined the effectiveness of using electronic rubrics to build teachers' competence in evaluating gamification resources. The results of the study showed that teachers' high-quality development and evaluation of digital gaming resources increases the effectiveness of the educational process.

Katanosaka et al. (2023), who developed an online game-based platform for teaching physics, analyzed the platform’s architecture, functionality, and impact on students’ academic achievement. The researchers found that virtual experiences, graded tasks, and reward systems facilitated students’ understanding of physical phenomena and improved learning outcomes.

Alarcon et al. (2025), who evaluated the effectiveness of the ABCCI serious game program used in science teacher training, found that the usability and gamification elements of the game positively influenced the development of professional competence. This study, published in the IEEE Access journal, demonstrates that digital games play an important role not only for students but also in the professional training of teachers.

Carvalho et al. (2024) developed a gamified digital platform aimed at organizing extracurricular activities for elementary and secondary schools. Preliminary results showed that game mechanics increase students’ active participation in school life and enhance interaction in the digital environment. This study demonstrates that digital platforms are not only effective in academic learning, but also in educational and social work.

In a systematic literature review on the use of board games in science education, Hashim et al. (2023) analyzed the impact of gaming technologies on the quality of education. They showed that gaming methods facilitate the acquisition of subject knowledge and contribute to the development of students' creativity, communication skills, and a culture of collaboration. The study emphasizes that the combined use of digital and traditional games yields effective results.

Khattib and Alt (2024) evaluated the effectiveness of digital gamification in science education using the CoSpaces Edu platform based on a quasi-experimental study. The results of the study show that the academic achievement, spatial thinking skills, and digital competences of students in the experimental group were significantly higher than those in the control group. This demonstrates the potential of digital platforms to improve the quality of education.

In their systematic literature review on the use of gamification in secondary education, Vrcelj et al. (2023) analyzed numerous studies published in recent years and concluded that gamification consistently improves learning motivation, engagement, and learning outcomes. They argued that pedagogical design, user interface, and the coherence of learning objectives should be among the key requirements in the development of digital platforms.

The analysis of the reviewed scientific works proves that game-based digital platforms are highly effective in teaching natural sciences. Many studies have proven that gamification, in addition to increasing students' interest in the subject, contributes to the organization of their own learning, the development of research skills, and the formation of digital competence. At the same time, it is noticeable in the literature that there is still a lack of research on complex solutions that combine several areas of natural sciences (chemistry, physics, computer science) within one digital platform. In this regard, the development of a complex game-based digital platform for secondary schools and the assessment of its effectiveness are relevant scientific issues for the modern education system.

Materials and Methods

Platform Overview

The main material for the study is the digital educational game platform EduGame.kz, developed for general secondary schools in the Republic of Kazakhstan. The platform is a web-based system designed to increase student motivation, monitor academic progress, and support the development of subject-specific competencies. Its interface is designed in accordance with the basic principles of game design and provides interactive learning in the natural sciences: physics, chemistry, and computer science.

The platform is not intended to replace traditional classroom teaching, but rather to expand and enhance it as an additional learning environment. Teachers have full control over the materials provided to students, the pace of task completion, and the activation or deactivation of individual game elements such as leaderboards, which allows for flexible adaptation to the needs of different grade levels and age groups.

Gamification Module

The most important of the main components of the digital platform developed during the study is its gamification module. This module helps to increase students’ motivation to learn and ensure their active participation in the learning process. It is designed to improve academic achievement in science subjects. By integrating gamification mechanics with educational content, it not only increases students’ cognitive interest, but also maintains their activity over time. In developing the module, the research team uses the basic framework proposed by Deterding, Dixon, Khaled, and Naik (2011), which defines modern game mechanics as, in particular, game design elements and the use of design elements in contexts; the work of Kapp (2012) on game-based methods and strategies for teaching and learning; and the taxonomy of

dynamics, mechanics, and components developed in the works of Werbach and Hunter (2015). These studies influenced decisions on how to prioritize, organize, and balance them in accordance with the developmental characteristics of secondary school students and the requirements of the science curriculum. Gamification elements in the platform are automatically activated when students complete learning tasks and the system is designed to provide immediate feedback on student progress, which, according to the literature reviewed above (e.g., Ateş & Kölemen, 2025; Katanosaka et al., 2023), is crucial for maintaining interest and supporting self-regulated learning.

