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Gamification in Biology Teacher Education: Bibliometric Analysis and Student Perceptions

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ABSTRACT: Gamification, defined as the integration of game design elements into educational contexts, has gained increasing attention for its potential to enhance student motivation, engagement, and learning outcomes. Despite growing research interest, limited evidence exists regarding the implementation of gamification in biology teacher education, particularly studies that integrate bibliometric analysis with empirical investigation. Grounded in Self-Determination Theory (SDT), this study examined global research trends in gamification and explored the awareness, experiences, and perceptions of future biology teachers regarding gamified learning. A mixed-methods approach was employed, combining a bibliometric analysis of 144 peer-reviewed publications indexed in Scopus, Web of Science, and PubMed between 2017 and 2024, following the PRISMA 2020 guidelines, with a questionnaire survey of 104 undergraduate students enrolled in the Biology Teacher Education program at Abai Kazakh National Pedagogical University during the 2025–2026 academic year. VOS viewer software was used to analyses keyword co-occurrence networks. The bibliometric analysis revealed a steady increase in publications and identified four major research themes: biology and computational applications, decision-making and socialization, game theory and learning processes, and curriculum-related gamification. The survey results indicated that 80.6% of students were familiar with gamification, while 67.0% reported internet-based games as the most commonly used instructional approach in biology education. Chi-square analysis revealed significant differences in gamification awareness across academic years ($p < 0.001$). However, students demonstrated limited practical experience in designing and implementing gamified learning activities independently. The alignment between bibliometric trends and student perceptions highlights the growing importance of gamification in biology teacher education while revealing a gap between theoretical knowledge and practical competence. These findings underscore the need for the systematic integration of gamification competencies into biology teacher education curricula and provide valuable evidence to support future curriculum development and educational practice.

Keywords: Gamification, Biology teacher education, Bibliometric review, Game-based learning, Student engagement, Educational technologies.

I. INTRODUCTION

In recent years, traditional learning formats have undergone significant transformation across all stages of education. The COVID-19 pandemic substantially accelerated the demand for online learning in higher education. However, the adoption of digital tools as substitutes for traditional instruction, alongside the

introduction of electronic textbooks and learning platforms, has presented higher education institutions with the unique challenge of rethinking their educational approaches. In this context, the need for interactive and student-centred teaching methods has become particularly relevant [1, 2]. To ensure high-quality learning, teachers must motivate students to participate actively and provide them with opportunities to develop creativity, initiative, and both cognitive and personal growth. Therefore, modern teaching should incorporate interactive, engaging, and stimulating methods that support active learning. One of the most effective strategies for motivating students is to integrate gamification principles into the learning and assessment process [3, 4, 5]. The role of gamification in supporting learning motivation has been widely discussed in the scholarly literature [6, 7, 8].

The integration of digital technologies into educational and scientific processes enhances their efficiency, accessibility, and adaptability. In this context, gamification has emerged as an important pedagogical approach that incorporates game design elements into non-game educational environments to improve learning outcomes and student engagement [9, 10, 11]. The use of gamification in education involves game elements such as scores, rewards, levels, and feedback to increase student motivation and achievement [6, 7, 12]. Gamification methods rooted in active learning principles offer an alternative to passive instruction and serve as a driver of student engagement. Previous research has shown that gamified learning environments can improve student motivation, engagement, and academic achievement [2, 8, 10]. Despite growing scholarly attention, convincing empirical evidence on the effectiveness of gamification across diverse educational contexts remains limited [1, 13]. Gamified learning therefore represents a promising strategy for improving academic performance and creating an integrated educational environment. Its potential includes increasing motivation, consolidating knowledge, and developing critical thinking and problem-solving skills.

1. THEORETICAL FRAMEWORK

This study is theoretically grounded in Self-Determination Theory (SDT), developed by Ryan and Deci [14], which provides the most analytically robust framework for explaining the motivational mechanisms underlying gamification in educational contexts. SDT posits that human motivation is optimised when three fundamental psychological needs are satisfied: autonomy (the experience of volition and self-direction in learning), competence (the perception of effectiveness and mastery), and relatedness (the sense of connection and belonging within a learning community). These three needs are directly applicable to gamified learning environments, making SDT a particularly appropriate theoretical lens for the present study.

Within the SDT framework, gamification elements can be mapped onto each of the three basic psychological needs. Autonomy is supported through game mechanics that allow students to choose their own learning paths, set personal goals, and progress at their own pace-for example, open-ended quests, voluntary challenges, and branching scenarios. Competence is reinforced through immediate and informative feedback (scores, badges, level progression), which signals achievement and mastery of subject content. Relatedness is fostered through collaborative and competitive game elements such as leaderboards, team-based challenges, and peer interaction, which create a shared learning community among future biology teachers.

SDT further distinguishes between intrinsic motivation (engagement driven by inherent interest and satisfaction) and extrinsic motivation (engagement driven by external rewards or recognition). Poorly designed gamification that relies exclusively on extrinsic rewards-such as points and badges with no pedagogical rationale-risks undermining intrinsic motivation through the overjustification effect. Conversely, gamification that supports autonomy, provides competence-relevant feedback, and encourages collaborative interaction aligns with SDT principles and has been shown to sustain long-term intrinsic motivation and deeper learning engagement [14]. This distinction is particularly relevant in teacher education, where developing intrinsic professional motivation is a key goal.

It is important to distinguish between several related concepts used throughout this study. Gamification refers to the use of game design elements such as points, badges, levels, and leaderboards in non-game educational contexts. Game-based learning involves the use of complete educational games specifically

designed to support learning outcomes. Serious games are developed primarily for educational or training purposes, while digital learning environments represent broader technological platforms that may incorporate gamification and game-based learning strategies. These distinctions are important because SDT applies differently across these formats: gamification primarily targets extrinsic-to-intrinsic motivational progression, whereas game-based learning and serious games can more directly activate intrinsic motivation through narrative immersion and problem-solving.

Based on SDT, the conceptual framework of this study proposes that gamification influences the professional development of future biology teachers through three interconnected mechanisms: (1) enhancement of intrinsic motivation through need-supportive game elements; (2) increased engagement and active participation enabled by immediate feedback and goal structures; and (3) development of professional competencies through collaborative and self-directed gamified tasks. This framework guided both the bibliometric analysis in terms of identifying SDT-relevant thematic clusters-and the design of the empirical survey, which examined students' awareness, engagement, and motivational attitudes toward gamification (see Figure 1).

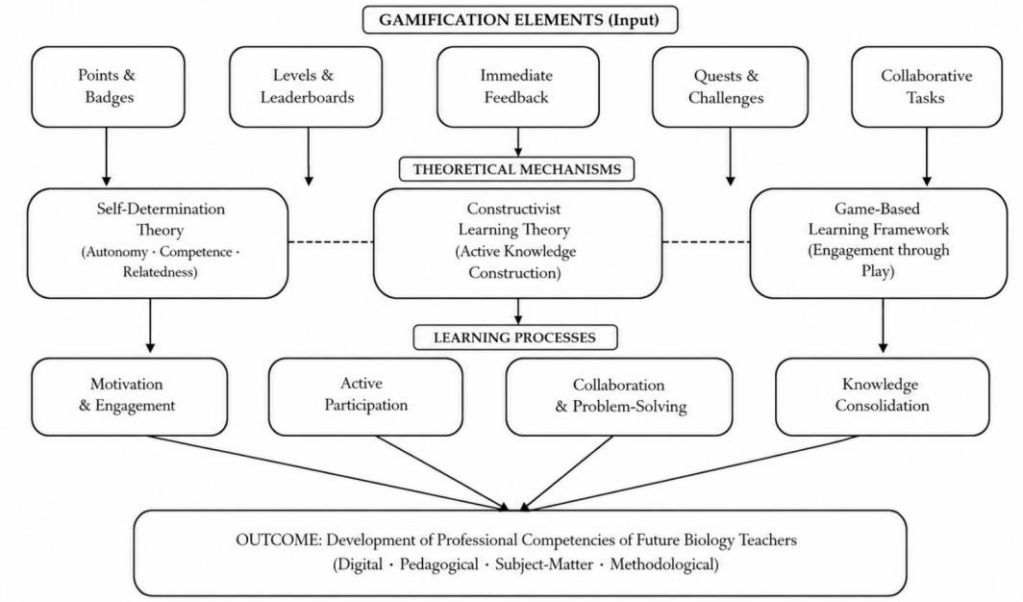

FIGURE 1. Conceptual model of gamification in biology teacher education.

