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Integrating Interactive Game-Based Learning into PBL: Effects on Students' Analytical Thinking and Engagement

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Abstract:
This study aims to investigate the effect of integrating Blooket into Problem-Based Learning (PBL) on students' analytical-thinking abilities in environmental change learning. Environmental issues require students to develop scientific reasoning skills, including analyzing evidence, identifying causal relationships, and evaluating solutions, yet Indonesian students continue to demonstrate challenges in applying scientific knowledge to real-world contexts. Classroom observations at Senior High School indicated difficulties among Grade 10 students in organizing information, connecting concepts, and solving environmental problems analytically. This study employed a quantitative quasi-experimental method using a nonequivalent control-group pretest-posttest design involving 78 Grade 10 students. Data were collected through analytical-thinking tests, implementation observations, and student-response questionnaires, and analyzed using descriptive statistics, N-Gain analysis, and an independent-samples t-test. The findings revealed that both learning conditions improved students' analytical thinking, but the Blooket-supported PBL group achieved higher gains (N-Gain = 70.12%) than the PBL-only group (34.16%). Statistical testing confirmed a significant difference between groups ($t = 9.612$, $p = .001$). Students also demonstrated very strong acceptance of Blooket-supported PBL, particularly regarding environmental learning and analytical-thinking development. These findings imply that digital game-based support can strengthen PBL effectiveness when integrated purposefully as a feedback and reinforcement mechanism. Future research should examine longer interventions and diverse learning contexts to determine the sustainability of these effects.

INTRODUCTION

Environmental issues have become a global concern because environmental changes directly influence human health, economic stability, biodiversity, and the sustainability of future generations. Therefore, science education has an important public responsibility to prepare students not only to understand scientific concepts but also to analyze evidence, identify causal relationships, and evaluate solutions for complex environmental problems. This ability is increasingly necessary as societies face challenges related to pollution, ecosystem degradation, climate change, and unsustainable human activities. Evidence from PISA 2022 shows that Indonesian students achieved an average science score of 383, considerably below the OECD average of 485, indicating limitations in applying scientific knowledge to real-world situations (OECD, 2023). These conditions demonstrate that improving analytical thinking through science learning is essential to develop citizens capable of making informed environmental decisions.

The development of analytical thinking in science learning can be explained through learning theories emphasizing active knowledge construction and meaningful problem solving. Problem-Based Learning (PBL) is based on constructivist theory, which argues that students build knowledge through interaction, investigation, and reflection on authentic problems. Through PBL, students are encouraged to identify problems, collect relevant information, analyze evidence, and formulate justified solutions. Meanwhile, Digital Game-Based Learning (DGBL) is supported by experiential learning theory, where learning occurs through active engagement, feedback, and repeated experiences in meaningful contexts. In this study, analytical thinking is positioned as a higher-order cognitive ability involving interpretation, analysis, evaluation, and decision-making. Therefore, integrating PBL with digital game-based support such as Blooket is theoretically expected to provide additional scaffolding that strengthens students' analytical processes during environmental change learning.

The environmental challenges faced by modern societies create a strong demand for science education that develops students' ability to reason scientifically. Environmental change involves interconnected systems, including pollution, climate instability, biodiversity loss, and changes in land use, which cannot be understood through memorization alone. Students need opportunities to examine evidence, connect multiple factors, and evaluate possible solutions. However, science learning in many contexts still focuses heavily on content transmission rather than analytical engagement. This situation may limit students' ability to apply scientific knowledge when encountering environmental problems in daily life. The need to improve scientific reasoning is particularly important in Indonesia, where environmental issues continue to affect communities while students' scientific literacy performance remains relatively low compared with international standards (OECD, 2023). Consequently, innovative learning approaches are required to transform science classrooms into environments that encourage investigation and critical decision-making.

