

Integration of Gamification and the Problem-Based Learning (PBL) Model in Chemistry Learning to Improve Critical Thinking Skills: A Literature Review

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ABSTRACT

21st-century education requires students to master the 4C skills, which include critical thinking, collaboration, communication, and creativity. This study is based on the problem of low student analytical skills influenced by the dominance of teacher-centered learning, limited use of digital media, and the inconsistency of learning strategies with the demands of 21st-century competencies. This study aims to examine the use of gamification-based learning and problem-based learning in improving students' critical thinking skills. The research method used in this study is a literature review method by compiling various national and international publications published in the last five years collected through searches of academic databases (Scopus, Google Scholar, DOAJ, and Sinta). The results of the study indicate that the application of gamification and problem-based learning has provided consistent improvements in student motivation, engagement, and learning outcomes. Educational games have provided a learning environment that allows for independent exploration, strengthening reflective reasoning, and improving decision-making skills. However, the effectiveness of implementing this strategy is still influenced by the teacher's pedagogical competence, the availability of technological infrastructure, and the quality of alignment between game design and learning objectives. Based on the synthesis results, this study concludes that the integration of gamification and problem-based learning has strategic potential to support the transformation of learning toward a more adaptive and learner-oriented approach. These findings are expected to form the basis for developing innovative learning models that are relevant and effective in strengthening students' critical thinking skills.

Keywords: *21st Century Skills, Chemistry Learning, Critical Thinking, Gamification, Problem-based Learning*



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INTRODUCTION

The rapid development of technology in the 21st century has impacted various aspects, one of which is education. 21st-century education faces increasingly complex challenges along with the development of digital technology and global demands. 21st-century education emphasizes students' development of the 4C skills: critical thinking, creativity, collaboration, and communication (Khafidh et al., 2025). These four skills are not only indicators of success in learning but also key assets in facing future challenges. Efforts to improve the quality of 21st-century skills will ensure improved education. Therefore, education must shift from conventional learning to one that is adaptive and relevant to current developments.

Critical thinking is one of the main skills in facing the challenges of the 21st century by involving the activities of receiving, processing, analyzing, and evaluating the information obtained to solve problems. However, its realization in the field has not been as expected, critical thinking skills in Indonesia are still relatively low (Amini et al., 2021). In the learning process, students' thinking skills can be developed through meaningful experiences, including problem-solving in the classroom. Teachers must be able to use appropriate media to motivate students to participate in the teaching and learning process and thus be able to absorb the material being studied (Efendi, 2022). The use of educational media and technology has proven effective in improving students' critical thinking skills. Schools that successfully integrate technology effectively are able to provide a more dynamic learning experience (Kusuma et al., 2024).

The current curriculum actually encompasses 21st-century skills in content, process, and assessment standards. However, in practice, learning remains teacher-centered (Arifin & Mu'id, 2024), characterized by the dominance of lecture methods and mechanical questions. Many teachers use more printed media, which causes students to feel bored during the learning process, so that students' academic grades and critical thinking skills are not honed properly (Kusuma et al., 2024). In addition to the factors mentioned above, the low student achievement in Indonesia can also be traced to the wide gap between curriculum policies, teacher capacity, and actual classroom conditions. Although the curriculum has adopted the principles of Higher Order Thinking Skills (HOTS), its implementation is hampered by the dominance of lecture methods and mechanical questions, which keep learning teacher-centered.

Study Rofi'ah & Rokhmaniyah, (2024), found that 85% of students still fall into the very low critical thinking skill category, with the primary cause being the conventional learning model. Furthermore, many teachers' pedagogical and technological competencies in designing inquiry-based learning and utilizing digital media are not evenly distributed, particularly in areas with limited access and facilities. This is exacerbated by a lack of ongoing training and an assessment system that does not fully measure analytical-evaluative thinking processes. As a result, students lack the space and meaningful experience to explore, argue, and solve problems, thus under-developing their critical thinking skills (Alfidyah, 2025).

21st-century teachers must be able to utilize technology and digital media as ideal instruments to provide enjoyable learning experiences for students. Batubara (2021), Digital learning media is a variety of teaching materials presented in visual form and can be accessed, processed, and shared through digital devices. Besides being known as multimedia, this type of media includes various forms of content such as audio, video, images, and animations that are used to increase student interest in the material being studied. The use of digital media as a medium for delivering learning materials is one of the most effective methods, because digital media is a medium that keeps up with the times and can be adapted to students' needs, abilities, and interests. The purpose of using digital media in the classroom is to make it easier for teachers and help students understand the material being explained (Fadiyah et al., 2024).