2. *RESEARCH GAP*

Despite the growing number of studies on gamification in education, limited evidence exists regarding its implementation in biology teacher education, particularly in Kazakhstan. Furthermore, previous studies have often focused either on bibliometric reviews or on classroom-based interventions. To the best of our knowledge, very few studies have integrated bibliometric analysis with empirical survey data to examine both global research trends and students' perceptions of gamification in biology teacher education. Therefore, this study seeks to address this gap by integrating these two approaches.

The novelty of the present study lies in the integration of bibliometric analysis and empirical survey data within the context of biology teacher education. Unlike previous studies that have focused either on literature reviews or classroom-based interventions, this research combines both approaches to provide a comprehensive understanding of global research trends and students' perceptions of gamification. This integrated perspective contributes new evidence regarding the current state and future development of gamification in biology teacher education.

II. LITERATURE REVIEW

Understanding gamification requires first examining the broader concept of play and games. The term game is considered an integral element of human nature, encouraging interaction, collaboration, and engagement [15, 16]. Among the new game-based learning methods that have emerged and gained widespread adoption, gamification occupies a central place. The term gamification was coined in 2002 by British game designer Nick Pelling and gained broad popularity by 2010, since when it has developed as an interdisciplinary concept applied in education, business, healthcare, and other fields [9, 10, 12]. It is now being implemented across a wide variety of domains. In education specifically, gamification is used as a pedagogical tool aimed at increasing students' motivation, engagement, and learning outcomes.

Gamification involves the use of game elements in non-game contexts, especially in an educational environment. It typically includes elements such as scores, badges, levels, leaderboards, and feedback mechanisms [6, 9, 11]. Numerous studies demonstrate that gamification can significantly increase students' motivation and engagement [4, 8, 17]. Learning through gamification, especially with digital technologies, promotes creativity, problem-solving skills, and deeper subject understanding [2, 5, 18]. The rapid development of digital technologies in education has driven the adoption of innovative learning approaches; however, for successful implementation it is important to ensure that the pedagogical benefits of gamification outweigh its potential limitations [1, 13]. Gamification can also significantly influence student engagement and learning outcomes. A number of bibliometric reviews confirm that game design elements play a crucial role in shaping motivation, participation, and collaboration in an educational environment [8, 9, 11]. Research also highlights its potential to improve knowledge acquisition and collaborative learning [2, 19]. Gamification enables students to increase learning efficiency and sustain interest over time. According to Karavaev and Soboleva, gamification represents “a modern element of creating a digital educational environment” [20]. Shelomova and Kotlyarova [21] note that gamification can be applied at all stages of the learning process, including assessment and consolidation of knowledge.

Matonin [22] identifies key elements of gamification-motivation, feedback, and interaction-which contribute to improving student achievement and engagement. Students often exhibit low motivation for routine academic tasks, while showing a clear preference for interactive and playful activities [4, 23]. Both Kazakhstani and international researchers emphasise the role of gamification in increasing students' motivation, engagement, and interest in the learning process [24, 25, 26]. Ovchinnikov [27] also highlights the effectiveness of gamification in stimulating cognitive activity and fostering deeper understanding of educational material.

Despite the predominantly positive results, some studies show that online learning can lead to negative consequences, such as frustration or decreased intrinsic motivation in certain groups of students [13, 28]. Nevertheless, the overall benefits of gamification, including improved problem-solving, decision-making, and knowledge retention, are consistent with the broader goals of modern education. The researchers also emphasize that gamification, as a student-centered approach, can be a more effective means of engagement and integration compared to traditional teaching methods [29, 30]. However, despite its recognized advantages, there is still insufficient empirical evidence regarding the optimal implementation of gamification in the educational context. For example, there is still a lack of comprehensive data on the impact of gamified learning on student interaction and long-term learning outcomes [29, 31, 32]. Moreover, the mechanisms by which gamification promotes knowledge acquisition and skill development have not yet been fully understood. As a result, inconsistencies can be observed in all studies, especially regarding student attitudes, satisfaction, and learning effectiveness.

The advantages and positive aspects of gamification in education have also been thoroughly studied by Kazakhstani researchers. In particular, the use of game elements to increase interest and motivation in various subjects was studied. These conclusions are also supported by research on the education of biology teachers in Kazakhstan, which highlights the importance of practice-based learning and the integration of innovative learning approaches in the development of professional competencies [33].

One of the key researchers of game-based learning in Kazakhstan is Akhmetov, author of the book "Technology for Creating Educational Games", which examines in detail the development and application

of educational games in the learning process [34]. The role of gamification in secondary and higher education is also explored in the works of Orazbaikyzy and Ilyassova, who note the continuous growth in the number of services and platforms incorporating gamification elements [24]. Tokzhigitova et al. investigate gamification as a method for improving learning activity and student motivation; drawing on a sample of more than 150 students, they evaluate participant satisfaction and attitudes towards gamification approaches [25]. Polulyakh examines the role of gamification in increasing student interest in biology, arguing that through assignments, quizzes, and quests, students not only memorise material but also develop their ability to understand and critically analyse it; gamification is therefore recommended as an effective means of introducing innovation into biology teaching [35].

Gamification can be implemented in both online and offline learning environments. Key features include the accumulation of points, a feedback system, and the ability to repeat tasks that help reduce anxiety and increase motivation [6, 11]. Games are usually divided into serious and non-serious (entertainment) ones. Serious games are primarily intended for educational and training purposes. In contrast, non-serious games are designed primarily for entertainment and are not aimed at achieving educational goals [36]. Serious games can also be divided into digital and non-digital games. Digital games can include immersive technologies such as virtual and augmented reality that increase user engagement [37, 38].

This bibliometric review was therefore conducted to synthesise current evidence on the use of game-based learning methods with varying designs and methodologies. The findings enable identification of effective gamification approaches and highlight potential challenges in their implementation, thereby providing useful guidance for educators and stakeholders in biology education. A bibliometric search was performed in peer-reviewed journals focused on gamified learning, and the results were synthesised to inform future research directions.

III. METHODS

This study aimed to identify current trends in the use of game-based learning in the educational process. To this end, a mixed-methods approach was employed, combining a bibliometric literature review with a student survey. This combination was chosen to enable a comprehensive analysis of both the theoretical landscape and the practical dimensions of gamification in biology education. The study drew on scientific works by both Kazakhstani and international researchers regarding the application of gamification in biology education. In line with the research goals, the following research questions were formulated:

- RQ1: How relevant is the application of gamification in academic publications within the specified time frame?
- RQ2: To what extent has gamification technology been addressed in global studies from 2017 to 2024?
- RQ3: What is the level of student engagement with gamification in biology education?

Bibliometric Search Strategy:The bibliometric review was conducted following the PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. The literature search was performed in three international databases: Scopus, Web of Science, and PubMed. The search query used the following Boolean operators and keywords: (“gamification” OR “game-based learning” OR “serious games”) AND (“biology education” OR “biology teaching” OR “biology teacher education” OR “science education”). The search covered publications published between 2017 and 2024. Only peer-reviewed journal articles and conference proceedings published in English were considered.