The classroom problem underlying this study emerged from an initial assessment conducted among 21 Grade 10 students at SMA Karya Budi Cileunyi. Ten questions designed to measure analytical thinking related to environmental change showed that students achieved an average of 5.2 correct answers, equivalent to a score of 52, while the school minimum mastery criterion was 75. Classroom observations further revealed that students experienced difficulties in organizing complex information, identifying cause-and-effect relationships, and connecting environmental concepts with authentic situations. These findings indicate that students' challenges are not limited to understanding environmental concepts but also involve processing and applying scientific information. Therefore, learning strategies that explicitly train analytical thinking processes are required. The implementation of student-centered approaches that provide structured investigation, discussion, and feedback may offer opportunities to overcome these difficulties.

Previous studies have demonstrated that Problem-Based Learning has potential in improving higher-order thinking skills in science education. Meta-analyses have consistently reported positive effects of PBL on science achievement and critical thinking, although the strength of these effects differs depending on instructional conditions and learning contexts (Busyairi & Kusuma, 2023; Funa & Prudente, 2021; Ranggi et al., 2021). In Indonesian secondary biology education, PBL has also been shown to enhance students' critical-thinking abilities (Harahap et al., 2023; Ramdani et al., 2023). Furthermore, recent syntheses indicate that PBL contributes to improvements in critical thinking and problem-solving across various science disciplines (Aripin et al., 2025; Yanto et al., 2026). Specifically, environmental learning research has reported that PBL can strengthen critical thinking and environmental awareness (Aripin et al., 2024). However, PBL effectiveness is influenced by instructional design, subject characteristics, group organization, and implementation quality (Liu & Pásztor, 2022; Lu et al., 2025).

Digital game-based learning has increasingly been explored as an instructional support to improve student engagement and learning outcomes. Research across science and STEM education indicates that game-based learning can positively influence achievement, motivation, behavior, and student competencies, although its effects vary depending on learner characteristics and game design (Arztmann et al., 2023; Lei et al., 2022; Safitri et al., 2025). Quasi-experimental research has also demonstrated that digital game-based learning can increase motivation and engagement, highlighting the importance of affective involvement in technology-supported learning (Zheng et al., 2024). Recent STEM research further suggests that the instructional position of games within learning sequences affects collaborative problem-solving outcomes, meaning that technology alone does not guarantee improvement (Chen & Chen, 2025). Studies involving Blooket have reported positive effects when integrated with structured learning approaches, including science learning contexts (Nur'aeni & Hasanudin, 2023; Paudia et al., 2025; Dani et al., 2026). Nevertheless, concerns regarding competition pressure and time limitations remain relevant considerations (Blacer-Bacolod et al., 2026).

The novelty of this study lies in examining the additional contribution of Blooket within an already established PBL environment rather than comparing technology-based learning with conventional instruction. Previous research frequently evaluates digital tools by comparing them with traditional classroom approaches, making it difficult to determine whether improvements result from the technology itself or from differences in pedagogy. This study addresses that limitation by comparing two groups receiving the same PBL approach, with one group receiving additional Blooket-based activities and the other experiencing PBL without digital game support. This design provides a more specific understanding of whether digital game-based reinforcement, immediate feedback, and repeated question exposure can strengthen analytical-thinking development. The study is therefore important because it provides practical evidence for teachers regarding how technology should be positioned within problem-based science learning.

Based on the identified problems and research gap, this study investigates whether integrating Blooket into Problem-Based Learning produces greater improvement in students' analytical thinking on environmental change topics compared with PBL alone. The research problem addressed is whether the addition of a digital game-based response and feedback layer can enhance the effectiveness of PBL implementation in developing students' analytical abilities. The hypothesis proposed is that students who experience Blooket-supported PBL will demonstrate higher analytical-thinking gains than students who participate in PBL without Blooket support. By examining implementation processes, pretest-posttest changes, statistical differences between groups, and student responses, this research contributes empirical evidence regarding technology-enhanced PBL design. The findings are expected to support science educators in designing learning environments that develop not only conceptual understanding but also students' capacity to analyze and respond to complex environmental challenges.