To address the persistence of teacher-centered learning, a fundamental shift in pedagogical strategy is required by integrating Problem-Based Learning (PBL) with gamification. PBL systematically shifts the teacher's role from a primary information source to a facilitator, placing students at the center of the learning process as they navigate real-world problems. When integrated with gamification, this model overcomes the passivity of traditional classrooms by utilizing game elements—such as points, badges, and challenges—to foster intrinsic motivation and active engagement. This combination creates a "joyful learning" environment where students are not just passive recipients of information but active explorers, allowing them to strengthen reflective reasoning and decision-making skills through structured, interactive participation.

Various studies show that the integration of gamification and interactive media in learning has the potential to improve critical thinking skills Lutfi (2023), reported that gamification in

chemistry learning can achieve learning completion, encourage more student-centered learning, and increase student motivation, curiosity, self-efficacy, and happiness, making it a suitable alternative for implementing the Independent Curriculum. Furthermore, Lukman et al. (2024) shows that practical and effective gamification-based mathematics teaching materials improve junior high school students' critical mathematical thinking skills with a moderate improvement category. In line with this, Pradnyana et al. (2025) proves that interactive gamification-based learning media in the Basic Computer and Network subject can be a source of independent and guided learning, while also contributing to improving students' critical thinking skills.

METHODS

This study employed a qualitative approach with a literature review model. This approach was chosen to examine, collect, and reconstruct various previous research findings related to Problem-Based Learning (PBL) and its influence on improving critical thinking skills. The study materials were obtained from national and international journal articles, scientific proceedings, and academic literature published within the last five years (2021-2025), ensuring the information remains relevant and reflects the latest developments.

References were collected through several scientific databases, such as Scopus, Google Scholar, the Directory of Open Access Journals (DOAJ), and Sinta. The search was conducted using keywords including "problem-based learning," "gamification," "critical thinking skills," and "chemistry learning," along with variations of similar keywords.

The data collection process was conducted systematically, starting with establishing inclusion and exclusion criteria. The inclusion criteria for this study were: (1) articles published between 2020 and 2025; (2) studies specifically discussing the integration of gamification or PBL; (3) research measuring critical thinking skills as a primary outcome; and (4) articles written in English or Indonesian. Conversely, the exclusion criteria were: (1) articles focusing solely on general game-based learning without a PBL framework; (2) studies published before 2020; and (3) papers without full-text access.

Following these criteria, the selection process moved from initial screening through a review of titles and abstracts to reading the entire manuscript to ensure content consistency. Through this rigorous selection process, 5 key articles (N=5) were identified as meeting all criteria and were selected as the primary sources for synthesis. Important information recorded included the research design, study context, key findings, and limitations of each work.

The collected data was analyzed using content analysis. The analysis process included data reduction by selecting the most relevant literature, grouping it into thematic categories such as motivation, engagement, problem-solving skills, adaptability, and implementation constraints, and then synthesizing it to obtain a more comprehensive overview and narrative reasoning. The selection of literature sources was carried out using a purposive sampling technique, where the researcher deliberately selected research considered the most representative and appropriate to the focus of the study.

RESULTS AND DISCUSSION

Results

Based on literature studies through various scientific databases, namely Scopus, Google Scholar, Directory of Open Access Journals (DOAJ), and Sinta, using the keywords problem-based learning, gamification, critical thinking skills, and chemistry learning along with variations of equivalent terms. Five primary studies (N=5) and supporting literature were analyzed using content analysis techniques through data reduction stages, grouping into main themes such as motivation, involvement, problem-solving skills, adaptability, and implementation constraints, as well as compiling narrative synthesis to obtain a comprehensive picture. The selection of literature sources was carried out using purposive sampling techniques to ensure the depth of

analysis in accordance with the focus of the study. The following is a summary of data from various international and local studies relevant to the implementation of Problem Based Learning (PBL) with gamification media in improving critical thinking skills.

Table 1. Summary of Referenced Research

Study	Focus/Subject	Key Mechanics	Impact on Critical Thinking (Conclusion)
Lutfi (2023)	Chemistry Learning	Student-Centered Rewards & Pathways	Gamification in chemistry learning can train curiosity, increase self-confidence, and critical thinking skills in solving complex chemical problems.
Sandi et al. (2025)	Chemistry Learning	PBL-based e-Modules	The use of e-Modules based on Problem Based Learning is effective in improving students' critical thinking skills in electron configuration material.
Rahmasari (2025)	General Education	Gamified Evaluation Tools	The implementation of gamification-based evaluation tools is not only a means of assessment, but also an effective pedagogical strategy to strengthen conceptual understanding and thinking skills in the digital era.
Asmi et al. (2024)	High School (General)	PBL Syntax	Problem Based Learning is able to improve the critical thinking skills of high school students, as evidenced by the N-Gain value of 0.48 (medium category) and an increase in the average score of critical thinking skills of 55%, higher than the control class which only increased by 35%.
Ahmar & Azzajjad (2025)	Science or Chemistry Learning	PBL, Animation and Gamification	PBL-based learning combined with gamification and animation has proven to be more effective in improving students' 21st-century skills than lecture and question-and-answer methods.