The inclusion criteria were: (1) studies focused on gamification or game-based learning; (2) studies related to biology education, science education, or teacher education; (3) empirical, review, and bibliometric studies; and (4) publications indexed in Scopus, Web of Science, or PubMed.

The exclusion criteria were: (1) duplicate publications; (2) studies unrelated to education; (3) publications without full-text access; and (4) editorials, book reviews, and non-peer-reviewed sources.

The initial search identified 2,576 records. After screening titles and abstracts and removing duplicate records, 320 publications remained for eligibility assessment. Following full-text review, 144 studies met the

inclusion criteria and were included in the final bibliometric analysis. The PRISMA 2020 flow diagram illustrating the study selection process is presented in Figure 2.

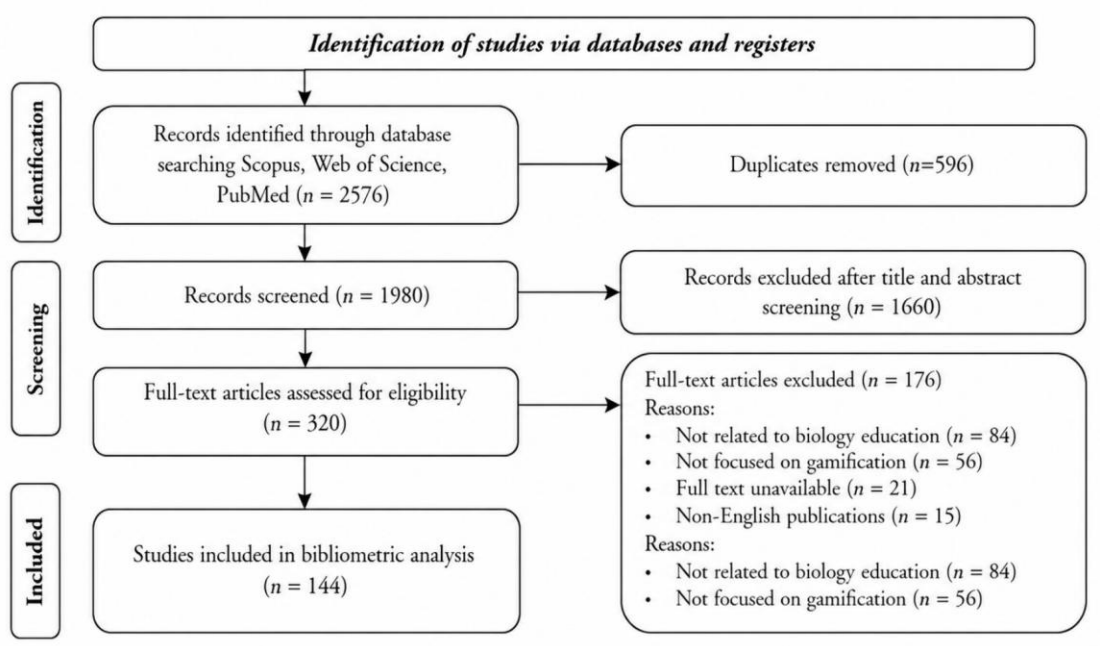

FIGURE 2. PRISMA 2020 flow diagram of the study selection process.

To answer the first two research questions, a bibliometric review was conducted. This method was selected because it enables a structured analysis and synthesis of a large body of scientific literature, as well as the identification of key trends, gaps, and patterns in previous research. In addition, elements of bibliographic analysis were employed to examine the dynamics and thematic focus of publications on gamification in education.

The second method used in the study was a survey, which was aimed at obtaining empirical data on students' awareness, experience and attitudes towards gamification. The use of the survey method complements the bibliometric review by providing insights into the practical application of gamification and the perceptions of future teachers. Thus, the combination of these two methods ensures a more comprehensive understanding of the research problem by integrating theoretical analysis with empirical evidence.

The empirical part of the study included a survey conducted among students of the Faculty of Natural Sciences and Geography at Abai Kazakh National Pedagogical University. The survey was carried out during the 2024–2025 academic year. A total of 104 students participated in the study. Among them, 43 were first-year students, 11 were second-year students, 25 were third-year students, and 18 were fourth-year students. Seven respondents did not provide sufficient information regarding their year of study and were therefore excluded from analyses comparing year groups. Consequently, year-group analyses were conducted using data from 97 participants. A convenience sampling strategy was employed in this study. All participants were enrolled in the biology educational program and voluntarily agreed to participate in the survey. The sample was considered appropriate for obtaining exploratory data regarding students' awareness, experiences, and perceptions of gamification in biology teacher education. Participants ranged in age from 18 to 23 years (M=20.4 years). The sample size was determined by the number of students enrolled in the biology teacher education programme who voluntarily agreed to participate during the data collection period. For exploratory descriptive research, the obtained sample was considered sufficient to identify general trends and patterns related to students' awareness, experiences, and perceptions of gamification.

The survey was conducted in a structured format and consisted of five questions aimed at identifying students' understanding of gamification, their experience in using game-based elements in biology classes, and their motivation to engage with gamified learning environments. The questionnaire included both closed and semi-open questions, allowing for both quantitative and qualitative analysis of responses. The full text of all five survey questions, including the original Kazakh/Russian wording and English translations of all response options, is provided in Supplementary Appendix A. The survey included questions about the types of games that are most often used in biology teaching, about students' theoretical understanding of gamification in the educational process, about the practical experience of teachers using game elements in specialised classes, about specific academic courses where students acquired skills in creating educational Internet games, as well as about which game mechanics most effectively motivate students to acquire scientific knowledge. The data was collected using an online questionnaire developed by the authors and administered using Google Forms https://forms.gle/3WDPQDZm4GFwqQqt6.

The questionnaire was developed by the authors in collaboration with the scientific supervisor, whose expert review ensured the content validity and relevance of all questionnaire items prior to distribution. Since the questionnaire consisted of five categorical and semi-open items measuring distinct aspects of gamification awareness, experience, and motivation rather than a single latent construct, the calculation of internal consistency measures such as Cronbach's alpha was not applicable to this instrument. Instead, content validity was ensured through collaborative development and expert review by the scientific supervisor, which are recognized as appropriate validation procedures for exploratory descriptive questionnaires [1].

Prior to the main data collection, the questionnaire underwent expert review involving specialists in biology education and educational technology. Based on their recommendations, minor modifications were made to improve clarity, relevance, and comprehensibility of the survey items. It should be noted that a formal pilot study with a separate participant group was not conducted; expert review was considered a sufficient validation procedure for an exploratory descriptive questionnaire of this scope. The final version of the questionnaire was considered suitable for exploratory descriptive research and adequately reflected the objectives of the study.

For the open-ended questions (Q4 and Q5), the coding procedure was independently conducted by two researchers. Inter-rater reliability was assessed using Cohen's kappa coefficient. For Question 4, Cohen's kappa was $\kappa = 0.84$, indicating strong agreement (88.5% agreement). For Question 5, Cohen's kappa was $\kappa = 0.87$, indicating strong agreement (91.3% agreement). Any discrepancies in coding were resolved through discussion until consensus was reached.

The collected data were analyzed using descriptive statistical methods. The responses were grouped into categories, and the frequency of each response was calculated as a percentage of the total number of participants. This approach made it possible to identify general trends, compare responses across different student groups and evaluate the level of awareness and engagement with gamification. In particular, the aim of the survey was to:

- Identify general student understanding of gamification in the learning process;
- Determine which games are used in teaching biology;
- Identify students' skills in creating online games;
- Determine which gamification elements are most frequently used and which types of games motivate students to acquire knowledge.

