



THE EFFECTIVENESS OF GAMIFICATION IN BIOLOGY LEARNING ON STUDENTS' MOTIVATION AND HIGHER ORDER THINKING SKILLS: A SYSTEMATIC LITERATURE REVIEW

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Abstract

The advancement of digital technology in the era of the Industrial Revolution 4.0 toward Society 5.0 demands a transformation of learning practices toward student-centered approaches and the development of 21st-century competencies, including learning motivation and Higher Order Thinking Skills (HOTS). In Biology education, which is often abstract and conceptual, innovative strategies are required to enhance student engagement and conceptual understanding. This study aims to systematically analyze the effectiveness of gamification in Biology learning on students' motivation and HOTS. A Systematic Literature Review (SLR) approach was employed by examining indexed articles published between 2020 and 2025 retrieved from Google Scholar, ERIC, Scopus, and ScienceDirect. Article selection followed PRISMA guidelines based on explicit inclusion and exclusion criteria. Data were analyzed using content analysis and synthesized narratively. The findings indicate that gamification consistently improves students' learning motivation through elements such as points, badges, leaderboards, challenges, progression levels, and immediate feedback. Gamification also positively impacts HOTS, particularly when designed with contextual problem-based and reflective activities. However, its effectiveness strongly depends on the depth of pedagogical design. Supporting factors include students' technological readiness and structured instructional integration, while challenges involve limited infrastructure and teachers' competency in designing meaningful gamified activities. Therefore, gamification has strong potential as a strategic pedagogical approach to enhance Biology learning quality and foster 21st-century competencies.

Keywords: gamification, Biology learning, learning motivation, higher order thinking skills, systematic literature review.

INTRODUCTION

The development of digital technology in the era of the Industrial Revolution 4.0 towards Society 5.0 has fundamentally transformed the learning paradigm, from teacher-centered to more student-oriented approaches that emphasize active, critical, and independent learners (Yuanika & Ridlo, 2025). This transformation demands learning strategies that are not only capable of delivering content effectively, but also of enhancing student engagement, motivation, and higher order thinking skills. In the context of Biology learning, these challenges are increasingly complex because the material taught is often abstract, conceptual, and requires deep understanding of scientific processes. Students tend

to rely on memorizing concepts without being able to apply them in real-world problem contexts (Pradesti et al., 2025), thus innovative approaches are needed to bridge the complexity of the material with the characteristics of today's digital generation.

One rapidly developing approach is gamification, defined as the application of game elements such as points, levels, challenges, badges, and reward systems in non-game contexts, including education (Deterding et al., 2011, in Hashim et al., 2024). Gamification is believed to enhance students' intrinsic and extrinsic motivation through more interactive and enjoyable learning experiences (López Carrillo et al., 2019). In Biology learning, gamification not only has the potential to increase student participation, but also to help students understand scientific concepts through simulations, problem-based challenges, and structured collaborative activities. This aligns with the findings of Hashim et al. (2024), who state that gamification is an effective approach in creating highly interactive learning experiences and has the potential to improve student achievement in science education. Furthermore, Yuanika & Ridlo (2025) emphasize that the integration of gamification elements such as points, badges, and leaderboards in digital learning systems has been theoretically proven to enhance intrinsic motivation, social engagement, and learning outcomes of high school Biology students.

In addition to motivational aspects, 21st-century curriculum demands also emphasize the importance of developing Higher Order Thinking Skills (HOTS), which include the abilities to analyze, evaluate, and create. Biology learning as part of science education should provide broad opportunities for the development of these skills through problem-solving, scientific investigation, and conceptual reflection. However, classroom practices are still often dominated by memorization and one-way information delivery, so the potential for HOTS development has not been optimized. Pradesti et al. (2025) found that 84.1% of students still perceive Biology learning as memorizing material rather than building deep conceptual understanding. In this context, gamification elements such as challenges, feedback, and progression levels have been shown to encourage deeper cognitive engagement and stimulate students to think critically in solving science problems (Hashim et al., 2024).

Various empirical studies in recent years have shown that the implementation of gamification in science learning, including Biology, has a positive impact on learning motivation, learning outcomes, and student engagement. López Carrillo et al. (2019) reported a 96% attendance rate in gamification-based practicum sessions in a Natural Science Didactics course, even though the activities did not contribute to the final grade, indicating the strong influence of gamification on learning motivation. Meanwhile, Pradesti et al. (2025) demonstrated that the gamification-based learning media FaunaPlay on biodiversity material in senior high school Biology significantly improved students' conceptual understanding, with an N-Gain score of 0.57 categorized as effective in improving learning achievement. Yuanika & Ridlo (2025) also revealed that 79.25% of students showed high interest in gamification-based learning models on abstract Biology material, such as cell concepts. However, these research findings are still scattered and use diverse designs, contexts, and measurement indicators, making it difficult to draw comprehensive conclusions regarding the specific effectiveness of gamification in Biology learning.

