International Journal of Innovative Research and Scientific Studies, 8(7) 2025, pages: 805-813

IJIRSS
International Journal of Innovative Research & Scientific Studies

ISSN: 2617-6548

URL: www.ijirss.com

Assessing the impact of game-based pedagogies and blockchain-issued badges on computer science learning motivation in Kazakhstan

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Abstract

Within the framework of Kazakhstan's national agenda for the digital transformation of education, the search for effective methods to engage students in technical disciplines – particularly programming – has become especially significant. Traditional forms of instruction often prove insufficient in fostering sustained interest and developing practical competencies among school students, especially at the introductory stages of learning programming. This study investigates the effectiveness of employing a game-based educational system in high school computer science instruction. The gamified platform developed by the authors enables students to interact with the learning environment by writing real Python code. The entered commands directly control virtual objects, such as moving characters, overcoming obstacles, or interacting with opponents. This approach ensures that fundamental programming concepts are acquired in tandem with the development of cognitive skills. The study involved two groups of secondary school students. The experimental group learned programming using the gamified platform, while the control group received traditional instruction. Both groups were exposed to identical learning content. The results demonstrated that students in the gamified environment exhibited higher levels of engagement, achieved greater success in mastering the material, and performed better on practical programming tasks. The observed outcomes suggest that the integration of game-based learning models contributes to the development of students' self-confidence, proactivity, and cognitive initiative. The findings highlight the effectiveness of well-structured gamification elements in achieving educational objectives in programming. Furthermore, the proposed methodology holds potential for adaptation to other practice-oriented disciplines within Kazakhstan's education system, aligning with the strategic goals of digital transformation and addressing pressing challenges of enhancing student motivation and engagement in technical fields.

Keywords: Blockchain, Gamification, Informatics education, Motivation, Secondary education.

DOI: 10.53894/ijirss.v8i7.10604
Funding: This study received no specific financial support.
History: Received: 15 August 2025 / **Revised:** 17 September 2025 / **Accepted:** 19 September 2025 / **Published:** 6 October 2025

Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.
Transparency: The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.
Publisher: Innovative Research Publishing

1. Introduction

Secondary education in the Republic of Kazakhstan is currently undergoing a large-scale transformation, with the strategic priority placed on the intensive development of digital literacy in schools. This process has been initiated through state policy measures that emphasize the integration of digital technologies as a core component of the modern educational process, aligning with the national agenda of embedding school education into global trajectories of innovative development [1, 2]. Such transformation is consistent with the broader objective of fostering students' sustainable ICT competencies, particularly in computer science and programming, which are recognized as factors of strategic importance for the country's long-term economic growth.

At the same time, the problem of insufficient student engagement in these subject areas persists, a challenge observed not only in Kazakhstan but also within the broader international educational context. According to recent studies [3, 4] a global decline in interest in computer science and programming is evident, largely attributed to outdated pedagogical practices and the insufficient contextualization of learning within practical applications. Such limitations negatively affect students' learning motivation, particularly in programming education. Traditional approaches, which predominantly rely on lectures and static exercises, have shown limited effectiveness, as they neither actively engage learners in cognitive activities nor contribute to the development of applied skills. Consequently, both academic motivation and performance tend to decline [5].

This issue is especially pronounced in programming instruction, where the high level of abstraction inherent in the subject matter often hinders students' ability to successfully master the material. Within this domain, gamified learning environments have demonstrated particular effectiveness, as game scenarios and mechanics can be seamlessly integrated into programming education. Such integration allows complex algorithmic concepts to be transformed into accessible and engaging tasks. In response to these challenges, gamification has increasingly been adopted in educational practice as a means of enhancing student engagement and fostering interactive learning environments. Gamification is generally defined as the incorporation of game-based elements – such as sequential tasks, interactive quizzes, and achievement reward systems – into non-game learning contexts. A growing body of research confirms that this approach can significantly improve student motivation and cognitive engagement, particularly in technical disciplines, by converting abstract programming concepts into game-like challenges, thereby facilitating deeper mastery of the subject matter.