Participation in the study was voluntary, before completing the questionnaire, all participants were informed about the purpose of the study and the anonymous nature of data collection. Informed consent was obtained from all respondents. No personally identifiable information was collected. All data were analyzed in aggregated form and used exclusively for scientific purposes. The study complied with the ethical principles of educational research, including confidentiality, anonymity, and voluntary participation.

The study was reviewed and approved by the Research Ethics Council of Abai Kazakh National Pedagogical University (Almaty, Kazakhstan). Ethical approval for this research was granted on 08 October

2025. The research was conducted in accordance with the Ethical Code of Educational Researchers of the Republic of Kazakhstan and institutional ethical guidelines.

IV. RESULTS

At the selection stage of the bibliographic analysis, online databases such as Scopus, Web of Science, and PubMed were used. In the initial screening from 2017 to 2024, a total of 2576 articles related to the use of games in the educational process were found. To ensure a more accurate selection of scientific articles, the following criteria were applied:

- Articles had to be published between 2017 and 2024;
- The field of education, particularly biology teaching, had to be covered;
- Priority was given to articles published in English and to conference proceedings.

As a result, 144 articles were reviewed at the selection stage (2017-2024) (see Figure 3). A year-by-year breakdown shows a steady increase in the number of publications from 2017 (n=11) to 2024 (n=26), with only a temporary dip in 2022 (n=17), followed by a renewed increase. This trend indicates that the use of gamification in biology education remains a relevant and timely topic.

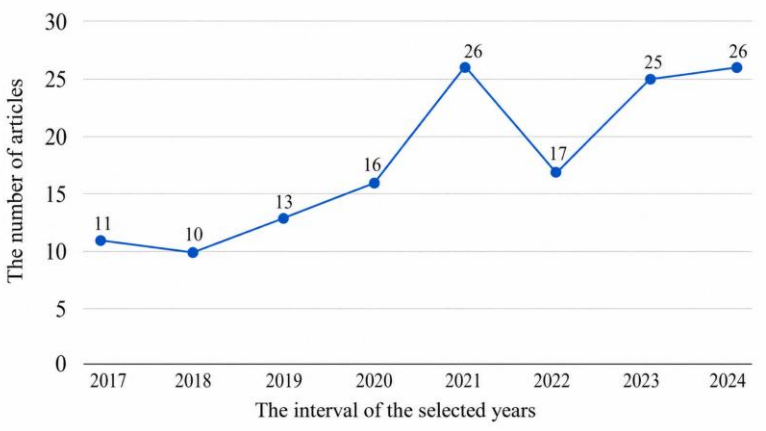

FIGURE 3. Annual distribution of reviewed publications on gamification in biology education (2017–2024)

Furthermore, a bibliographic analysis of the content of the selected scientific works was conducted. At the summarizing stage, a conclusion based on the analysis was prepared. The VOSviewer analysis processed the full keyword dataset extracted from titles and abstracts of all 144 included articles. After applying the minimum co-occurrence threshold of five occurrences per term, the software identified 829 unique keyword items in total across the dataset; of these, 32 terms met the threshold and were retained for network visualization (referred to here as '32 network nodes' or 'retained keyword groups'). The terms that did not meet the threshold were excluded from the network map but remained in the full keyword inventory. The resulting co-occurrence network is presented in Figure 4. For this analysis, scientific articles and abstracts were exported from the Scopus, Web of Science, and PubMed online databases. The data were then imported and processed using the VOSviewer software. VOSviewer is a computer program used to create bibliometric maps and visualize research findings [39]. For keyword co-occurrence analysis, a minimum threshold of five occurrences per keyword was applied. Keywords were normalized using the association-strength method built into VOSviewer, and plural or variant forms (e.g., “gamification” / “gamify”) were manually merged prior to network construction. With the help of VOSviewer, the frequency of terms such as “biology teaching”, “education”, and “gamification” appearing in the article titles and abstracts was tracked in the dataset.

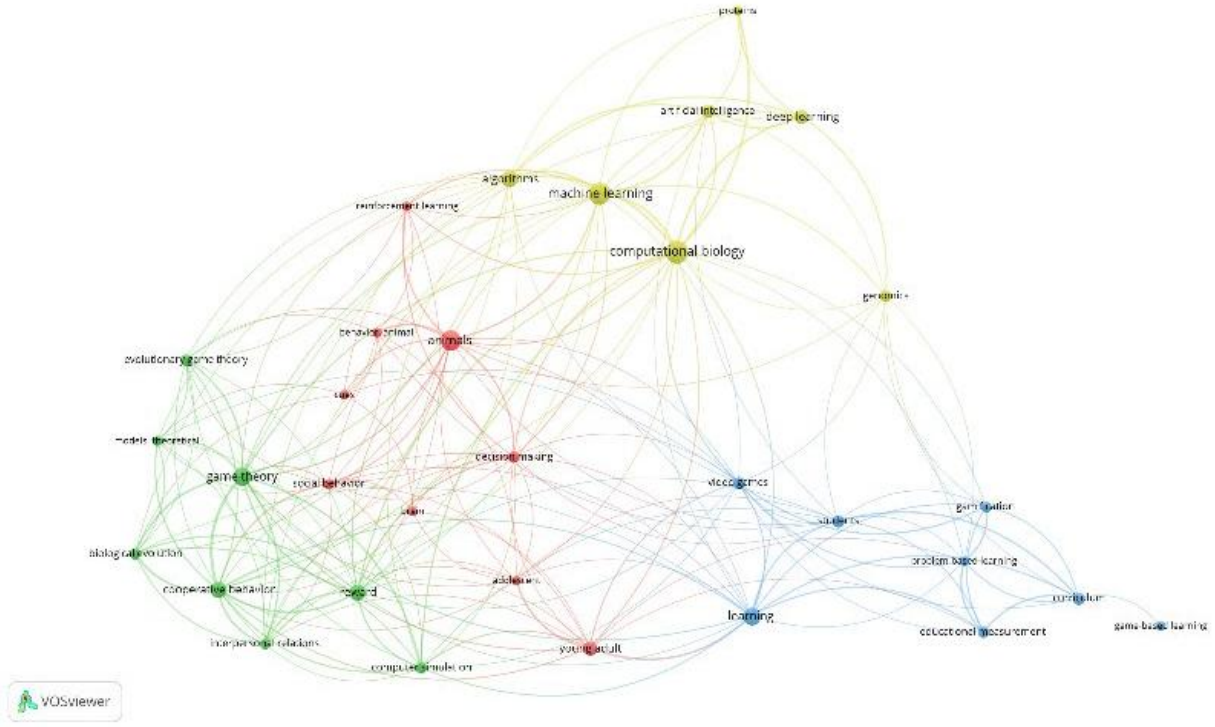

FIGURE 4. Network visualization of keyword co-occurrence based on selected publications (VOSviewer).

According to Figure 4, VOSviewer's automatic clustering algorithm (using the modularity-based community detection method built into the software) identified four thematic clusters, each automatically assigned a distinct colour by the software (yellow, red, green, and blue). The cluster labels used in this paper are descriptive interpretations assigned by the authors based on the dominant topics within each cluster; they were not generated automatically by VOSviewer:

- Yellow cluster (7 items, 192 occurrences): covers topics such as biology, genetics, algorithms, artificial intelligence, and more.
- Red cluster (9 items, 133 occurrences): includes topics such as animals, decision-making, socialization, etc.
- Green cluster (8 items, 252 occurrences): includes topics such as game theory, biological evolution, computer simulation, group learning, assessment, interpersonal relationship, and more.
- Blue cluster (8 items, 149 occurrences): covers topics such as curriculum, gamification, game-based learning, learner, video games, problem-based learning, instruction, educational criteria, and more.