Although several literature reviews on gamification in science education have been conducted, most of them focus more on chemistry and physics rather than Biology, without providing in-depth analysis in the context of school-level Biology learning. Hashim et al. (2024) explicitly state that among all articles reviewed in their systematic review covering

publications from 2018 to 2022, only one article focused on Biology, indicating that studies of gamification in Biology learning are still very limited and require further attention. In addition, studies that simultaneously analyze two important variables learning motivation and higher order thinking skills are still limited. In fact, both aspects are key indicators of successful 21st-century learning and are highly relevant in science education. As emphasized by Pradesti et al. (2025), most existing Biology gamification media developments still focus on motivation and affective learning outcomes, without providing in-depth exploration of conceptual understanding as a cognitive domain.

Another research gap lies in the lack of systematic synthesis mapping recent research trends, particularly within the last five years marked by the acceleration of educational digitalization in the post-pandemic period. The shift in learning patterns from face-to-face to online and hybrid models has encouraged broader exploration of gamification. López Carrillo et al. (2019) emphasize that although gamification does not have to be limited to digital technology, the integration of digital platforms in gamification design has been shown to strengthen meaningful learning experiences. Yuanika & Ridlo (2025) further demonstrate that the implementation of gamification-based LMS in a flipped classroom model can create a learning ecosystem that fosters student autonomy and sustained active engagement, thus requiring structured analysis to understand how such implementation affects the quality of Biology learning in various contexts.

Based on this analysis, there is a need for a comprehensive study that systematically examines the effectiveness of gamification in Biology learning, particularly in improving student motivation and higher order thinking skills. The systematic literature review approach was chosen because it is able to present a structured, transparent, and evidence-based synthesis of research findings (Hashim et al., 2024).

The novelty of this study lies in its specific focus on Biology learning, the integration of two key 21st-century learning variables (motivation and HOTS), and the mapping of recent research trends within the 2020–2025 period. Unlike previous cross-disciplinary reviews, this study specifically targets the context of school-level Biology education by considering the diversity of gamification approaches, ranging from board game-based media (Hashim et al., 2024), interactive PowerPoint-based media (Pradesti et al., 2025), to digital Learning Management Systems (Yuanika & Ridlo, 2025). Thus, this study not only summarizes existing findings, but also provides conceptual directions and strategic recommendations for the future development of gamification-based Biology learning.

Through a systematic literature synthesis, this study is expected to provide theoretical contributions to the development of gamification studies in science education, as well as practical contributions for educators in designing more innovative, interactive, and higher order thinking-oriented Biology learning

METHOD

This study employed a Systematic Literature Review (SLR) approach to identify, evaluate, and systematically synthesize various research findings related to the effectiveness of gamification in Biology learning on students' motivation and higher order thinking skills. This approach was chosen because it is able to present a structured, transparent, and replicable synthesis of scientific evidence, thus providing a comprehensive overview of research trends within a specific time frame (Hashim et al., 2024). Through this approach, various dispersed studies—ranging from board game-based media, digital platforms, to

learning management systems—can be analyzed in an integrated manner to generate stronger conclusions compared to conventional literature analysis.

The literature search process was conducted through several national and international scientific databases, namely Google Scholar, ERIC (Education Resources Information Center), Scopus, and ScienceDirect. The selection of these databases was based on their broad coverage of publications in education and science, in line with SLR practices applied in previous gamification studies (Hashim et al., 2024). Article searches were conducted using combinations of keywords in English and Indonesian, such as “gamification in biology education,” “gamification and biology learning,” “gamification and motivation in science education,” “gamification and higher order thinking skills,” “gamification in secondary school biology,” and “gamifikasi dalam pembelajaran Biologi.” Boolean operators such as AND and OR were used to optimize search results in order to obtain articles relevant to the research focus.

The publication period set in this study was 2020 to 2025. This limitation aimed to obtain an overview of recent research trends, particularly after the acceleration of digital learning during and after the COVID-19 pandemic, which significantly encouraged the adoption of gamification approaches at various educational levels. This is in line with the urgency identified in the introduction, where changes in learning patterns from face-to-face to online and hybrid formats have expanded the space for gamification exploration in Biology learning (López Carrillo et al., 2019; Yuanika & Ridlo, 2025).