In the context of the digital transformation of education in Kazakhstan, regarded as a strategic priority of national development, such methodological approaches are recognized as essential for creating a more accessible and stimulating learning environment [6]. Educational institutions across the country are actively adopting digital technologies to reduce the gap between the demands of the modern labor market and existing curricula. Parallel to the development of new forms of certification in education, increasing attention is being given to the use of blockchain technology, which has the potential to provide secure and verifiable digital certificates. Blockchain addresses the problem of data authenticity through a decentralized ledger system that is resistant to falsification, enabling students to obtain digital badges or certificates that confirm their competencies and skills without relying exclusively on traditional diplomas issued by schools, colleges, or universities. This technology enhances the recognition of learning outcomes, as it offers a transparent and trustworthy mechanism for verifying educational histories while simultaneously motivating students by providing tangible, demonstrable evidence of progress [7]. Furthermore, blockchain can be employed to store digital badges – micro-certificates awarded for specific educational achievements – which increases both their reliability and transferability. Badges recorded in a distributed blockchain ledger are protected from fraud and remain fully owned by the student, offering a novel means of credential recognition that can be shared across various platforms and institutional contexts. Research indicates that such mechanisms can boost learning motivation by providing students with visible and lasting evidence of their success [8].

Although the integration of blockchain technologies into Kazakhstan's education system remains at an early stage, there are already practical examples of their use in school settings, demonstrating the potential of this innovation to strengthen trust in educational institutions. In particular, within domestic online educational platforms, blockchain elements are increasingly regarded as effective tools for ensuring data transparency, academic integrity, and institutional reliability [9].

To empirically assess the effectiveness of the developed platform, an experimental study was conducted involving high school students from secondary schools in Kazakhstan. The experimental group learned the material using a gamified educational platform as part of the computer science curriculum, while the control group followed an identical program

delivered through traditional instruction. Participant selection was carried out on the basis of accessibility and voluntary consent, with strict adherence to ethical standards. During the experiment, students in the experimental group completed programming tasks in Python, where the control of game characters was achieved through writing code. This instructional format demonstrated a high degree of adaptability to programming tasks, thereby confirming the effectiveness of gamified environments as a tool for developing fundamental algorithmic skills.

The methodological framework of the study was based on a mixed-methods approach. To evaluate engagement and learning motivation, pre- and post-intervention questionnaires were administered, complemented by the analysis of activity indicators such as the number of completed tasks, frequency of system logins, and progression through levels. In addition, academic performance in computer science was recorded both before and after the intervention, enabling the identification of potential changes in learning outcomes.

The results confirmed that the gamified learning format, when combined with a blockchain-based system of digital badges, had a positive impact on students' motivation and their perception of the value of educational achievements.

The developed educational platform represents an integrated game-based environment designed to support programming instruction in Kazakhstani schools. It combines interactive elements – such as controlling characters through Python code –with the completion of practice-oriented programming tasks. This approach lowers entry barriers and makes the process of acquiring programming skills more appealing to beginners. Programming, therefore, can be regarded as one of the most promising domains for the application of gamified solutions, as game mechanics enable the transformation of abstract concepts into a practical and engaging format.

In addition, blockchain technology was incorporated into the platform to issue verifiable digital badges. According to participants in the experiment, this feature significantly enhanced the perceived value of earned rewards and exerted a strong motivational effect. Within the framework of the study, the following key research questions were formulated:

RQ1. How does the integration of gamified elements influence students' engagement and learning motivation in computer science education?

RQ2. In what ways do blockchain-based digital badges shape students' perceptions of the value of educational achievements and their willingness to pursue further learning?

RQ3. What advantages and limitations, from the perspectives of both students and teachers, characterize the use of such a gamified educational platform?

2. Materials and Methods

2.1. Research Design and Participant Selection

An experimental pilot study was conducted to investigate the impact of gamified learning and blockchain-based digital badges on student engagement, learning motivation, and academic performance. The primary objective was to compare the effectiveness of a gamified educational environment with that of a traditional instructional approach in the context of a secondary school computer science course. The study was carried out in Kazakhstan and involved two cohorts of 9th-grade students, both taught by the same computer science teacher. The experimental group (n = 42) utilized a gamified learning platform, whereas the control group (n = 44) was instructed using conventional methods. Both groups studied identical topics, specifically the section *"Programming Algorithms in Python"*.