The green cluster contains the highest number of interrelated terms, indicating that terms related to game theory, the learning process, and interpersonal relationships appear most frequently across the covered cluster topics. By using the interactive function of the network map and clicking on any given item, the connections between elements can be viewed more clearly (see Figure 5).

The identified clusters demonstrate the interdisciplinary nature of gamification research and its growing integration into educational practice. The strong interconnections between biology education, curriculum development, game-based learning, and student engagement indicate that gamification is increasingly viewed not only as a motivational tool but also as a pedagogical strategy for developing professional competencies. These findings suggest that future research should focus on strengthening the methodological foundations of gamification and expanding its application within teacher education programs.

For example, one can observe a strong connection between the term "gamification" and terms such as "computational biology," "video games," "problem-based learning," "learner," "curriculum," and "game-based learning."

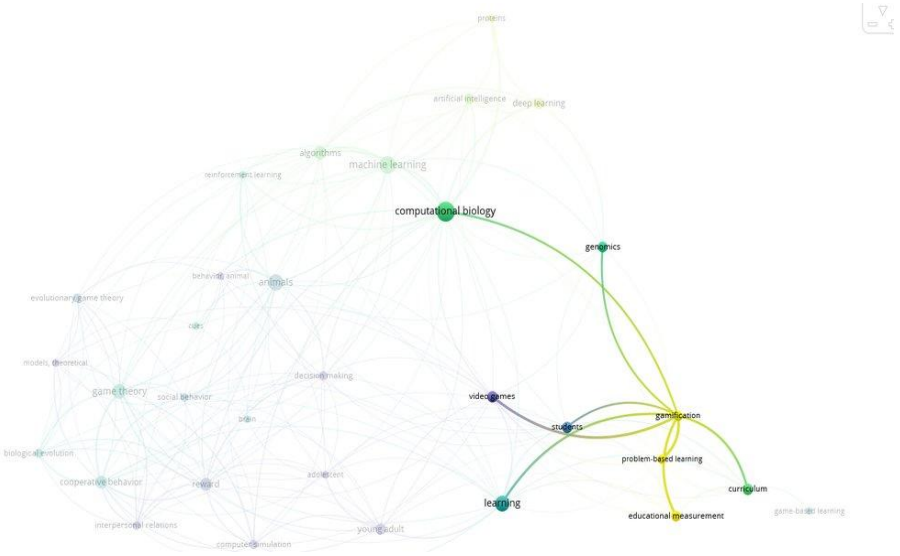

FIGURE 5. Interrelationship of keyword elements within the bibliometric cluster.

The network map thus enables a more precise examination of the relationships between individual terms. Consistent with the aim of the study, the findings confirm that gamification in biology education represents a highly relevant and growing area of scholarly inquiry.

The survey results are presented below. The results for the first survey question showed that Internet-based games are the most frequently used format in biology instruction (67%), followed by role-playing games (38.8%) and board games (31.1%). It was also found that in some cases respondents reported no use of game elements at all (10.7%) (see Figure 6). Since respondents were able to select multiple options, the total across response categories exceeds 100% (147.6%).

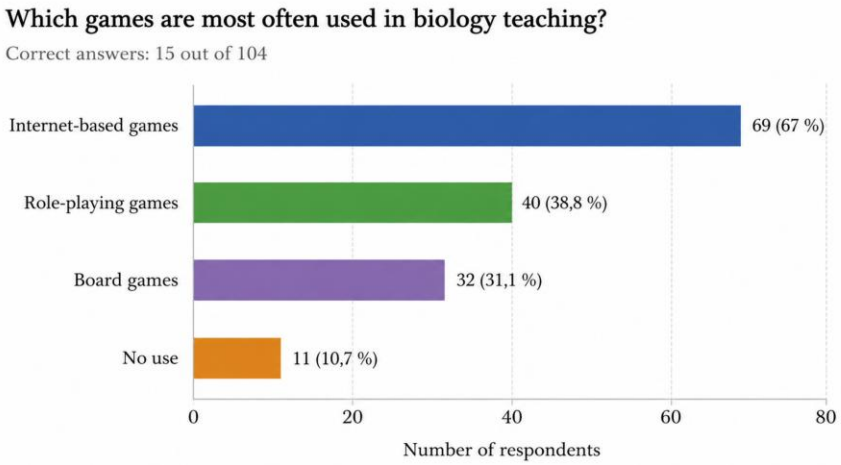

FIGURE 6. Distribution of game types used in biology instruction among surveyed students (n=104)

These findings indicate that Internet-based games are the most widely used form of gamified learning in biology education. The predominance of digital game formats may be explained by their accessibility, flexibility, and compatibility with modern educational technologies. The results also demonstrate that traditional game formats remain relevant, although to a lesser extent.

For the second question, 80.6% of students reported using various types of games during lessons, while 28.2% indicated that they actively design games in biology-related classes. However, 7.8% of respondents stated that they have no knowledge of game-based learning methods (see Figure 7).

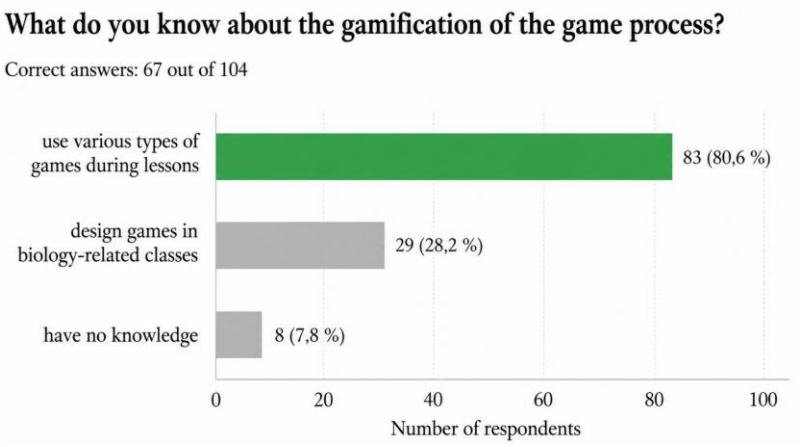

FIGURE 7. Students' reported use and design of game-based learning activities in biology classes (n=104)

The results demonstrate that awareness of gamification among future biology teachers is relatively high. However, the percentage of students who actively design educational games remains considerably lower. This finding suggests that theoretical familiarity with gamification does not always translate into practical implementation skills.

The third question revealed the following distribution of responses regarding where students acquired educational game design skills (see Figure 8). Since respondents were able to select multiple options, the total exceeds 100% (143.6%): 40.8% responded that they learned to design Internet-based games in biology-related subjects; 29.1% learned it in the course “Pedagogy”; 58.2% learned it in the course “Methods of Teaching Biology”; 15.5% of students noted that they had not yet acquired this skill.