RESEARCH METHODS

This study employed a quantitative quasi-experimental method with a nonequivalent control-group pretest–posttest design. This design was selected because individual random assignment was not feasible within the existing classroom structure, so intact classes were maintained to compare the experimental and control groups while preserving authentic learning conditions (Creswell & Creswell, 2023; Stratton, 2021). The intervention was conducted in three meetings on environmental change using the same Problem-Based Learning (PBL) stages in both groups, including problem presentation, investigation, discussion, presentation, reflection, and evaluation. The experimental group received additional Blooket-based activities for reinforcement and feedback, whereas the control group implemented PBL without digital game support.

The study was conducted at SMA Karya Budi Cileunyi, Bandung Regency, West Java, Indonesia, during the second semester of the 2025/2026 academic year. The population comprised 234 Grade 10 students in six intact classes. Two classes were selected through cluster random sampling: Class X-C served as the control group ($n = 39$) and received PBL without Blooket, while Class X-D served as the experimental group ($n = 39$) and received Blooket-supported PBL. This approach minimized selection bias while accommodating the practical constraints of classroom-based educational research (Creswell & Creswell, 2023).

Data were collected through analytical-thinking tests, implementation observations, and student-response questionnaires. Analytical thinking was measured using essay-based pretest and posttest instruments. From 30 pilot items administered to Grade 11 students, 20 valid items were selected based on validity, discrimination, difficulty, and reliability analyses. The final instrument assessed four processes: identifying relevant information, organizing and connecting information, determining strategies, and evaluating proposed solutions; its reliability was high (Cronbach's $\alpha = .877$). Instructional implementation was observed by a biology teacher using a five-point scale, while students in the experimental group completed a 28-item questionnaire covering environmental-change materials, PBL implementation, Blooket use, and perceived analytical-thinking development. These measures were included because engagement and feedback are important components of digital game-based learning (Zainuddin et al., 2020; Yu, 2021).

Ethical approval and permission were obtained from the relevant school authorities. Students and their parents or legal guardians received information about the study, and participation was voluntary with the right to withdraw without academic consequences. Student assent and parental consent were obtained before data collection. Confidentiality was maintained by using participant codes, securely storing the data, and reporting results in aggregate form. The study involved minimal risk, did not affect students' grades, and provided the control group with access to information about the Blooket-supported activities after the intervention.

Data were analyzed using IBM SPSS Statistics version 26. Descriptive statistics were calculated for pretest, posttest, N-Gain, implementation, and questionnaire scores. Learning improvement was assessed using normalized gain, which indicates the proportion of possible improvement achieved between the pretest and posttest (Hake, 1998; Sundayana, 2021). The Shapiro–Wilk test was used to assess normality, and Levene's test was used to examine variance homogeneity. Because both assumptions were satisfied, an independent-samples t-test was conducted at $\alpha = .05$ to compare analytical-thinking improvement between the experimental and control groups. This procedure was appropriate for comparing two independent groups in a quasi-experimental educational study (Pallant, 2020).

RESULTS AND DISCUSSION

Results

Implementation Fidelity of PBL With and Without Blooket

The implementation data demonstrate that both learning conditions were successfully delivered with high procedural fidelity throughout the three instructional meetings. The experimental group, which received Problem-Based Learning supported by Blooket, showed a brief adjustment period during the first meeting, particularly related to the teacher's operation of the digital platform. However, the implementation level improved consistently and reached full completion by the third meeting. Meanwhile, the control group receiving PBL without Blooket demonstrated stable implementation from the beginning until the end of the intervention. These findings indicate that both instructional treatments were implemented according to the planned procedures, allowing subsequent comparisons of learning outcomes to be interpreted based on differences in instructional support rather than variations in implementation quality. The implementation percentages across meetings are presented in Table 1.