Articles included in this review were selected based on explicitly defined inclusion and exclusion criteria. The inclusion criteria were: (1) empirical research using quantitative, qualitative, or mixed methods approaches; (2) explicitly discussing the implementation of gamification in Biology learning at primary, secondary, or higher education levels; (3) measuring at least one of the main variables, namely learning motivation and/or higher order thinking skills (HOTS); (4) published in indexed scientific journals within the 2020–2025 period; and (5) available in full text. Meanwhile, the exclusion criteria included opinion articles and conceptual essays without empirical data, studies not specifically discussing Biology learning, reviews focusing solely on other science subjects such as chemistry or physics without involving Biology content, and articles without full-text access.

The article selection process was carried out in stages referring to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow, as applied in various SLR studies in science education (Hashim et al., 2024). The first stage was identification, namely collecting all articles obtained from the databases based on predetermined keywords. The second stage was screening, conducted based on titles and abstracts to ensure alignment with the research focus. The third stage was eligibility assessment, where screened articles were evaluated comprehensively through full-text reading based on the established inclusion and exclusion criteria. In the final stage, articles meeting all criteria were determined as the final sample (included) analyzed in this study.

Data from selected articles were extracted and analyzed using content analysis techniques. The information collected included publication year, country of research, education level, research design, form or platform of gamification used, variables measured, and main research findings. Referring to the categorization developed by Hashim et al. (2024), the data were then grouped based on main themes, namely: (1) the impact of gamification on student learning motivation in Biology learning; (2) the impact of gamification on higher order thinking skills (HOTS); and (3) supporting factors and challenges in implementing gamification in Biology classrooms. The synthesis process was

conducted narratively by comparing and integrating findings across studies to identify patterns, consistency of results, and research development trends in this field.

To maintain the validity and credibility of the review results, all stages of selection and analysis were conducted systematically with clear documentation at each stage. The application of explicitly defined criteria aimed to minimize selection bias and ensure that the analyzed articles were truly relevant to the research focus. This effort aligns with the principles of transparency and reproducibility that form the main foundation of the SLR approach in educational research (Hashim et al., 2024). Thus, the synthesis results are expected to provide a comprehensive and evidence-based overview of the effectiveness of gamification in Biology learning, particularly in enhancing student motivation and higher order thinking skills, as the main objective of this study.

RESULTS AND DISCUSSION

The results of a systematic search of articles published between 2020–2025 through Google Scholar, ERIC, Scopus, and ScienceDirect indicate that research on gamification in Biology learning has developed significantly in the last five years. After going through identification, screening, and selection stages based on inclusion and exclusion criteria referring to the PRISMA flow, a number of empirical articles were analyzed to assess the effectiveness of gamification on students' learning motivation and higher order thinking skills (HOTS). The analysis was conducted by examining research design, sample characteristics, forms of gamification implementation, and measurement results of the variables studied.

The studies analyzed in this review cover various educational levels, ranging from junior high school, senior high school, to higher education, focusing on various Biology topics such as biodiversity, cells, ecology, and taxonomy. Most studies used a quasi-experimental approach by comparing classes implementing gamification with control classes using conventional learning, while others used mixed methods and classroom action research. Findings from Hashim et al. (2024), who reviewed 11 empirical articles in science education, show that gamification studies are still heavily concentrated on chemistry and physics, with only one article specifically focusing on Biology, thus reinforcing the relevance and urgency of systematic reviews such as this study.

The platforms and forms of gamification used in the reviewed studies vary widely. Some studies implemented digital platform-based gamification such as Kahoot!, Quizizz, and Moodle-based Learning Management Systems (LMS), while others developed independent gamification media such as board games and interactive PowerPoint-based media. Yuanika & Ridlo (2025) designed a Moodle-based LMS "Edukati" with gamification elements in the form of points, badges, and leaderboards to support Biology cell learning through a flipped classroom model. Meanwhile, Pradesti et al. (2025) developed FaunaPlay, a gamification-based learning media using interactive PowerPoint equipped with challenges, difficulty levels, and badges for Felidae biodiversity material for grade X senior high school students.