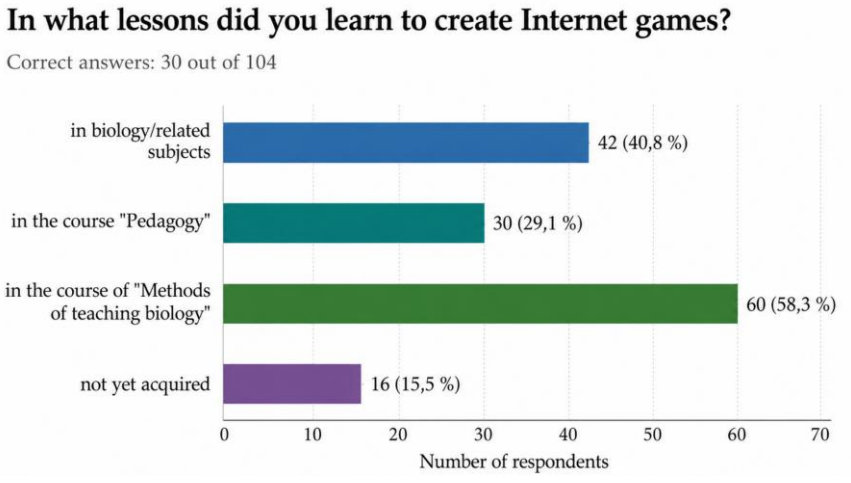

FIGURE 8. Academic courses through which students acquired educational game-design skills (n=104)

The responses to the fourth question were diverse. Students answered this question in their own words. The open-ended format was used to assess students' genuine understanding and attitudes towards gamification in their university learning. To ensure the reliability of the categorisation process, all open-ended responses to Questions 4 and 5 were independently coded by two researchers (the first and second authors). The coding scheme for Question 4 distinguished four categories: (1) responses demonstrating knowledge of specific game names and internet platforms; (2) general responses describing gamification without naming specific tools; (3) responses indicating no knowledge of educational games; and (4) responses unrelated to the survey topic. Inter-rater agreement was calculated using Cohen's kappa coefficient. For Question 4, initial agreement between the two coders was 88.5% ($\kappa = 0.84$, indicating strong agreement). For Question 5, inter-rater agreement was 91.3% ($\kappa = 0.87$, indicating strong agreement). Discrepancies were resolved through discussion until full consensus was reached. The final categorised responses are presented in Tables 1 and 2 below.

The findings suggest that the course "Methods of Teaching Biology" plays a particularly important role in developing students' competencies related to educational game design. This result highlights the importance of integrating gamification-related activities into teacher education curricula.

Table 1. Categorized responses to Survey Question 4: Students' knowledge of educational games and platforms (n=104)

№	Group of responses	Quantity %
1	Specific answers with knowledge of game names and Internet platforms	49 (47.1%)
2	General answers without specifying game names	25 (24.0%)
3	Answers lacking knowledge of games	17 (16.3%)
4	Answers unrelated to the survey topic	13 (12.5%)

Notably, 16.3% of students were unable to name any specific games, and 12.5% provided responses that were unrelated to the survey topic. The fifth survey question, "What types of games motivate you to acquire knowledge?", produced diverse and informative responses, as it invited students to reflect on their own motivational preferences. Educational and quiz-based games were mentioned most frequently, followed by role-playing games, simulations, and competitive game formats. These findings indicate that students generally prefer game formats that combine active participation, knowledge acquisition, and immediate feedback.

Table 2. Categorized responses to Survey Question 5: Game types that motivate students to acquire knowledge (n=104)

№	Group of responses	Quantity %
1	Internet-based games	47 (45.2%)
2	Role-playing	40 (38.5%)
3	All games	10 (9.6%)
4	I do not know	7 (6.7%)

Internet-based games were identified as motivating by 45.2% of respondents, while 38.5% preferred role-playing games. A further 9.6% expressed interest in all game types, and 6.7% indicated no particular preference (see Table 2).

To examine whether responses differed significantly across student year groups, chi-square tests of independence (χ^2) were performed on the three closed-ended survey items (Q1–Q3). The analysis compared responses of Year 1 (n=43), Year 2 (n=11), Year 3 (n=25), and Year 4 (n=18) students whose year-group

affiliation could be identified from registration data (n=97 out of 104). Survey item Q5 was an open-ended question and was therefore excluded from inferential analysis; its responses were categorised descriptively and reported in Table 2. Results of the chi-square analysis are presented in Table 3.

Table 3. Chi-square analysis of responses to closed-ended survey items by year group (n=97)

Survey Item	Year 1 (n=43)	Year 2 (n=11)	Year 3 (n=25)	Year 4 (n=18)	χ^2 (df=3)	p	Cramer'V	Sig.
Q1: Use of Internet-based games in biology instruction.	**44.2%**	**72.7%**	**84.0%**	**94.4%**	**19.69**	**<.001**	**0.45**	***
Q2: Students who design educational games themselves.	23.3%	54.5%	36.0%	27.8%	4.44	.218	0.21	n.s.
Q3: Game design skills via Methods of Teaching Biology.	**37.2%**	**54.5%**	**84.0%**	**88.9%**	**21.83**	**<.001**	**0.47**	***

Note. n.s. = not significant. Bold values indicate statistical significance. df = 3 for all tests. Cramer's V was calculated as a measure of effect size. Values of 0.10, 0.30 and 0.50 indicate small, moderate and large effects, respectively.

Chi-square analysis revealed statistically significant differences across year groups for two survey items. Seven respondents did not provide sufficient information about their year of study and were therefore excluded from the chi-square analysis. Consequently, all inferential analyses were conducted using the data of 97 participants. First, the proportion of students reporting the use of Internet-based games in biology instruction increased markedly with year of study: from 44.2% among first-year students to 94.4% among fourth-year students ($\chi^2(3) = 19.69$, $p < .001$). This finding indicates that exposure to and integration of digital gamification tools deepens progressively as students advance through the biology teacher education curriculum. Second, the proportion of students who acquired educational game design skills through the course "Methods of Teaching Biology" also increased significantly across year groups, from 37.2% in Year 1 to 88.9% in Year 4 ($\chi^2(3) = 21.83$, $p < .001$), reflecting the placement of this course in the later years of the program. No statistically significant differences were found for the proportion of students who actively design educational games themselves ($\chi^2(3) = 4.44$, $p = .218$), suggesting that self-reported game design activity remains relatively stable regardless of year of study. Survey item Q5 was an open-ended question; its descriptive results are reported in Table 2 and discussed in relation to motivational preferences.

V. DISCUSSION

The bibliometric analysis revealed a continuous and statistically consistent increase in scholarly publications on gamification in biology education from 2017 (n=11) to 2024 (n=26), confirming that gamification remains an active and expanding research direction in contemporary higher education. These findings are consistent with previous bibliometric studies by Subhash and Cudney [8] and Zeybek and Saygı [13], who similarly documented growth in game-based learning and gamification publications over comparable periods. The sustained upward trend in publication frequency suggests that the scholarly community increasingly recognizes gamification as a significant pedagogical strategy, particularly in the post-pandemic context of digital education transformation.

The keyword co-occurrence network constructed using VOSviewer [39] revealed four thematic clusters that closely correspond to the competency areas identified in the student survey. Specifically, the cluster centred on "gamification and curriculum-related terms" aligns with the survey finding that 58.2% of students acquired game design skills through the course "Methods of Teaching Biology", confirming the curricular relevance of this thematic domain. Similarly, the cluster associated with "student engagement and game-based learning" mirrors students' strong preference for Internet-based and role-playing games as motivating formats. The convergence between the bibliometric clusters identified via VOSviewer and the empirically observed patterns in students' perceptions suggests that the scholarly discourse on gamification is broadly reflected in the practical experiences of future biology teachers. This alignment strengthens the internal validity of the mixed-methods approach employed in the present study.

The empirical survey demonstrated that future biology teachers generally hold positive attitudes toward gamification: 80.6% reported familiarity with gamification concepts, and 67% identified Internet-based games as the most frequently used format in biology instruction. These findings are consistent with Hamari et al. [10], who reported that gamification positively influences student motivation, engagement, and participation in learning activities, and with the meta-analysis by Sailer and Homner [11], which demonstrated that gamification enhances cognitive, motivational, and behavioural learning outcomes. At the national level, similar positive perceptions were reported by Tokzhigitova et al. [25] among Kazakhstani students, confirming that the benefits of gamification are recognized across different educational contexts. Chi-square analysis further revealed statistically significant differences in gamification awareness across year groups ($p < .001$), indicating that exposure to gamification increases progressively over the course of the biology teacher education programme.