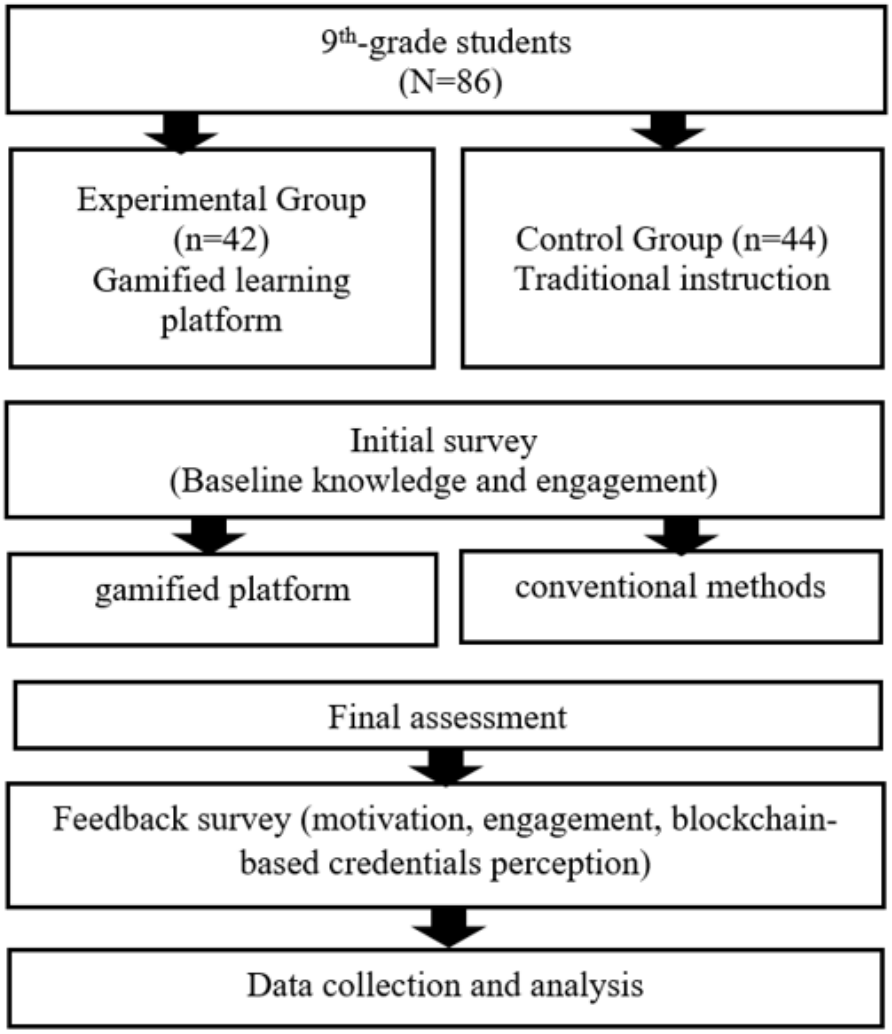

Figure 1.
Experimental Procedure.

To ensure comparability of conditions, educational materials, lesson content, and assignment deadlines have been standardized. The level of initial training was assessed based on the quarter grades received before the start of the study. The average score of the experimental group was 79.2%, and that of the control group was 78.6%, which revealed no statistically significant differences ($p = 0.74$). All participants had personal computers and had basic programming skills.

2.2. Educational Platform Design

For the purposes of this study, a previously developed gamified model was employed, designed as a multiplayer game in which students solved programming problems within an interactive environment. The platform enabled learners to write code, receive instant feedback, monitor their progress, access debugging support, and utilize hints or collaborative tools to engage with peers.