Table 1. Implementation of PBL With and Without Blooket Across Three Meetings

Group	Observed activity	Meeting 1 (%)	Meeting 2 (%)	Meeting 3 (%)
PBL + Blooket	Students	98	100	100
PBL + Blooket	Teacher	92	97	100
PBL only	Students	100	100	100
PBL only	Teacher	100	100	100

The data in Table 1 indicate that both groups achieved a high level of implementation consistency across the intervention period. The PBL + Blooket group demonstrated progressive improvement, particularly in teacher implementation, increasing from 92% in the first meeting to 100% in the third meeting. This pattern suggests that the initial adjustment to digital learning tools did not hinder the overall implementation process. In contrast, the PBL-only group maintained complete implementation across all meetings. Therefore, both learning environments provided comparable procedural conditions, strengthening the validity of the subsequent analysis of students' analytical-thinking outcomes.

Improvement of Students' Analytical Thinking After the Intervention

The analysis of learning outcomes revealed different patterns of improvement between students who experienced PBL supported by Blooket and those who experienced PBL alone. Both groups started with identical mean pretest scores of 65.77, indicating comparable initial analytical-thinking abilities before the intervention. After the learning process, both groups demonstrated improvement; however, the magnitude of improvement differed substantially. The experimental group achieved a higher posttest mean score and greater normalized gain compared with the control group. These findings suggest that the integration of Blooket within the PBL framework provided additional support for developing students' analytical-thinking abilities. The comparison of analytical-thinking achievement and N-Gain values is presented in Table 2.

The difference in analytical-thinking achievement between the two learning conditions is further illustrated in Figure 1, which presents a visual comparison of students' pretest and posttest mean scores.

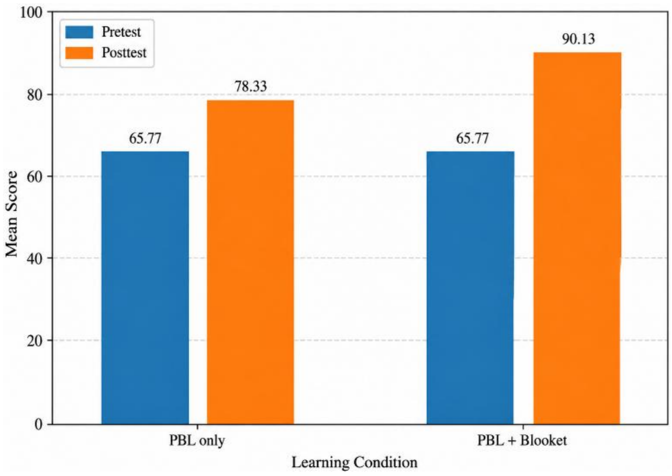

Figure 1. Comparison of Pretest and Posttest Mean Scores by Learning Condition

Figure 1 illustrates the difference in analytical-thinking development between the two learning conditions. Both groups showed similar baseline performance, as indicated by identical pretest mean scores of 65.77. However, after the intervention, the PBL + Blooket group achieved a considerably higher posttest mean score (90.13) compared with the PBL-only group (78.33). This pattern indicates that while PBL alone contributed to improving students' analytical-thinking abilities, the integration of Blooket provided additional support that strengthened learning outcomes. The higher posttest achievement in the experimental group suggests that digital game-based activities combined with problem-based investigation may enhance students' engagement with analytical tasks, allowing them to process information, evaluate problems, and construct solutions more effectively.

Table 2. Analytical-Thinking Scores and N-Gain by Learning Condition

Group	Pretest mean	Posttest mean	N-Gain (%)	Interpretation
PBL only	65.77	78.33	34.16	Moderate
PBL + Blooket	65.77	90.13	70.12	High

Table 2 shows that although both instructional approaches improved analytical-thinking scores, students receiving PBL supported by Blooket experienced substantially greater improvement. The PBL-only group achieved a moderate N-Gain of 34.16%, increasing from 65.77 to 78.33, whereas the PBL + Blooket group achieved a high N-Gain of 70.12%, increasing from 65.77 to 90.13. This difference indicates that the addition of Blooket within PBL may strengthen students' analytical engagement by providing repeated practice opportunities, immediate feedback, and interactive learning experiences. Thus, the digital game-based component appears to enhance the effectiveness of PBL in supporting analytical-thinking development.