Key Elements and Functions of the Gamification Module

The game module developed for the study includes 10 key elements, briefly described in Table 1 below, each of which performs a specific pedagogical function in the overall system.

Table 1
Core Elements of the EduGame.kz Gamification Module

Element	Function and Capabilities
Points	Awarded automatically for every correctly completed task. Points function as the primary quantitative indicator of learning activity, allowing both students and teachers to monitor engagement and achievement over time.
Badges	Digital badges are granted upon reaching specific learning milestones (e.g., completing a topic, achieving a streak of correct answers). Badges serve as visible symbols of competence and are intended to strengthen students' intrinsic motivation.
Levels	Students advance through sequential levels as they accumulate experience points. Each new level unlocks tasks of increasing complexity, ensuring that challenge scales with demonstrated competence.
Leaderboard	Displays student rankings based on performance, fostering a spirit of friendly competition. Teachers may enable or disable this feature depending on classroom needs, to avoid demotivating lower-performing students.
Quests	Thematic learning missions aligned with specific topics in physics, chemistry, and computer science. Quests require the sequential completion of several related tasks, encouraging sustained engagement with a topic.
Daily Challenges	Short, time-limited tasks designed to encourage regular, spaced learning activity and to build consistent study habits.
Progress Bar	A visual indicator that displays a student's cumulative progress through a course or module, helping learners track how much material remains.
Immediate Feedback	Following each task, students receive instant information about the correctness of their answer along with explanatory comments, supporting formative assessment and timely correction of misconceptions.
Rewards	Additional privileges, certificates, or virtual prizes granted upon reaching defined performance thresholds, reinforcing sustained achievement.
Adaptive Tasks	The difficulty level of subsequent tasks is automatically adjusted based on a student's prior performance, supporting individualized learning trajectories.

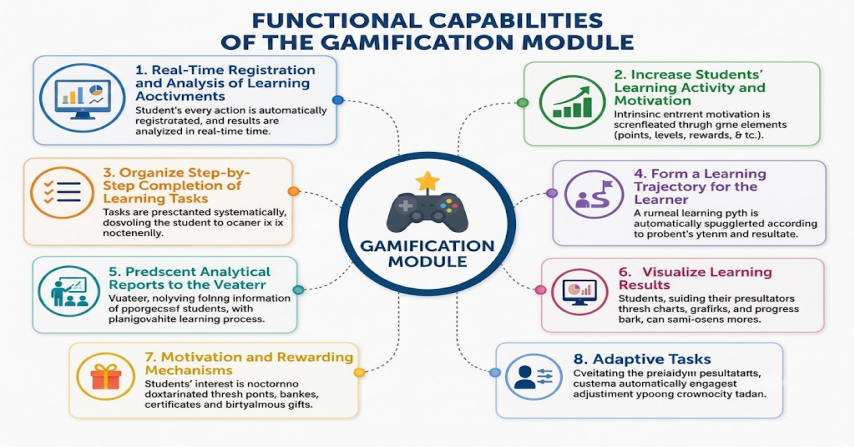
Module Functionalities

This module was subsequently piloted to assess the pedagogical effectiveness of the platform during the practical phase of the study. The developed gamification module provides the following functionality, schematically illustrated in Figure 1: automatic tracking of student

progress across topics and tasks; calculation and real-time display of accumulated points, badges, and level status; teacher dashboards that summarize class and individual performance; and settings that allow teachers to customize the visibility of competitive elements, such as leaderboards, to suit the needs of a particular class.