Discussion

1. The Urgency of Improving High-Level Cognitive Skills in the Digital Era

All reviewed sources highlight a critical gap between 21st-century skill requirements and current conventional learning environments in Indonesia. Critical thinking and spatial abilities are recognized as higher-order cognitive skills crucial for solving complex problems, particularly in science and mathematics (Ahmar & Azzajjad, 2025; Angelelli et al., 2023). Within the context of Chemistry, these skills are indispensable for mastering abstract concepts that cannot be observed directly. However, reports such as TIMSS and PISA consistently show that Indonesian students' achievement in spatial reasoning remains low. This is exacerbated by a tendency toward monotonous, passive learning. Therefore, a pedagogical transformation is needed to develop thinking skills that are vital for the "digital native" generation (Berlin & Berlin, 2021).

2. Problem Based Learning (PBL) as a Core Pedagogical Framework

The Problem-Based Learning (PBL) model has emerged as a major pedagogical framework to address these challenges by placing real-world problems as a context for learning (Ahmar & Azzajjad, 2025; Miterianifa et al., 2021). PBL places real-world problems as a context for students to acquire essential concepts and learn about critical thinking (Asmi et al., 2024; Oktaviani & Munahefi, 2025; Sandi et al., 2025; Wahyudiati, 2022). In the context of chemistry, PBL is used in the development of E-Modules for the material Electron Configuration and Electrolyte or Non-electrolyte Solutions, where this module guides students through the PBL syntax to analyze and find solutions to contextual problems (Sandi et al., 2025). The combination of PBL with appropriate media provides opportunities for students to develop analytical, evaluation, and problem-solving skills in both mathematics and chemistry.

3. Technology Integration Strategy: Gamification and Interactive Media

To address the issues of student engagement and media appeal in conventional PBL, the integration of visual technology and gamification is a superior solution. Gamification is defined as the use of game elements (such as points, badges, levels, and challenges) in non-game contexts to increase student motivation and active engagement (Oktaviani & Munahefi, 2025). Gamification has been proven to create a joyful learning atmosphere, increase learning motivation, curiosity, self-efficacy, and student happiness, so that learning becomes more student-centered and enjoyable (Chans & Castro, 2021; Rahmasari, 2025). Visual support is also important; animated videos and interactive e-modules present abstract concepts, such as chemical bonding and atomic or molecular configurations, in a dynamic and concrete way, helping students grasp spatial representations. Gamification and visual media enhance the process of visualization and spatial imagination, which are essential for three-dimensional chemistry concepts (Ahmar & Azzajjad, 2025; Jenkins & Mason, 2020; Lutfi, 2023).

4. Empirical Evidence of Improved Cognitive Skills

The effectiveness of implementing these innovative models is supported by empirical findings showing significant improvements in higher-order thinking skills. In a chemistry study, the integration of PBL with gamification and animated videos was shown to be significantly effective in improving students' spatial abilities ($p < 0.001$) compared to a control class (Ahmar & Azzajjad, 2025). The average achievement in all spatial indicators (visualization, mental rotation, spatial orientation, and geometric transformation) in the experimental class was consistently higher. Meanwhile, the PBL-based E-Module development study showed a significant increase in students' critical thinking skills, achieving an N-gain value of 0.48 (moderate category) and an average score increase of 55%, placing students in the critical category (Asmi et al., 2024; Istianah et al., 2025). In addition, the PBL-based gamification approach also shows great potential to improve students' critical thinking skills and metacognition (Abbassyakhrin et al., 2024).

5. Impact on In-Depth Learning and Independent Curriculum Implementation

Overall, learning strategies that combine PBL with gamification and interactive media support deep learning achievements (Asmi et al., 2024). Deep learning requires students to analyze, evaluate, and apply new concepts with prior knowledge, a process driven by the tiered challenges and rapid feedback offered by gamification (Rahmasari, 2025). In fact, gamification-based assessment tools like Wordwall play a significant role in supporting deep learning because they foster student motivation and engagement in the assessment process, provide instant feedback, and reduce evaluation stress. By creating an interactive and enjoyable learning environment (joyful learning), this strategy aligns with the objectives of the Independent Curriculum, helps achieve complete classical learning outcomes, and supports the formation of the Pancasila Student Profile, particularly in the areas of critical and independent reasoning (Lutfi, 2023).