A self-determination theory interpretation, despite high levels of familiarity with gamification, a substantial gap was identified between students' theoretical awareness and their practical skills in designing and implementing educational games. This pattern is consistent with Dichev and Dicheva [1], who argued that awareness of gamification does not necessarily translate into effective pedagogical implementation, as successful integration requires methodological preparedness and pedagogical design skills. From the perspective of Self-Determination Theory [14], this gap can be interpreted as a deficit in competence support within the current curriculum: students have been exposed to gamification as a concept but have not yet received sufficient need-supportive instruction to develop autonomous professional motivation and practical design competence. SDT further predicts that without structured opportunities to experience mastery (competence) and self-directed application (autonomy), students' engagement with gamification will remain at the level of controlled rather than intrinsic motivation, limiting its long-term integration into their professional practice.

Institutional barriers to gamification implementation, several institutional factors may explain the awareness-to-practice gap observed in this study. These include insufficient methodological preparation of future teachers in educational game design, limited availability of digital educational resources, lack of dedicated professional training in gamification within the curriculum, and varying levels of digital competence among instructors. These barriers are not unique to Kazakhstan: similar constraints have been documented in international higher education systems, where curriculum inertia and inadequate teacher training infrastructure frequently impede the practical integration of innovative pedagogical approaches [1, 13]. Addressing these barriers in the Kazakhstani context will require targeted policy interventions, including the systematic embedding of gamification competencies across all years of the biology teacher education programme and institutional investment in digital infrastructure and faculty professional development.

Novelty and scholarly contribution, the principal contribution of this study lies in the integration of bibliometric analysis and empirical survey data within the specific context of biology teacher education – a combination not previously reported in the literature. While prior studies have focused either on bibliometric reviews of gamification trends or on classroom-based interventions, the present research provides a comprehensive and converging perspective on both global research patterns and the practical realities of future teachers in Kazakhstan. The use of VOSviewer to identify thematic clusters, combined with SDT-grounded survey analysis, demonstrates that mixed-methods bibliometric designs can generate theoretically coherent and practically actionable insights for curriculum development in teacher education.

This study has several limitations. First, the survey was conducted at a single university in Kazakhstan, which limits the generalizability of the findings. Second, convenience sampling and unequal year-group sizes may have influenced the results. Third, the study used a cross-sectional design and therefore cannot establish causal relationships. Future studies should involve larger multi-institutional samples and longitudinal research designs.

VI. CONCLUSION

This study successfully achieved its stated objectives by combining two complementary research methods. First, a bibliometric analysis of 144 publications indexed in Scopus, Web of Science, and PubMed (2017–2024) was conducted, demonstrating a steady increase in scholarly interest in gamification in biology education. Four key thematic clusters were identified: biology and computational topics, decision-making and socialization, game theory and the learning process, and gamification and curriculum-related terms. Second, an empirical survey of 104 undergraduate Biology teacher education students provided evidence-based insights into their current levels of awareness and practical skills.

The survey results showed that future biology teachers generally demonstrate positive attitudes toward gamification. Internet-based games were identified as the most frequently used type of educational game (67%), while 80.6% of respondents reported familiarity with gamification concepts. In addition, 58.2% of students indicated that they acquired educational game-design skills through the course "Methods of Teaching Biology". At the same time, the findings revealed a gap between students' awareness of gamification and their practical experience in designing and implementing educational games. This indicates the need for greater integration of gamification-related competencies into biology teacher education programs and for expanding opportunities for practical training in educational game design.

The novelty of this study lies in the integration of bibliometric analysis and empirical survey data, providing a comprehensive overview of both global research trends and students' perceptions of gamification in biology teacher education. The findings may be useful for educators, curriculum developers, and higher education institutions seeking to enhance student engagement through innovative teaching approaches.

From a theoretical perspective, the findings of this study confirm the relevance of Self-Determination Theory (SDT) as the guiding framework for understanding gamification in teacher education: students' awareness and motivation are linked to the presence of game design elements that support the three basic psychological needs autonomy, competence, and relatedness as identified by Ryan and Deci [14]. The gap between awareness and practical implementation observed in this study is consistent with SDT's distinction between controlled and autonomous motivation: students who have only surface-level familiarity with gamification have not yet internalized its professional value, suggesting the need for more need-supportive instructional design in teacher training. From a policy perspective, the results suggest that higher education institutions and curriculum developers should consider systematically embedding gamification competencies across all years of the biology teacher education program, rather than concentrating them in a single course. Institutional investment in digital infrastructure and professional development for educators in educational game design is recommended. Future research should focus on evaluating the effectiveness of gamification-based interventions in biology education and on developing evidence-based models for integrating gamification into teacher training programs. The practical significance of this study lies in its potential to support curriculum developers and teacher education programs. The findings suggest that systematic integration of gamification competencies can contribute to the development of future biology teachers' digital, pedagogical, and professional skills.

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Author Contributions

Conceptualization, A.A., A.N., and G.S.; methodology, A.A. and A.N.; software, A.A.; validation, A.N., U.B., and L.N.A.; formal analysis, A.A. and A.N.; investigation, A.A., U.B., and G.S.; resources, U.B. and G.S.; data curation, A.A. and U.B.; writing—original draft preparation, A.A. and A.N.; writing—review and editing, A.A., A.N., U.B., L.N.A., and G.S.; visualization, A.A. and L.N.A.; supervision, A.N. and G.S.; project administration, A.A., A.N., and U.B.; funding acquisition, G.S. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare that there is no conflict of interest.

Data Availability Statement

The data will be made available upon reasonable request from the corresponding author Abdelsalam Hamid".

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Not applicable.

REFERENCES

1. Akhmetov, N. (**2013**). *Technology of educational game creation* (pp. 121–150). Kazakh National Pedagogical University Press.
2. Alahmari, M., Jdaitawi, M. T., Rasheed, A., Abduljawad, R., Hussein, E., Alzahrani, M., et al. (**2023**). Trends and gaps in empirical research on gamification in science education: A bibliometric review of the literature. *Education Sciences, 13*(3), Article 286.
3. Bai, S., Hew, K. F., & Huang, B. (**2020**). Does gamification improve student learning outcome? Evidence from a meta-analysis and synthesis of qualitative data in educational contexts. *Educational Research Review, 30*, 100322.
4. Buckley, P., & Doyle, E. (**2016**). Gamification and student motivation. *Interactive Learning Environments, 24*(6), 1162–1175.
5. Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (**2011**). From game design elements to gamefulness: Defining gamification. In *Proceedings of the 15th International Academic MindTrek Conference* (pp. 9–15). Association for Computing Machinery.
6. Dichev, C., & Dicheva, D. (**2017**). Gamifying education: What is known, what is believed and what remains uncertain: A critical review. *International Journal of Educational Technology in Higher Education, 14*, Article 9.
7. El-Tanahi, N., Soliman, M., Hady, H., Alfrehat, R., Faid, R., Abdelmoneim, M., et al. (**2023**). The effectiveness of gamification in physical education: A systematic review. *International Journal of Education in Mathematics, Science and Technology, 12*(2), 406–417.
8. Fakhrunnisaa, N., Putri, R. H., Edy, M. R., Armiana, A., Zainab, Z., & Juharman, M. (**2023**). Gamification sebagai strategi peningkatan kualitas belajar mahasiswa. *Jurnal Pendidikan Terapan, 2*(1), 63–68.
9. Hamari, J., Koivisto, J., & Sarsa, H. (**2014**). Does gamification work? A literature review of empirical studies on gamification. In *2014 47th Hawaii International Conference on System Sciences* (pp. 3025–3034). IEEE.
10. Kapp, K. M. (**2012**). *The gamification of learning and instruction: Game-based methods and strategies for training and education*. Pfeiffer/John Wiley & Sons.
11. Karavayev, N. L., & Soboleva, Y. V. (**2019**). *Improving the methodology of gamification in the educational process in a digital learning environment*. Vyatka State University.
12. Landers, R. N. (**2014**). Developing a theory of gamified learning: Linking serious games and gamification of learning. *Simulation & Gaming, 45*(6), 752–768.
13. Majuri, J., Koivisto, J., & Hamari, J. (**2018**). Gamification of education and learning: A review of empirical literature. Paper presented at the GamiFIN Conference.
14. Matonin, V. V. (**2017**). Trends in modern education: Gamification. *Bulletin of Buryat State University: Education, Personality, Society, 2*, 36–40.
15. McCoy, L., Lewis, J. H., & Dalton, D. (**2016**). Gamification and multimedia for medical education: A landscape review. *Academic Pathology, 3*, 1–8.
16. Naderi, S., & Moafian, F. (**2023**). The victory of a non-digital game over a digital one in vocabulary learning. *Computers & Education Open, 4*, 100135.
17. Nurgaliyeva, A., Childibayev, D., Sagyndykova, S., Azman, M. N. A., & Saparova, G. (**2022**). Scientific and methodological basis of practice-oriented training of students-biologists: A case study in Kazakhstan. *Jurnal Pendidikan IPA Indonesia, 11*(1), 24–34.
18. Omarova, M. K., & Gelishili, U. (**2025**). Gamification in vocational education: A comparative analysis of existing research frontiers. *Bulletin of the Karaganda University: Pedagogy Series, 11730*(1), 178–186.
19. Orazbaikyzy, K., & Ilyassova, G. U. (**2021**). Theoretical foundations of the role of gamification in the educational process. *Bulletin of Aba Kazakh National Pedagogical University, Series "Natural-Geographical Sciences," 4*(70), 150–154.
20. Ovchinnikov, V. M. (**2021**). Gamification and visualized content in history lessons. *Scientific-Methodological Electronic Journal "Kaliningrad Bulletin of Education," 2*(10), 29–40.
21. Pallavicini, F., Pepe, A., & Minissi, M. E. (**2019**). Gaming in virtual reality: What changes in terms of usability, emotional response