Figure 1

Functional Capabilities of the EduGame.kz Gamification Module



Research Methodology

A quasi-experimental research design combining pre- and post-assessment with student motivation and engagement measurements was used to evaluate the effectiveness of the proposed platform. The study was conducted among 7th grade students, for whom the platform was introduced into the regular curriculum of the target science subjects. This age group was chosen because 7th grade represents the stage when students begin to systematically study individual physics, chemistry, and computer science courses. It is a suitable context to study the impact of the platform on basic knowledge acquisition and interest in specific subjects.

The assessment tools used in this study are based on widely accepted measurement approaches in education, including Likert-scale questionnaires for assessing motivation and attitudes and indicator-based assessment criteria for assessing academic performance. This combination of tools was chosen to quantitatively analyze learning outcomes and qualitatively understand students' subjective experiences in a game-based learning environment.

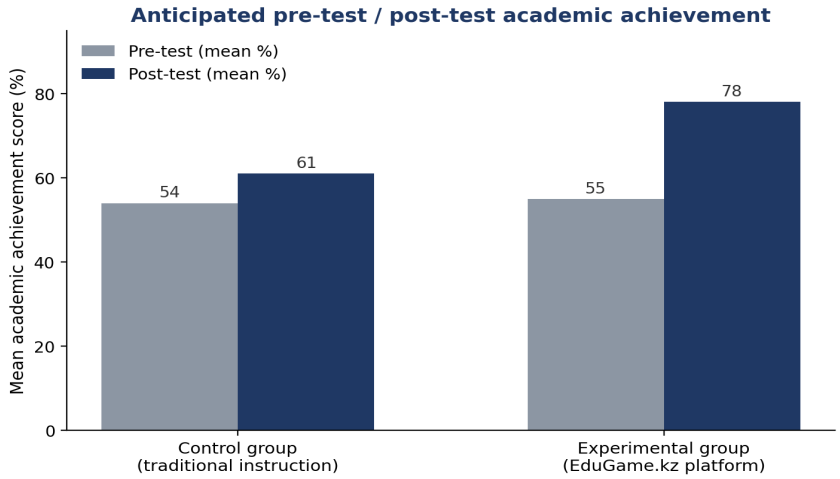
Analysis and Expected Results

The proposed game-based digital platform will be evaluated through a pilot study aimed at comprehensively assessing the impact of the proposed game-based digital platform on the acquisition of natural science subjects (Physics, Chemistry, and Computer Science), motivation to learn, and overall academic performance of secondary school students.

In the next stage of the study, experimental and control groups will be created, and students' knowledge will be assessed through pre- and post-testing. This design will allow us to identify changes in academic performance as a result of using the platform. At the same time, the results of the experimental and control groups will be compared, and the statistical significance of any differences observed will be assessed using appropriate inferential methods. Figure 2 shows an illustrative projection of the expected results of this comparison based on the trends described in the game-based literature discussed.

