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Integrating the Eco Explorers Game to Enhance Elementary Students' Problem-Solving Skills in Ecosystem Learning

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ABSTRACT

Science education at the primary level plays a critical role in fostering students' higher-order thinking skills, particularly their problem-solving abilities. However, many elementary students continue to face challenges in developing these competencies, leading to generally low levels of performance. This study investigates the effectiveness of the Eco Explorers educational game in enhancing the problem-solving skills of fifth-grade students within the topic of ecosystems. A pre-experimental one-group pretest-posttest design was employed, involving 25 participants selected through a non-probability sampling technique. Data were collected using observation sheets and standardized problem-solving tests, and analyzed using descriptive statistics, paired sample t-tests, and effect size calculations (Cohen's d) with SPSS version 26. The results revealed a statistically significant improvement in students' problem-solving abilities ($p = 0.000 < 0.05$), with a large effect size (Cohen's $d = 2.55$). These findings reinforce previous studies highlighting the benefits of game-based learning for cognitive development. In conclusion, the Eco Explorers game is a highly effective instructional tool for improving students' problem-solving skills in science education, particularly within ecological contexts. The study implies that incorporating interactive digital games into science instruction can significantly enhance student engagement and higher-order thinking, ultimately supporting more meaningful and effective learning experiences in primary education.

Keywords: Ecosystem, Eco Explorers Game, Problem Solving Skills.

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INTRODUCTION

In the 21st century, education is expected to prepare students to face rapidly evolving technological and societal challenges. Accordingly, schools must shift from traditional knowledge transmission to fostering essential 21st-century competencies, including critical thinking, creativity, communication, and collaboration—commonly referred to as the 4Cs (González-pérez & Ramírez-montoya, 2022; OECD, 2019; Sipayung et al., 2018; Sulaiman & Ismail, 2020). Science education at the primary level plays a strategic role in cultivating these competencies, particularly by engaging students in real-world phenomena that develop higher-order thinking skills such as problem-solving (Abdullah et al., 2015; Bybee, 2008; Maryani et al., 2021; Sari et al., 2023).

Problem-solving is recognized as a core skill necessary for student success in the Industry 5.0 era, where innovation and adaptability are paramount (González-pérez & Ramírez-montoya, 2022). However, numerous studies and international assessments reveal that Indonesian students continue to

face significant challenges in this area. The 2019 TIMSS results, for example, positioned Indonesia among the bottom four of 47 participating countries, with an average score of 396 in science (Hadi & Novaliyosi, 2019). This underperformance suggests a persistent gap in instructional practices that fail to promote active, student-centered learning and cognitive engagement (Dada et al., 2023; Lee & Hannafin, 2016; Tang, 2023).

Field observations at Tamanan 3 Elementary School, Yogyakarta, confirmed that science instruction in the classroom tends to rely on conventional teaching methods, with limited use of problem-based learning models or interactive digital media. This results in students lacking opportunities to develop critical problem-solving abilities. To address this issue, the current study introduces the Eco Explorers game, a digital educational game specifically designed to align with the learning objectives of ecosystem content and integrate the four core indicators of problem-solving skills: identifying, diagnosing, formulating, and evaluating problems.

What distinguishes Eco Explorers from other digital games is its purposeful integration of ecological scenarios, challenge-based missions, and reflective decision-making activities. These features are expected to motivate students through immersive gameplay while simultaneously improving their analytical and metacognitive skills (Checa-Romero & Gimenez-Lozano, 2024; Mitsea et al., 2023, 2025; Teng, 2024). Despite the promising theoretical foundations, empirical research on the application of game-based learning for problem-solving development in Indonesian elementary schools remains scarce, particularly in the context of ecosystem instruction.

Based on this context, the study is guided by the following research question: How effective is the Eco Explorers game in improving fifth-grade students' problem-solving skills in ecosystem learning? The objective of this study is to examine whether the integration of the Eco Explorers game significantly enhances students' problem-solving skills in ecosystem-based science learning at the elementary level.

METHOD

This study employed a quantitative pre-experimental method using a one-group pretest-posttest research design to examine the effect of the Eco Explorers game on students' problem-solving skills. The design involved measuring one intact group before and after the treatment. The research design is illustrated in Table 1.