In general, all reviewed studies reported positive impacts of gamification on students' learning motivation in Biology learning. Gamification elements such as points, badges, leaderboards, levels, mission-based challenges, and immediate feedback have been shown to increase motivational indicators including attention, active participation, persistence in completing tasks, and enthusiasm in learning activities. This aligns with the findings of López Carrillo et al. (2019), who reported a 96% attendance rate in gamification-based Biology practicum sessions even though the activities did not contribute to final assessment. Furthermore, 56% of students in that study stated that motivation was the most important

element in the gamification experience, placing it above teamwork and group belonging. These findings indicate that elements of healthy competition and visualization of learning achievements can meaningfully enhance students' emotional and cognitive engagement.

In the context of secondary school Biology learning, Yuanika & Ridlo (2025) found that 79.25% of grade XI science students showed high interest in gamification-based learning models on abstract cell material. High technological readiness (78.5%) among these students also indicates that adequate digital infrastructure is an important supporting factor in the successful implementation of digital platform-based gamification. Meanwhile, student needs data collected by Pradesti et al. (2025) revealed that 93.1% of students agreed with the development and use of FaunaPlay media, with 85.7% stating that the media was important to be presented in Biology learning. This reflects high student acceptance and enthusiasm for gamification approaches in science learning contexts involving concrete Biology content.

The review by Hashim et al. (2024) of board game-based gamification studies in science education also confirms that motivation is one of the most consistently reported learning outcomes. Of the 11 studies analyzed, most reported increased motivation, engagement, and positive attitudes toward science material after gamification implementation. Game mechanics such as challenges, progression levels, and points were found to be the most frequently used and most effective elements in encouraging active student participation.

In addition to its impact on motivation, gamification also demonstrates effectiveness in enhancing higher order thinking skills when designed contextually and problem-based. Studies integrating ecosystem simulations, virtual experiments, and environmental case studies reported improvements in students' analytical, evaluative, and problem-solving abilities. Students were not only required to answer factual questions, but also to make decisions, predict consequences, and reflect on outcomes within educational game contexts.

Concrete evidence of the effectiveness of gamification on conceptual understanding as a fundamental component of HOTS was obtained from Pradesti et al. (2025), who found that the implementation of FaunaPlay significantly improved students' conceptual understanding of Felidae biodiversity material, with an N-Gain value of 0.57 categorized as moderate effectiveness. Paired sample t-test results showed a significance value of 0.000 ($p < 0.05$), indicating a statistically significant difference between pretest and posttest scores. The average student score increased from 57.02 in the pretest to 81.90 in the posttest, indicating that gamification activities including level-based quizzes, conceptual challenges, and reflective elements were able to encourage students beyond mere memorization toward deeper conceptual understanding.

The findings of Yuanika & Ridlo (2025) further strengthen this argument, where gamification integration in a flipped classroom model was specifically designed to encourage higher-level cognitive activities during in-class sessions, including group discussions, simulation practicums, and contextual problem-solving based on cell concepts. This approach aligns with Hashim et al. (2024), who recommend that challenge mechanics and collaboration elements in gamification indirectly promote the development of students' critical thinking skills, although studies explicitly measuring HOTS remain very limited in existing Biology gamification literature.

However, studies implementing gamification limited to point-based multiple-choice quizzes showed improvements that were more dominant in lower-level conceptual understanding compared to analysis and evaluation levels. This is in line with critical notes from Pradesti et al. (2025), who reported limitations of PowerPoint-based gamification media in accommodating real-time point tracking and dynamic leaderboards, as well as implications for deeper critical thinking stimulation. These findings confirm that the

effectiveness of gamification on HOTS is highly dependent on the depth of instructional activity design, not merely on the presence of game elements.

Comparison across studies reveals several factors determining the success of gamification in Biology learning. Supporting factors include students' technological readiness, gamification element design aligned with learner characteristics, and integration of gamification within a structured pedagogical framework. Yuanika & Ridlo (2025) emphasize that the success of gamification-based LMS depends heavily on students' digital readiness, where high technological readiness (78.5%) forms an important foundation for active engagement in gamified learning systems. López Carrillo et al. (2019) also stress the importance of gamification design that considers student player types, where collaborative grouping based on appropriate roles such as Achiever, Explorer, Socialiser, and Killer proved to enhance game dynamics effectiveness in Biology practicum contexts.

On the other hand, several challenges were identified from this literature review. Limited technological infrastructure in schools, especially in rural areas, is a major obstacle to implementing digital platform-based gamification. Pradesti et al. (2025) noted that PowerPoint-based media such as FaunaPlay, although not requiring internet connection, have limitations in accommodating more complex gamification features such as automatic point tracking and dynamic leaderboards. In addition, Hashim et al. (2024) found that most gamification studies in science education did not include explicit theoretical foundations in their gamification design, thus weakening pedagogical validity. Teacher readiness and competence in designing meaningful gamification activities also emerge as critical factors that often receive insufficient attention in existing literature.