The platform was implemented using the Backbone.js framework (Figure 2) and connected to a prototype via a RESTful API. The programming challenges concentrated on fundamental topics, including loops, functions, and variables. Illustrative examples of these tasks are presented in Figure 3**.**

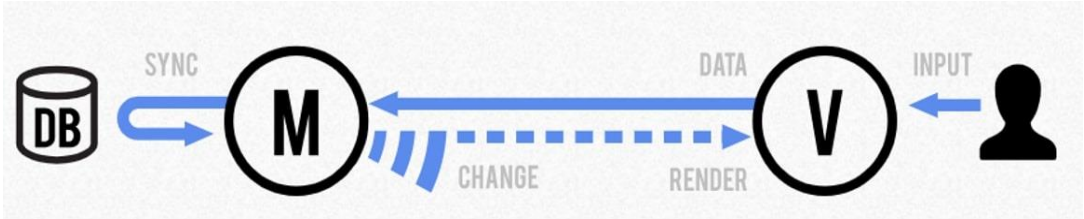

Figure 2.
Structural model of the gamified platform based on Backbone.js.

Both classroom lessons and homework assignments were embedded within the overarching storyline of the game, ensuring continuity between learning activities and the narrative context. In certain cases, individual student achievements were displayed publicly during class sessions in order to stimulate peer interest, encourage healthy competition, and

enhance overall motivation. By contrast, the control group completed the same set of tasks using conventional instructional tools, without the integration of game mechanics or additional motivational features. This contrast in learning conditions was designed to isolate the effect of gamified elements on engagement, persistence, and learning outcomes.

Figure 3.
Example of a loop-based programming task in the gamified platform.

2.3. Data Collection

The research adopted a mixed-methods framework, combining quantitative indicators with qualitative evidence to obtain a comprehensive view of student learning and motivation.

Following the intervention, all participants completed a standardized survey consisting of two validated instruments: (a) a student engagement scale and (b) a motivation scale. Both instruments applied a 5-point Likert response format, ranging from strongly disagree to strongly agree. Reliability analysis indicated strong internal consistency, with Cronbach's alpha values of 0.82 for engagement and 0.85 for motivation. Additional survey items measured course satisfaction and students' perceived learning gains. In the experimental group, additional data were obtained from platform activity logs, which tracked the number of completed programming tasks, participation in supplementary quizzes, and frequency of forum contributions. These indicators served as objective measures of behavioral engagement within the gamified setting.

To complement the survey data, the instrument included open-ended items that allowed participants to elaborate on their experiences. Furthermore, semi-structured focus group interviews were conducted with four students from each group. In addition, the computer science teacher participated in an interview to provide a practitioner's perspective on instructional feasibility and perceived effectiveness of the platform. Qualitative responses were coded thematically, highlighting student perceptions of game mechanics, enjoyment, competitiveness, and attitudes toward blockchain-based digital badges. Teacher feedback contributed additional contextual insights into classroom integration and pedagogical challenges.

Although exploratory in scale, the study employed a replicable framework for evaluating gamification and blockchain-based credentialing in authentic school settings. The combination of validated quantitative scales, platform usage data, and qualitative interviews offers a robust methodological basis for informing subsequent large-scale implementations and comparative studies.

3. Results

The pilot study yielded a detailed picture of how the gamified platform shaped learning processes in secondary school informatics classes. System log data from the experimental group demonstrated consistently high levels of engagement: students completed 92% of the required programming tasks, and 39 out of 42 participants (89%) attempted at least one additional assessment. Furthermore, 93% successfully solved optional exercises and achieved high performance, particularly in Python-related assignments.

Survey results also revealed clear differences between the experimental and control groups. The gamified class reported significantly higher engagement ($M = 4.6$, $SD = 0.4$) compared to the control class ($M = 3.5$, $SD = 0.6$). This difference was statistically significant, $t(56) = 8.22$, $p < 0.001$, with a large effect size ($d = 1.50$). Motivation scores followed a similar trend: the experimental group averaged 4.5, whereas the control group reported 3.7, again indicating a

significant difference ($p < 0.001$). Enjoyment levels were also substantially higher among the experimental participants ($M = 4.7$) relative to the control group ($M = 3.4$).

These findings suggest that the game-based learning environment provided by the platform fostered considerably stronger engagement and enjoyment compared to traditional instruction. The interactive features of the platform – such as progressive challenges, immediate feedback, and reward mechanisms – likely contributed to sustaining intrinsic motivation. However, while the higher enjoyment scores in the experimental group underscore the appeal of the platform, it remains uncertain whether such affective responses translate into deeper or more durable learning outcomes. Further longitudinal research is needed to evaluate the long-term educational impact of gamified approaches [10].