Table 1. Research Design

Pretest	Treatment	Posttest
O_1	X	O_2

Description:

O_1: Pretest on problem-solving skills

X: Treatment using the *Eco Explorers* game integrated into science learning

O_2: Posttest on problem-solving skills

This study was conducted from May 2024 to February 2025 at Tamanan 3 Elementary School, Yogyakarta, involving 25 fifth-grade students selected using a convenience sampling technique, due to accessibility, school policy, and ethical considerations. Although this limits generalizability, it is commonly used in exploratory classroom-based intervention studies.

Two instruments were used to collect data. The first instrument is Problem-Solving Skills Test. The test consisted of 20 multiple-choice questions developed based on four indicators of problem-solving skills: (1) Identifying problems, (2) Diagnosing problems, (3) Formulating solutions, and (4) Evaluating solutions. The test items were validated by two science education experts and one assessment specialist. Each item was reviewed for content alignment, clarity, and relevance. The reliability of the instrument, tested using Cronbach's alpha, was 0.87, indicating high internal consistency. The second is observation sheet of learning implementation. This instrument evaluated the fidelity of implementation across several components: lesson opening, content delivery, mastery of ecosystem concepts, application of problem-based learning syntax, integration of the Eco Explorers game, evaluation process, and lesson closure. Observations were rated on a 5-point Likert scale, and inter-rater agreement was ensured through a trial and calibration session between two raters, achieving a Cohen's Kappa coefficient of 0.82, which reflects substantial agreement.

The intervention involved integrating the Eco Explorers game into two ecosystem lessons using the Problem-Based Learning (PBL) model. Each session lasted approximately 80 minutes, including a 40-minute gameplay segment. Teachers applied the TPACK (Technological Pedagogical Content Knowledge) framework to balance content mastery, pedagogy, and technology use. Implementation protocols ensured consistency across sessions, including teacher briefings, lesson plan alignment, and standard media usage instructions. This study was guided by the following hypotheses:

- H_0 (Null Hypothesis) : There is no significant difference in students' problem-solving skills before and after using the Eco Explorers game.
- H_1 (Alternative Hypothesis) : There is a significant improvement in students' problem-solving skills after using the Eco Explorers game.

The pretest and posttest data were analyzed using descriptive statistics, paired sample t-tests, and effect size (Cohen's d) to determine the magnitude of the intervention's impact.

RESULTS & DISCUSSION

Result

The implementation of the Eco Explorers game was conducted across two science learning sessions using a Problem-Based Learning (PBL) framework. The intervention began with the administration of a pretest to assess students' initial problem-solving skills, followed by structured ecosystem learning activities supported by the TPACK framework. During the first session, students were introduced to ecosystem concepts using multimedia tools, and were guided through problem-orientation tasks that encouraged critical engagement with environmental scenarios (Figure 1).

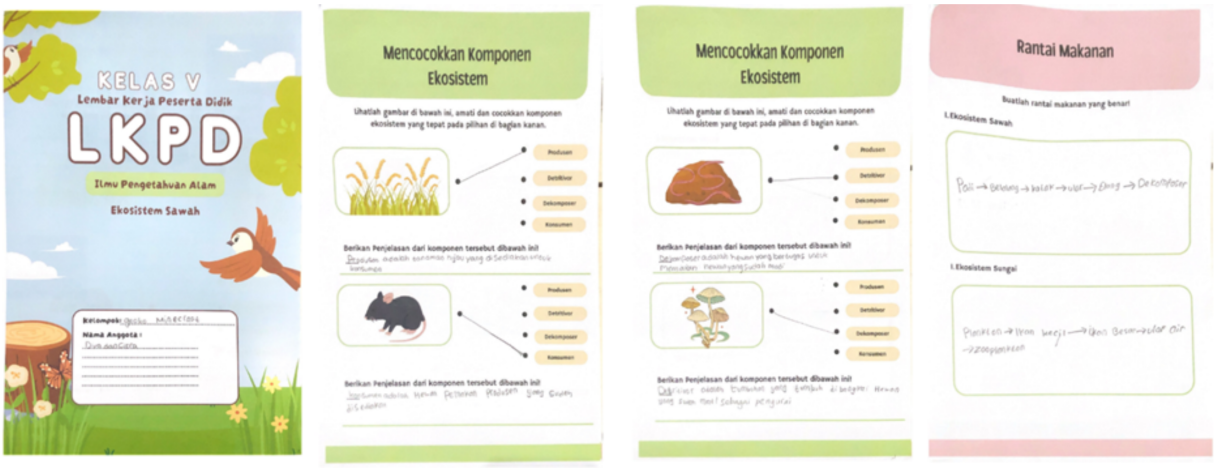
Figure 1. Students engaging in initial problem orientation activities