Based on a literature review, the results of the study indicate that the application of gamification consistently contributes positively to the quality of learning. Gamification can improve student achievement, engagement, and learning motivation, with the most frequently used elements including points and rewards, leaderboards, and digital badges. These findings are in line with the development of interactive, collaborative-based learning media in the Basic Computer and Networking subject at SMK Negeri 1 Nusa Penida, which has proven effective as a resource for independent and guided learning and plays a role in improving students' critical thinking skills (Pradnyana et al., 2025). Similar results were also seen in the development of gamification-based mathematics teaching materials (GEMAS Game) for junior high school students. Based on the practicality analysis, the GEMAS Game obtained a practicality score of

81% and is classified as practical, while the results of the effectiveness analysis showed that the media significantly improved mathematical critical thinking skills with a moderate improvement category. Thus, these various findings confirm that the integration of gamification through both collaborative interactive media and digital teaching materials such as the GEMAS Game has met the practical and effective criteria and has strong potential in supporting the improvement of students' critical thinking skills (Lukman et al., 2024).

According to recent international journals, the application of gamification and Problem-Based Learning (PBL), both separately and integrated, has proven effective in improving students' critical thinking skills at various levels of education. Experimental studies show that gamification- and PBL-based learning models, especially those supported by technologies such as artificial intelligence (AI), can significantly improve critical thinking scores compared to conventional methods (Naatonis et al., 2024). In addition, the combination of gamification and PBL also increases student motivation, engagement, and learning outcomes (Boom-Cárcomo et al., 2024).

While gamification offers significant potential, several limitations need to be addressed. Infrastructure issues are a significant obstacle in various educational institutions. The availability of devices, stable internet access, and the uneven availability of digital platforms have prevented gamification from being fully implemented. Research findings at the local level also indicate that limitations in digital media often hinder the optimal use of gamification in the learning process (Hidayatullah & Mitarlis, 2024). Furthermore, teacher readiness is a determining factor in the success of GBL implementation. Many educators still need to improve their techno-pedagogical competencies, particularly in designing interactive quizzes, managing digital classrooms, and utilizing adaptive data as a basis for learning decisions. Therefore, training focused on gamification-based instructional design is highly recommended (Fithri et al., 2021). Furthermore, the use of game elements that are not aligned with learning objectives has the potential to cause distraction. Several international meta-analyses have shown that gamification that overemphasizes external rewards, such as points and leaderboards, or that overemphasizes entertainment aspects, can reduce the depth of learning and even decrease students' intrinsic motivation (Gui et al., 2023). The game needs to be improved, especially in terms of unclear mathematical symbols, the addition of audio features that can be turned on and off, and the leaderboard that still cannot save automatically if there are the same accounts (Lukman et al., 2024). Thus, the success of gamification is largely determined by the quality of the design and the appropriate pedagogical integration, not solely by the presence of game components.

CONCLUSION

Based on the results of the literature review that has been conducted, it can be concluded that the integration of the Problem Based Learning (PBL) model with gamification and interactive media has strong potential in improving students' critical thinking skills, especially in chemistry and other science learning fields. PBL acts as an effective pedagogical framework in encouraging students to be actively involved in contextual problem solving, while gamification functions as a supporting strategy that can increase motivation, engagement, and a meaningful and enjoyable learning experience. Empirical findings from various studies show a significant increase in indicators of critical thinking skills, problem-solving abilities, and higher-order cognitive skills when learning is designed in an innovative and learner-centered manner.

Furthermore, the use of gamification-based digital media, such as interactive e-modules, animated videos, and digital evaluation tools, has been proven to support deep learning and align with the objectives of the Independent Curriculum and the strengthening of the Pancasila Student Profile, particularly in the areas of critical reasoning and independent learning. However, the implementation of gamification and PBL still faces several challenges, including limited infrastructure, teachers' techno-pedagogical readiness, and the risk of distraction if

game elements are not designed in alignment with learning objectives. Therefore, thorough instructional design planning, ongoing teacher training, and adaptive education policy support are needed. With the right approach, the integration of PBL and gamification is expected to become an effective, inclusive, and sustainable learning strategy to improve the quality of education and students' critical thinking skills in the 21st century.

CONFLICT OF INTEREST

No conflict of interest for this study.

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