Furthermore, the magnitude of improvement between the two groups can be observed through the N-Gain comparison presented in Figure 2.

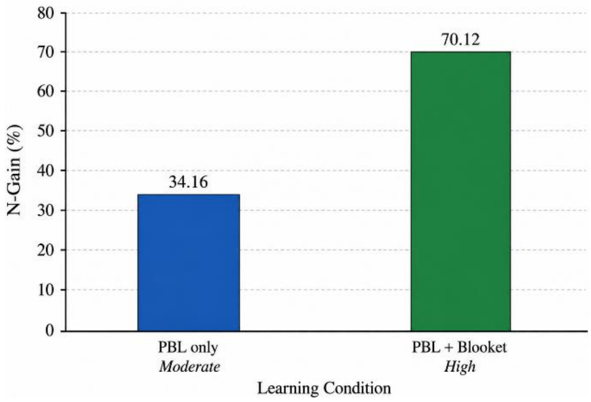

Figure 2. Comparison of N-Gain Percentages by Learning Condition

Figure 2 demonstrates that the improvement magnitude differed substantially between the two instructional conditions. Students who participated in PBL supported by Blooket achieved an N-Gain percentage of 70.12%, categorized as high improvement, whereas students who experienced PBL only achieved 34.16%, categorized as moderate improvement. The difference indicates that the additional digital game-based component provided meaningful reinforcement within the PBL framework. Through interactive question activities, immediate feedback, and repeated opportunities to evaluate information, Blooket may have supported students in developing stronger analytical-thinking processes. Therefore, the N-Gain findings reinforce the posttest comparison by demonstrating that the improvement advantage of the experimental group was not only reflected in final scores but also in the magnitude of learning progress.

Statistical Difference Between PBL With Blooket and PBL Only

Before testing the research hypothesis, assumption analyses were conducted to determine whether parametric statistical procedures were appropriate. The normality test using Shapiro-Wilk indicated that all datasets met the normal distribution assumption, with significance values exceeding 0.05. Homogeneity testing using Levene's test also showed that the variance between groups was homogeneous. After confirming these assumptions, an independent-samples t-test was conducted to examine whether the difference in analytical-thinking outcomes between groups was statistically significant. The results of the assumption tests and hypothesis testing are summarized in Table 3.

Table 3. Assumption Checks and Between-Group Hypothesis Test

Analysis	Dataset	Statistic	p value
Shapiro-Wilk	Control pretest	-	.124
Shapiro-Wilk	Control posttest	-	.103
Shapiro-Wilk	Experimental pretest	-	.15
Shapiro-Wilk	Experimental posttest	-	.097
Levene's test	Between groups	2.683	.106
Independent-samples t test	Between groups	t = 9.612	.001

The statistical analysis presented in Table 3 confirms that the assumptions required for parametric testing were fulfilled. The Shapiro-Wilk results indicated that the pretest and posttest data from both groups were normally distributed, while Levene's test confirmed equal variance between groups (p = .106). The independent-samples t-test revealed a statistically significant difference between the two learning conditions ($t = 9.612$, $p = .001$). Therefore, the improvement observed in the PBL + Blooket group was significantly higher than that of the PBL-only group. These findings provide statistical evidence supporting the hypothesis that integrating Blooket into PBL contributes to greater analytical-thinking improvement.