In the second session, students were organized into small collaborative groups and introduced to the Eco Explorers game. The teacher provided clear guidance on navigating the game interface, which required students to engage with environmental scenarios, make strategic decisions, and work together to complete problem-solving tasks. This process facilitated both cognitive and interpersonal development (Figures 2 and 3).

Figure 2. Students collaborating during gameplay preparation

Figure 3. Teacher guiding student groups during Eco Explorers game activity

Following the game-based learning experience, students completed worksheets focused on food chains, food webs, and environmental challenges within ecosystems. These tasks enabled learners to apply concepts encountered in the game to real-world ecological contexts, deepening their understanding through analysis and synthesis (Figures 4 and 5).



(a) (b) (c) (d)

Figure 4. Example of student worksheet on food webs and local ecosystem analysis (a) cover page, (b) Matching Ecosystem Components, (c) Matching Ecosystem Components (continued), and (d) Food Chain

The translation of Figure 4 shows in Table 2

Table 2. Research Design

Figure-page	Part	Translation
(a)-Page 1	Cover Page	Grade V – Student Worksheet Natural Sciences Rice Field Ecosystem Group: Gacha Minecraft Members: Diva dan Gifari
(b)-Page 2	Matching Ecosystem Components	Matching Ecosystem Components Observe the pictures below, identify and match each with the correct ecosystem component on the right side. • Picture of rice → Producer *Explanation:* Rice is a plant that produces its own food through photosynthesis. • Picture of a rat → Consumer *Explanation:* A rat is an animal that eats plants. Therefore, it is a consumer.
(c)-Page 3	Matching Ecosystem Components (continued)	Observe the pictures below, identify and match each with the correct ecosystem component on the right side. • Picture of soil → Detritivore *Explanation:* Soil contains living organisms that function to break down decaying matter. • Picture of mushrooms → Decomposer *Explanation:* Mushrooms are fungi that help decompose dead plants. They act as decomposers.
(d)-Page 4	Food Chain	Create a correct food chain! I. Rice Field Ecosystem Rice → Grasshopper → Frog → Snake → Eagle → Decomposer II. River Ecosystem Plankton → Small fish → Big fish → Water snake *Zooplankton*

The final stage of the learning implementation involved analysis and evaluation. At this stage, the teacher systematically reviewed students' worksheet responses to identify patterns of understanding, conceptual mastery, and areas requiring further development. This evaluative process not only informed subsequent instructional planning but also facilitated the delivery of targeted feedback aimed at improving student learning outcomes. The analysis of students' answers provided insights into individual and group comprehension of ecosystem concepts, including food chains, food webs, and ecological interactions. These findings indicated that students had begun to internalize the key concepts presented, demonstrating emerging competencies in analyzing real-world environmental issues. Moreover, the evaluation process revealed a progression in students' critical thinking abilities, particularly in articulating ecological relationships and proposing solutions to environmental challenges. By bridging classroom instruction with authentic problem-solving experiences, this stage fostered a deeper understanding of sustainability principles and encouraged learners to apply ecological reasoning to their everyday contexts.

Figure 5. Teacher reviewing and evaluating students' worksheet responses

We evaluated the learning model's implementation using an observation sheet. Results indicated a high level of effectiveness, with a 96.9% success rate across instructional components. This suggests that the integration of the Eco Explorers game within the PBL model effectively supported student engagement and instructional delivery. To measure learning outcomes quantitatively, pretest and posttest scores were analyzed using SPSS 26. Descriptive statistical results (Table 3) showed a significant increase in mean scores—from 58.80 to 84.80—along with a decrease in standard deviation, suggesting improved

consistency in student performance.