Comparative survey results are presented in Table 1, which illustrates the overall positive reception of the gamified methodology among students.

Table 1.
Comparative feedback scores from the pilot (Experimental vs. control group).

Measure	Experimental group (n = 42)	Control Group (n = 44)	t-value	p-value	Effect size (Cohen's d)
Engagement	4.6 (SD = 0.4)	3.5 (SD = 0.6)	8.22	< 0.001	1.50
Motivation	4.5 (SD = 0.5)	3.7 (SD = 0.5)	6.45	< 0.001	1.20
Enjoyment	4.7 (SD = 0.3)	3.4 (SD = 0.7)	8.90	< 0.001	1.60
Course satisfaction	4.6 (SD = 0.4)	3.6 (SD = 0.6)	7.85	< 0.001	1.40

To gain deeper insights into the platform's impact, student interaction was analyzed across three dimensions: behavioral (e.g., task completion), emotional (e.g., enjoyment), and cognitive (e.g., effort invested in understanding). As shown in Table 2, the experimental group outperformed the control group across all dimensions. The most pronounced difference was observed in emotional involvement, with the gamified students reporting a mean score of 4.8 compared to 3.3 in the control group ($p < 0.001$, $d = 1.67$).

Table 2.
Breakdown of Engagement Dimensions (Experimental vs. control group).

Engagement Dimension	Control Group (M, SD)	Experimental group (M, SD)	t-value	p-value	Cohen's d
Behavioral	3.6 (0.5)	4.5 (0.4)	7.14	< 0.001	1.30
Emotional	3.3 (0.7)	4.8 (0.3)	9.18	< 0.001	1.67
Cognitive	3.7 (0.6)	4.4 (0.5)	4.92	< 0.001	0.89

The final evaluation of content mastery was administered in written form for both groups. Analysis of the outcomes revealed that students in the gamified condition demonstrated superior learning performance compared to their counterparts in the traditional classroom. The experimental group achieved an average score of 84.3, surpassing the control group's mean of 78.6. Furthermore, 43% of students in the gamified cohort earned grades of 90 or above, whereas only 20% reached this benchmark in the control group. Even the lowest-performing student in the gamified class obtained a score of 68, which was higher than the lowest score of 60 recorded in the traditional setting. These findings provide empirical support for the effectiveness of integrating game-based elements into the instructional process as a means of enhancing overall academic achievement.

A more detailed analysis by task type indicated that students in the gamified class performed significantly better on practical programming exercises, with an average of 85% compared to 77% in the control group ($p < 0.01$). This improvement appears closely tied to the interactive, practice-oriented design of the gamified platform. By contrast, the difference on theoretical questions was smaller – 83% for the experimental group versus 80% for the control group – and failed to reach statistical significance ($p > 0.1$). These results suggest that while gamification is particularly effective in strengthening applied programming skills, its impact on theoretical knowledge acquisition remains limited.

Qualitative feedback added further depth to these findings. Students in the experimental group repeatedly emphasized the value of instant feedback and the motivational effect of progression systems, which made the learning process more dynamic and rewarding. Additionally, when the potential application of blockchain for securely recording and validating achievements was introduced, 68% of participants expressed enthusiasm for verifiable and shareable credentials. Many noted that such records could both highlight their strengths and identify areas for improvement, thereby enhancing the personal relevance of their learning experience.

Table 3 provides a synthesis of the dominant themes from student feedback, offering a comprehensive perspective on the most valued dimensions of the gamified learning environment.

Table 3.
Thematic Analysis of Qualitative Feedback from Gamified Class.

Theme	Student Perspective	Percentage
Instant feedback	"It was motivating to see right away if my code worked or not."	72%
Sense of progression	"Leveling up made me feel like I was really achieving something, not just doing homework."	65%
Practical skill development	"The practice tasks helped me understand programming better than theory alone."	61%
Blockchain-based credentials	"I liked the idea that my progress could be officially tracked and shared – it feels more valuable."	68%
Increased engagement	"It didn't feel like a boring class, it felt like a challenge I wanted to win."	70%

Teacher feedback indicated that the overall implementation of the gamified platform was largely smooth. Students demonstrated high levels of activity, with many requesting additional learning opportunities beyond the planned tasks. Minor technical issues were observed during the initial phase, such as login difficulties, but these were quickly resolved. To address concerns about competitiveness, optional anonymous features (e.g., hidden score displays) were introduced to reduce pressure for students who felt uncomfortable with public ranking.