Figure 2

Anticipated Pre-test / Post-test Academic Achievement

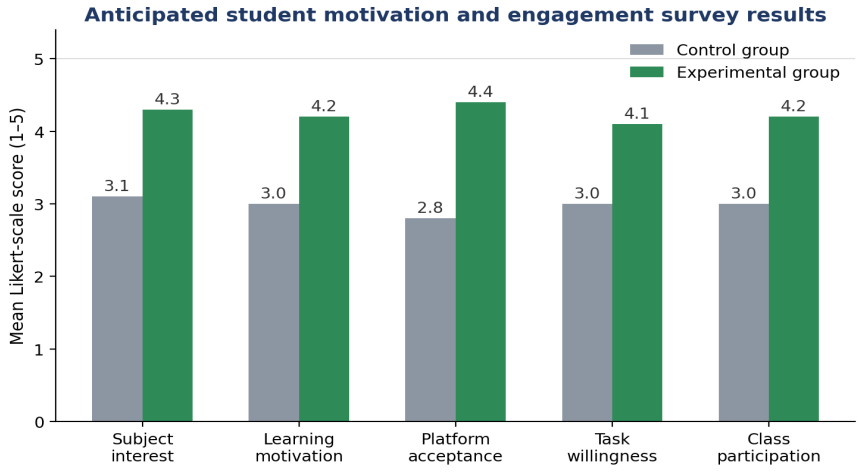


Note. illustrative projection, not empirical data

A Likert-scale survey is planned to assess students' motivation to learn. The survey results will be used to analyze students' interest in the subject, their acceptance of the digital platform, their readiness to complete assigned tasks, and their overall level of engagement in the learning process. The survey questions are designed to capture cognitive aspects of motivation, such as perceived competence and value, as well as emotional aspects, such as enjoyment and reduced anxiety related to the subject. The expected survey results for these aspects are shown in Figure 3.

Figure 3

Anticipated Student Motivation and Engagement Survey Results

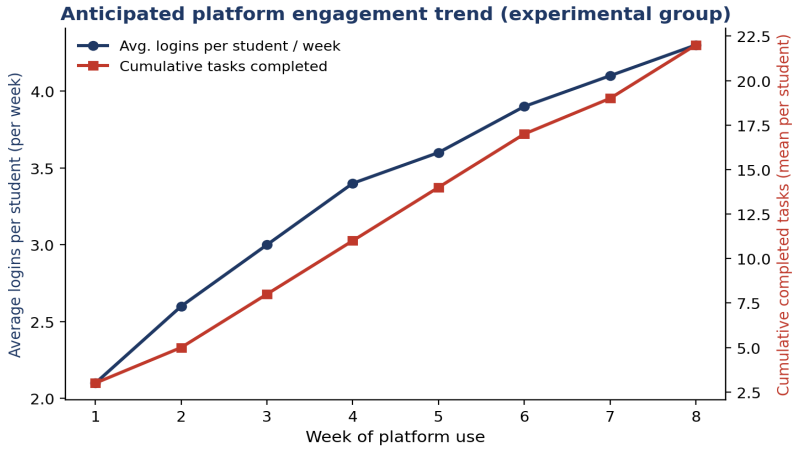


Note. illustrative projection, not empirical data

The platform's built-in analytics module automatically tracks users' learning activity. This analysis looks at metrics such as login frequency, number of tasks completed, points earned, badges earned, tasks completed, and overall learning progress. This data allows us to assess students' engagement on the digital platform and explore the relationship between engagement and academic performance. Figure 4 shows the expected engagement trend over the 8-week trial period, with both login frequency and total number of tasks completed gradually increasing as students become more familiar with the platform.

Figure 4

Anticipated Platform Engagement Trend Over an Eight-Week Trial



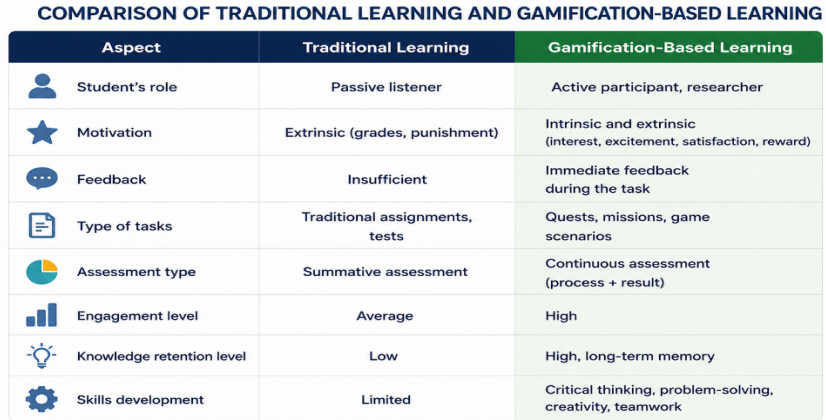
Note. illustrative projection, not empirical data