and sense of presence compared to non-immersive videos? *Simulation & Gaming, 50*(2), 136–159.
22. Plass, J. L., Homer, B. D., & Kinzer, C. K. (**2015**). Foundations of game-based learning. *Educational Psychologist, 50*(4), 258–283.
23. Polulyakh, E. V. (**2024**). Gamification methods in the context of digital transformation of education. *Bulletin of West Kazakhstan University Named After M. Utemissov, Series: Pedagogy, 1*(93), 44–52.
24. Rabah, J., Cassidy, R., & Beauchemin, R. (**2018**). Gamification in education: Real benefits or edutainment. Paper presented at the 17th European Conference on e-Learning, Athens, Greece.
25. Ryan, R. M., & Deci, E. L. (**2020**). Intrinsic and extrinsic motivation from a self-determination theory perspective: Definitions, theory, practices, and future directions. *Contemporary Educational Psychology, 61*, 101860.
26. Sailer, M., & Homner, L. (**2020**). The gamification of learning: A meta-analysis. *Educational Psychology Review, 32*, 77–112.
27. Seaborn, K., & Fels, D. I. (**2015**). Gamification in theory and action: A survey. *International Journal of Human-Computer Studies, 74*, 14–31.
28. Shelomova, A. A., & Kotlyarova, O. A. (**2021**). Gamification in the system of school historical education: Experience and contemporary practice. *Scientific Electronic Journal "Meridian," 6*(59), 1–4.
29. Staller, M. S., & Koerner, S. (**2021**). Beyond classical definition: The non-definition of gamification. *SN Computer Science, 2*(2), Article 88.
30. Subhash, S., & Cudney, E. A. (**2018**). Gamified learning in higher education: A bibliometric review of the literature. *Computers in Human Behavior, 87*, 192–206.
31. Toda, A. M., do Carmo, R. M. C. S., da Silva, A. P., Bittencourt, I. I., & Isotani, S. (**2018**). An approach for planning and deploying gamification concepts with social networks within educational contexts. *International Journal of Information Management, 46*, 294–303.
32. Tokzhigitova, A. N., Yermaganbetova, M. A., & Tokzhigitova, N. K. (**2023**). Identifying student engagement through element of gamification. *Bulletin of L. N. Gumilyov Eurasian National University, Series: Pedagogy and Sociology, 3*(144), 253–261.
33. Tsay, C. H. H., Kofinas, A., & Luo, J. (**2018**). Enhancing student learning experience with technology-mediated gamification: An empirical study. *Computers & Education, 121*, 1–17.
34. van Gaalen, A. E., Brouwer, J., Schönrock-Adema, J., Bouwkamp-Timmer, T., Jaarsma, A. D. C., & Georgiadis, J. (**2021**). Gamification of health professions education: A systematic review. *Advances in Health Sciences Education, 26*(2), 683–711.
35. van Eck, N. J., & Waltman, L. (**2010**). Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics, 84*(2), 523–538.
36. Yaniaja, A. K., Wahyudrajat, H., & Devana, V. T. (**2020**). Pengenalan model gamifikasi ke dalam e-learning pada perguruan tinggi. *ADI Pengabdian Kepada Masyarakat, 1*(1), 22–30.
37. Yates, D. (**2021**). Why so serious? The role of non-serious games in sparking educational curiosity: A reflection. In *Games, simulations and playful learning in business education* (p. 23).
38. Zeybek, N., & Saygi, E. (**2024**). Gamification in education: Why, where, when, and how? A systematic review. *Games and Culture, 19*(2), 237–264.
39. Zimmerling, E., Höllig, C. E., Sandner, P. G., & Welpe, I. M. (**2019**). Exploring the influence of common game elements on ideation output and motivation. *Journal of Business Research, 94*, 302–312.

APPENDIX A

Survey Questionnaire

Gamification in Biology Teacher Education: Bibliometric Analysis and Student Perceptions

The questionnaire consisted of five items. The original Kazakh/Russian wording is presented below together with an English translation. Questions 1–3 allowed selection from predefined response options (including multiple selections where applicable). Questions 4 and 5 were open-ended and respondents answered in their own words.

Question 1

Original wording: Оқу процесінің геймификациясы туралы не білесіз?
English translation: What do you know about gamification in the learning process?
Response options:

- Сабақтарда ойындарды қолдану: Use of games in lessons
- Сабақтарда ойындар құрастыру: Designing/creating games in lessons

- Білмеймін: I do not know

Question 2
Original wording: Какие игры чаще всего используются в преподавании биологии?
English translation: Which games are most often used in biology teaching?
Response options:

- Интернет ойындары: Internet-based games
- Рөлдік ойындар: Role-playing games
- Үстел ойындары: Board games
- Қолданылмайды / Не используется: Not used

Question 3
Original wording: Сіз қандай сабақтарда Интернет ойындарын құруды үйрендіңіз?
English translation: In which courses/classes did you learn to create Internet-based educational games?
Response options:

- Биологиялық пәндер бойынша: Biology-related subjects
- Педагогикада: Pedagogy
- Биологияны оқыту әдістемесінде: Methods of Teaching Biology
- Оқытылған жоқ: I have not been taught this

Question 4
Original wording: Мұғалімдер сабақта геймификацияның қандай элементтерін жиі пайдаланады?
English translation: Which gamification elements do teachers most often use in class?
Response format: Open-ended response (respondents answered in their own words).
Question 5
Original wording: Қандай ойындар сізді білім алуға ынталандырады?
English translation: What types of games motivate you to acquire knowledge / learn?
Response format: Open-ended response (respondents answered in their own words).

Note. The questionnaire was administered online using Google Forms. The wording above is based on the original questionnaire export used for the study.