Students' Responses Toward Blooket-Supported PBL

In addition to measuring learning outcomes, this study examined students' perceptions toward the implementation of PBL supported by Blooket. The questionnaire results showed that students responded positively across all measured domains, including environmental change materials, PBL activities, Blooket utilization, and analytical-thinking development. The highest response was related to environmental change learning materials, followed by analytical-thinking activities, Blooket use, and the PBL learning process. These findings indicate that students perceived the learning approach as meaningful, engaging, and supportive of their learning process. The response results are presented in Table 4.

Table 4. Experimental-Group Student Responses After Blooket-Supported PBL

Response domain	Mean score	Percentage (%)	Category
Environmental change material	28.72	98.74	Very strong
Problem-Based Learning	21.31	88.78	Very strong
Blooket	21.69	90.38	Very strong
Analytical thinking	29.95	93.59	Very strong

Table 4 demonstrates that students showed very strong acceptance of the Blooket-supported PBL approach across all response domains. The environmental change material received the highest percentage (98.74%), indicating that students considered the learning content relevant and understandable. The analytical-thinking domain also received a very strong response (93.59%), suggesting that students recognized the activities as supporting their ability to analyze problems. Furthermore, positive responses toward Blooket (90.38%) indicate that the digital game element contributed to student engagement and participation during learning. Overall, these findings suggest that Blooket-supported PBL was not only effective in improving cognitive outcomes but also positively perceived by students as a learning experience.

Discussion

The central finding is not merely that students improved after PBL. Both groups improved, which is consistent with evidence that problem-centered science instruction can support meaningful learning (Funa & Prudente, 2021). The more informative result is the size of the difference between two groups that both experienced PBL. Because the experimental class achieved a substantially higher posttest mean and N-Gain, the data suggest that the Blooket layer was associated with additional analytical-thinking growth beyond the common PBL structure. This interpretation aligns with recent meta-analyses showing that PBL can improve higher-order thinking, while also emphasizing that implementation features and instructional context moderate effectiveness (Liu & Pásztor, 2022; Lu et al., 2025). It also fits evidence that collaborative problem-solving can support critical thinking, although its effects depend on factors such as duration, subject area, group size, and learning scaffolds (Xu et al., 2023).

A plausible mechanism is that PBL and Blooket supported different but complementary parts of the learning process. PBL organized the intellectual work around authentic environmental problems, requiring students to identify causes, interpret information, discuss competing explanations, and formulate responses. Blooket then added repeated response opportunities, immediate feedback, visible progress, and a game structure that could sustain attention during evaluation and reinforcement. This interpretation is consistent with science game-based learning research, which reports positive average effects on achievement (Lei et al., 2022) and shows that game design and timing can influence cognitive, motivational, and collaborative outcomes (Chen & Chen, 2025; Ding & Yu, 2024). Directly relevant Indonesian evidence also reports higher critical-thinking and learning outcomes when PBL is supported by Blooket (Paudia et al., 2025), while Blooket-supported PBL has recently shown promise for problem-solving outcomes in another school context (Lituhayu & Andrijati, 2026).

Yet a digital game should not be romanticized as a shortcut to deeper thinking. A fast, competitive quiz can increase visible participation without necessarily increasing the quality of reasoning. The educational value depends on what students are asked to do before, during, and after the game. In this study, Blooket was embedded within a PBL sequence rather than used as a stand-alone entertainment activity. That distinction is important. Systematic reviews of K-12 digital game-based learning argue that learning outcomes depend on the pedagogical mechanism added by the game, not simply the presence of a digital platform (Hussein et al., 2025; Safitri et al., 2025). Meta-analytic evidence also indicates substantial heterogeneity across learners and settings (Arztmann et al., 2023), while experimental work shows that digital games can enhance motivation and engagement without eliminating the need for careful instructional design (Zheng et al., 2024).