The platform will conduct a comparative analysis of the impact of gamification elements such as point systems, levels, badges, leaderboards, tasks, and feedback on student motivation and academic performance. In addition, the relationship between the frequency of use of each element and student academic performance will be examined, allowing the research team to determine which mechanisms contribute most to the observed improvements and which may require further improvement. Descriptive statistical methods, including means, standard deviations, and percentage distributions, are planned to process the collected experimental data. Depending on the characteristics of the data, student t-tests or non-parametric statistical methods will be used to identify differences between groups. In addition, correlation analysis is proposed to assess the relationship between learning activity and academic performance, which will allow us to understand whether high-level interaction with the platform is systematically associated with improved academic performance. Tables, histograms, line charts, and graphs describing academic performance have been developed to visually present the research results. These visualizations are intended to support a comprehensive assessment of the platform's effectiveness and to facilitate the interpretation of the results, both for the research team and for teachers and administrators who may subsequently consider implementing the platform.

The expected outcomes of using a gamified digital platform are to increase students' interest in science, increase their motivation to learn, increase their engagement in learning tasks, and contribute to improved academic performance. The results of the planned experiment provide scientific justification for the pedagogical effectiveness of the proposed platform. It is expected that they will serve as a basis for developing practical recommendations for its integration into the school curriculum. A comparative review of traditional teaching approaches with gamification-based learning, shown in Figure 5, highlights several key differences with respect to the expected outcomes of this study. Traditional science teaching is typically based on passive transmission of knowledge, providing delayed feedback through periodic testing, and relatively limited opportunities for individualized learning. In contrast, gamification-based learning implemented through the EduGame.kz platform is characterized by active, task-oriented participation, immediate feedback after each learning activity, visible and gradual progress indicators, and an adaptive task sequence that takes into account the individual performance of students.

Figure 5

Comparison of Traditional Instruction and Gamification-Based Instruction



COMPARISON OF TRADITIONAL LEARNING AND GAMIFICATION-BASED LEARNING

Aspect	Traditional Learning	Gamification-Based Learning
Student's role	Passive listener	Active participant, researcher
Motivation	Extrinsic (grades, punishment)	Intrinsic and extrinsic (interest, excitement, satisfaction, reward)
Feedback	Insufficient	Immediate feedback during the task
Type of tasks	Traditional assignments, tests	Quests, missions, game scenarios
Assessment type	Summative assessment	Continuous assessment (process + result)
Engagement level	Average	High
Knowledge retention level	Low	High, long-term memory
Skills development	Limited	Critical thinking, problem-solving, creativity, teamwork

Conclusion

The study presents the structure and functionality of a game-based digital platform for teaching natural sciences in secondary schools. The platform integrates gamification elements aimed at activating the learning process, such as points, levels, badges, tasks, leaderboards, progress indicators, and instant feedback, and describes the methodological framework for integrating these elements with educational content.

An evaluation model was developed to evaluate the proposed platform, which includes indicators of learning achievement, learning motivation, learning activity, and platform usage. In addition, the data collection and statistical analysis methods used in the planned pilot study were described. Together, these methods are designed to provide a comprehensive assessment of the pedagogical effectiveness of the platform.

In the next stage of this study, the proposed digital platform will be tested in real school practice, the results of the experimental and control groups will be compared, and the impact of gamification elements on learning outcomes will be determined through statistical analysis. The expected results are expected to scientifically substantiate the conclusion that the use of game-based digital technologies increases students' interest in natural sciences, increases motivation to learn, and improves the overall quality of education. In general, the proposed game-based digital platform offers a promising pedagogical solution for improving the effectiveness of natural science teaching and can serve as a basis for further research and practical studies aimed at integrating it into the educational process of general secondary education institutions.

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Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

Generative artificial intelligence technology was used only to assist in the translation and linguistic processing of this manuscript. In particular, the ChatGPT tool (OpenAI) was used to improve the English translation, grammar, and readability of the text. This artificial intelligence tool was not used to generate research ideas, methodology, data analysis, results, or conclusions.

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