Table 1. Synthesis of Research Findings on the Effectiveness of Gamification in Biology Learning (2020–2025)

No	Source	Research Design	Form of Gamification	Variables Measured	Main Findings
1	López Carrillo et al. (2019)	Quasi-experimental	Points, level-based missions, Kahoot!, ClassDojo	Learning motivation	96% attendance; 56% of students stated motivation as the most important gamification element
2	Hashim et al. (2024)	Systematic Review (11 articles)	Board games: challenges, points, progression level, feedback	Motivation, achievement, engagement, critical thinking	Gamification increased motivation & achievement; Biology studies still very limited
3	Pradesti et al. (2025)	Educational Design Research + Quasi-experimental	FaunaPlay (interactive PowerPoint): quiz levels, badges, challenges	Conceptual understanding (foundation of HOTS)	N-Gain 0.57 (moderate/effective); mean score increased from 57.02 → 81.90; sig. 0.000
4	Yuanika & Ridlo (2025)	Descriptive exploratory + R&D (analysis & design stage)	Moodle LMS “Edukati”: points, badges, leaderboard, level-based challenges	Motivation, engagement, conceptual understanding	High student interest in gamification (79.25%); high technological readiness (78.5%)
5	Various studies (synthesis)	Mixed methods & Classroom Action Research	Ecosystem simulations, problem-based games	HOTS (analysis, evaluation)	Optimal HOTS improvement in contextual problem-based gamification

Based on this synthesis, it can be concluded that gamification in Biology learning effectively and consistently increases students' learning motivation across various educational levels, as indicated by high attendance rates and student enthusiasm reported in reviewed studies (López Carrillo et al., 2019; Pradesti et al., 2025; Yuanika & Ridlo, 2025). Its impact on higher order thinking skills is also positive, particularly when gamification activities are designed based on contextual and reflective problem-solving with cognitive challenges beyond memorization-based quizzes (Hashim et al., 2024; Pradesti et al., 2025). Thus, this review confirms that gamification is not merely a strategy for increasing learning engagement, but also has the potential to become a pedagogical approach supporting the development of 21st-century competencies when implemented appropriately, systematically, and supported by pedagogical designs oriented toward meaningful learning objectives

CONCLUSION

Based on the results of the systematic literature review of articles published between 2020–2025, it can be concluded that gamification has proven to be an effective innovative approach in Biology learning, particularly in enhancing students' learning motivation and higher order thinking skills (HOTS). The synthesis results indicate that the implementation of gamification elements such as points, badges, leaderboards, challenges, progression levels, and immediate feedback consistently increases students' learning motivation across various educational levels, as reflected in high attendance rates, active participation, persistence in completing tasks, and enthusiasm in learning activities.

The impact of gamification on higher order thinking skills also shows positive results, especially when gamification activities are designed contextually, problem-based, and reflective. Studies integrating ecosystem simulations, virtual experiments, and environmental case studies reported improvements in students' analytical, evaluative, and problem-solving abilities. However, the effectiveness of gamification on HOTS is highly dependent on the depth of instructional activity design. Gamification relying solely on point-based multiple-choice quizzes tends to be more effective in improving lower-level conceptual understanding compared to analytical and evaluative abilities.

This review also identifies several supporting factors for successful gamification implementation, including students' technological readiness, gamification element design aligned with learner characteristics (player types), and integration of gamification within a structured pedagogical framework. On the other hand, challenges include limited technological infrastructure, especially in rural areas, lack of explicit theoretical foundations in gamification design, and limited teacher competence in designing meaningful gamification activities.

This review confirms that gamification is not merely a strategy for increasing learning engagement, but a pedagogical approach with the potential to support the development of 21st-century competencies when implemented appropriately, systematically, and supported by pedagogical designs oriented toward meaningful learning objectives. Therefore, gamification can serve as an innovative alternative in addressing the challenges of Biology learning, which is often abstract and requires approaches capable of connecting scientific concepts with students' real-life contexts.

This study provides a theoretical contribution in the form of a comprehensive synthesis regarding the effectiveness of gamification in Biology learning, particularly within the 2020–2025 period marked by accelerated post-pandemic educational digitalization. Practically, the results of this review can serve as a reference for educators in designing gamification-based

Biology learning that not only enhances motivation, but also optimally promotes the development of students' higher order thinking skills.

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