The implementation data illustrate this human side of technology use. The experimental condition did not begin with perfectly smooth execution. The thesis reports early adaptation to Blooket and differences in internet quality that delayed access for some students. Teacher implementation increased from 92% in the first meeting to 100% in the third, suggesting that technical fluency itself required learning. This matters for practice because a tool that is engaging for some students can become exclusionary for others when connectivity, device quality, or time pressure is uneven. Recent Blooket research similarly identifies pacing, question clarity, competitive stress, and the need for explanatory debriefing as important implementation issues (Blacer-Bacolod et al., 2026). Teachers therefore need fallback access, clear joining instructions, reasonable pacing, and brief explanation after quiz items. Blooket is most defensible when it supports the reasoning cycle of PBL rather than replacing discussion with speed.

The response questionnaire adds a useful but limited perspective. Students rated the Blooket domain at 90.38% and the analytical-thinking domain at 93.59%, indicating that they experienced the learning sequence positively. Similar studies have reported strong motivation and achievement responses to Blooket-based learning (Nur'aeni & Hasanudin, 2023), and recent science research has also reported improved learning outcomes when Blooket is integrated into a structured classroom model (Dani et al., 2026). Blooket has additionally been used as an interactive support in science-related higher education settings (Christianto et al., 2024). However, self-reported enthusiasm is not equivalent to demonstrated analytical competence. Positive ratings may reflect novelty, competition, classroom climate, or perceived enjoyment. The strength of the present study is that the response data accompany, rather than substitute for, pretest-posttest evidence.

Several limitations constrain the strength of causal claims. First, only one intact class represented each condition. Consequently, treatment is partly confounded with class membership, and student-level t testing does not model possible within-class dependence. A class-specific teacher-student dynamic, peer culture, or unmeasured classroom characteristic could therefore contribute to the observed difference. Second, the intervention lasted only three meetings, so the durability of the gains is unknown. Third, the same test set was used for pretest and posttest, which may introduce familiarity effects. Fourth, the study did not isolate which Blooket feature, such as feedback, competition, repetition, timing, or novelty, was responsible for the added gain. This is important because current research indicates that game sequencing and instructional context can alter learning effects (Chen & Chen, 2025). Finally, the thesis does not report a formal ethics approval identifier or explicit consent procedures, and these details need to be documented before publication.

Future research should use several classes per condition, randomize conditions at the class level when feasible, and analyze clustered data with multilevel or cluster-robust methods. Longer interventions and delayed posttests would help determine whether analytical-thinking gains persist beyond short-term quiz familiarity. Researchers should also compare different uses of Blooket within the same PBL sequence, for example retrieval practice, collaborative reasoning, or post-discussion feedback, because PBL effects can vary with implementation features and learning scaffolds (Xu et al., 2023; Yanto et al., 2026). Experimental comparisons of game timing would also help clarify whether Blooket is most productive before inquiry, during investigation, or after conceptual instruction (Chen & Chen, 2025). Such designs would move the field from asking whether gamification works toward identifying when, for whom, and through which learning mechanism it works.

CONCLUSION

This study concludes that integrating Blooket into Problem-Based Learning provides a meaningful enhancement to students' analytical-thinking development in environmental change learning. The most important insight gained from this research is that digital technology does not function merely as an additional learning medium, but can strengthen the effectiveness of an established pedagogical approach when it is appropriately embedded within the learning process. Although both PBL and Blooket-supported PBL improved students' analytical-thinking abilities, the experimental group demonstrated substantially higher gains, indicating that interactive feedback, repeated practice opportunities, and student engagement supported by Blooket may provide additional cognitive scaffolding. The main contribution of this study lies in its comparative design, which examines the added value of Blooket within a shared PBL framework rather than comparing technology-based learning with conventional instruction, thereby providing clearer evidence regarding the role of digital game-based reinforcement in science education. However, this study has several limitations, including the use of only two intact classroom groups, a relatively short intervention period, the absence of delayed posttest measurement, and the inability to isolate which specific Blooket features contributed most to learning improvement. Future research should involve larger samples across multiple schools, apply longitudinal designs, and investigate how different game elements, implementation strategies, and instructional sequences influence the development and sustainability of students' analytical-thinking skills.

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