Although the experimental group exhibited only moderate improvements in academic performance compared to the control group, their levels of participation and engagement in hands-on practice were substantially higher. These findings suggest that the platform was particularly effective in fostering active learning behaviors during practical exercises, even though comprehension of lecture-based content remained largely comparable across both groups.

4. Discussion

The results of this pilot study provide strong evidence for the effectiveness of gamified learning environments in secondary school computer science education. Incorporating game-based elements into instruction produced a marked increase in both motivation and engagement compared to traditional methods. Students in the experimental group demonstrated nearly three times the level of active participation and interest, highlighting the potential of such platforms as transformative tools for classroom practice.

By leveraging an interactive, multiplayer format, routine programming tasks were reframed as engaging challenges, which enhanced students' willingness to participate. The gamified class consistently exhibited greater involvement in lessons and activities, underscoring that game-based learning not only makes education more enjoyable but also more effective. In this way, the classroom was transformed from a passive learning environment into an active and productive space where students could thrive [11].

RQ1: How does the integration of gamified elements influence students' engagement and learning motivation in computer science education?

The first research question (RQ1) investigated the impact of gamified elements on student engagement and motivation in informatics lessons. The results revealed a substantial positive effect. Learners in the experimental group reported markedly higher engagement, with a mean score of 4.6 compared to 3.5 in the control group ($p < 0.001$, $d = 1.50$). Motivation outcomes showed a similar trend, with the gamified class averaging 4.5 versus 3.7 in the traditional classroom ($p < 0.001$). Furthermore, peer dynamics appeared to amplify these effects, as many students indicated that observing their classmates' progress encouraged them to participate more actively.

RQ2: In what ways do blockchain-based digital badges shape students' perceptions of the value of educational achievements and their willingness to pursue further learning?

The second research question (RQ2) was explored through students' responses regarding blockchain-based achievement records. Approximately 68% of participants expressed interest in obtaining blockchain-verified credentials, emphasizing that such records would render their accomplishments more official and easily shareable, thereby enhancing their motivation. Some students also highlighted the appeal of showcasing their competencies with trusted certification, even if they had not yet mastered the technical aspects of blockchain.

These observations align with prior research demonstrating that verifiable digital badges can strengthen learners' sense of ownership over their progress and provide tangible recognition for micro-achievements [12]. From a psychological perspective, the ability to display blockchain-backed accomplishments can create a perceived increase in both social and academic capital, reinforcing positive learning behaviors. Nevertheless, many students admitted having only limited knowledge of the underlying technology, suggesting that additional digital literacy support is necessary [11]. This raises a critical consideration: digital badges may lose motivational value if students do not fully understand or trust the supporting technology. Furthermore, excessive reliance on extrinsic validation mechanisms could undermine intrinsic motivation if badges are perceived merely as external rewards rather than authentic indicators of personal growth.

RQ3: What advantages and limitations, from the perspectives of both students and teachers, characterize the use of such a gamified educational platform?

From a practical perspective, the platform demonstrated strong usability, requiring minimal technical instruction from instructors. Even students who were typically reserved became more active and frequently requested additional tasks in order to "level up." The majority of participants (79%) indicated that the system was easy to use, while 68% appreciated the collaborative features and progress-tracking functions. These outcomes illustrate a key strength of gamified systems: they promote inclusivity and learner-driven engagement through low-barrier participation and embedded social motivation

mechanisms. Features such as visual progress bars, point accumulation, and collective class challenges appeared to democratize classroom participation, particularly for students who are usually less active in conventional settings [13]. This aligns with prior findings in the gamification literature, which highlight gains in autonomy, relatedness, and engagement when learners interact with systems that provide meaningful feedback and goal-oriented progression.

Nevertheless, several drawbacks were also observed. A small number of students (n = 4) reported experiencing stress linked to leaderboard standings. This challenge was addressed through the implementation of anonymous scoring, which reduced pressure but also highlighted the dual role of competition: while motivating for some, it may act as a stressor or deterrent for others. Therefore, gamification design should carefully balance challenge with inclusivity, avoiding mechanisms that encourage excessive comparison. Instructors should remain attentive to individual differences in personality and stress sensitivity when adopting such approaches.

Technical challenges were minimal and primarily limited to initial login difficulties, which were promptly resolved and did not interfere with the flow of learning. However, these instances emphasize the importance of robust infrastructure when considering large-scale implementation. Broader deployment – particularly within public schools where device heterogeneity is common – may face greater obstacles. To ensure equitable access across diverse educational contexts, future iterations of the platform should integrate offline access, mobile compatibility, and backup protocols [14].

The findings indicate that such a gamified learning system can be particularly valuable in secondary education, especially in disciplines requiring the integration of theoretical understanding with applied practice. The platform not only supports comprehension of abstract concepts but also facilitates the acquisition of practical experience. Its interactive design sustains student engagement, making the learning process more hands-on and dynamic. Furthermore, the flexibility of the platform allows for seamless adaptation to future technological enhancements, such as more sophisticated progress-tracking mechanisms [15, 16].

Blockchain technology presents considerable potential in this context by providing a secure and transparent framework for documenting student achievements. Once recorded, the data cannot be easily altered, which enhances the credibility of the records and fosters trust among users. This mechanism could also strengthen connections between schools, students, and higher education institutions by enabling the issuance of reliable, verifiable credentials [17].

To fully evaluate the educational value of blockchain, further research is required in more diverse contexts. Student needs and learning behaviors differ across age groups, cultural backgrounds, and learning styles. Large-scale studies may therefore help to clarify whether blockchain contributes to higher engagement, facilitates skill acquisition, and better prepares students for future educational and professional challenges.

Nevertheless, blockchain is not a universal solution and presents certain limitations. Challenges include safeguarding data security, integrating blockchain with existing institutional systems, and ensuring equitable access for all learners [18]. Addressing these issues will require significant effort, yet their resolution has the potential to generate substantial improvements in the education system. If implemented effectively, blockchain could simplify learning processes, enhance skill development, and accelerate the integration of innovative practices into education in Central Asia [18]. Given the region's ongoing transformation, blockchain has the potential to make these changes more effective, transparent, and equitable.

This study has several limitations that should be acknowledged. The relatively small sample size and the short duration of the intervention constrain the generalizability of the findings. Although the initial results are promising, broader investigations across multiple schools and diverse geographical contexts are necessary to validate the applicability of these outcomes on a larger scale. Future research should also examine long-term knowledge retention, the professional development and training requirements for teachers, and the potential for extending the platform to other subject domains.

5. Conclusion

This study provides new evidence that gamified learning environments can substantially improve student engagement, motivation, and performance in secondary school computer science education. The findings extend previous work on gamification, which has largely concentrated on higher education, by demonstrating its effectiveness in middle and high school contexts. Moreover, the integration of blockchain-based credentialing introduces an innovative dimension, linking interactive learning systems with secure and verifiable recognition of student achievement. This highlights the potential of such platforms not only as pedagogical tools but also as instruments for building digital trust in education.

From a practical perspective, the platform proved user-friendly and required minimal teacher training, making it scalable across diverse educational environments. Even typically less active students became more engaged, showing that gamification can democratize participation and foster inclusivity. Features such as progress tracking, levels, and collaborative tasks gave learners a tangible sense of progress and autonomy. These characteristics are especially relevant for schools in Central Asia, where technological infrastructure is often heterogeneous, and flexible solutions are essential. The use of blockchain for issuing verifiable digital badges further increases the value of student accomplishments by providing credentials that may be recognized beyond the school setting.

Despite the positive outcomes, this pilot study was limited by sample size and duration, suggesting that further research is required to generalize the findings. Larger-scale investigations, extended observation periods, and cross-subject applications will be necessary to fully assess the long-term impact of gamification on learning outcomes. Future studies should also explore differences across cultural, gender, and socio-economic groups and examine how to balance intrinsic and extrinsic forms of motivation within gamified systems. By addressing these questions, the approach outlined here has the potential to inform educational practice not only in Kazakhstan but also in comparable contexts worldwide.

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