Table 3. Descriptive Statistics for Pretest and Posttest Scores

Test Type	Mean	Standard Deviation	M - 1SD	M + 1SD
Pretest	58.80	12.01	46.78	70.81
Posttest	84.80	8.71	76.08	93.51

Figure 6 illustrates the distribution of student performance categories before and after the intervention, highlighting a positive shift in achievement levels.

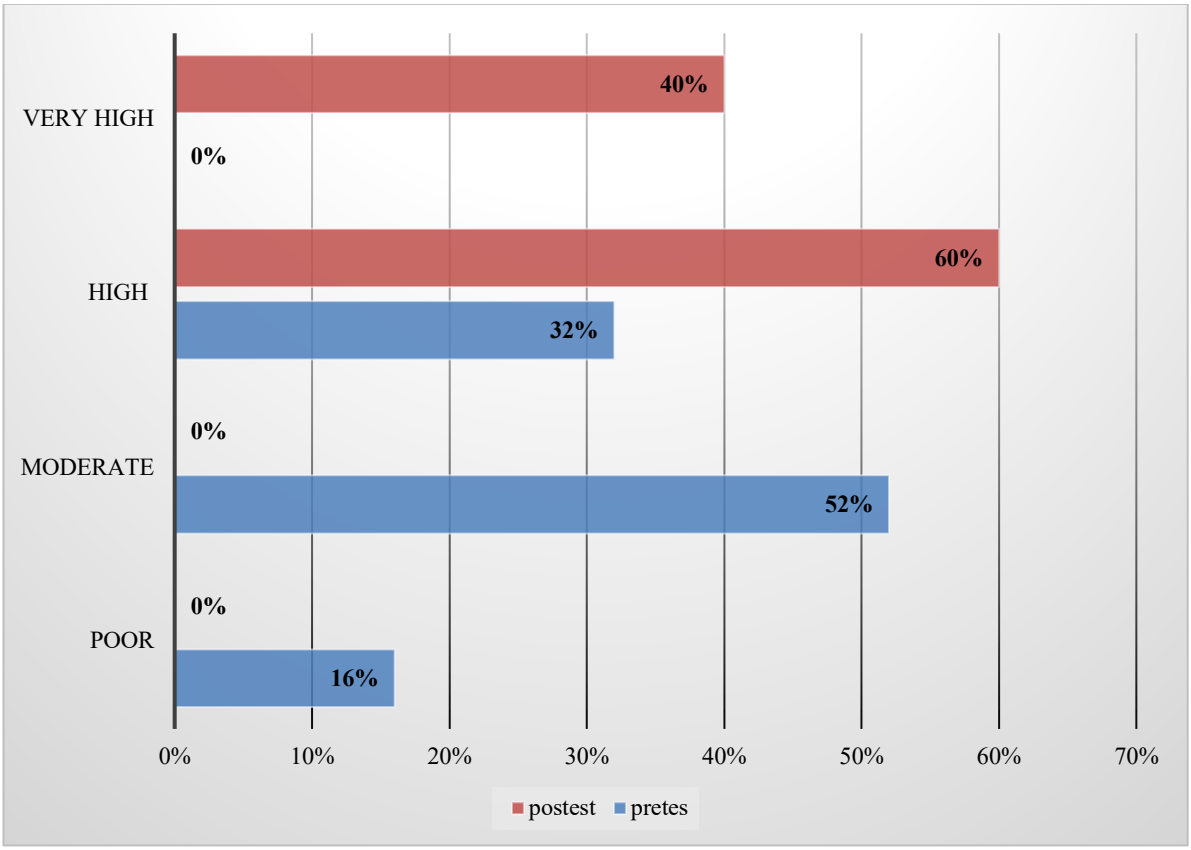


Figure 6. Comparison of Problem-Solving Skill Categories Before and After the Intervention

Before the intervention, 4 students were categorized as having poor problem-solving skills, 13 were at a sufficient level, and 8 were at a good level. Following the intervention, the distribution shifted significantly: 15 students were categorized as good, and 10 as excellent. This shift indicates a marked improvement in student abilities and suggests the intervention successfully fostered problem-solving competence. Normality was checked using the Kolmogorov–Smirnov test. The results, presented in Table 3, indicate that the data is normally distributed ($p = 0.044 > 0.05$), validating the suitability of subsequent parametric analyses.

Table 4. Normality Test Results (Kolmogorov–Smirnov)

N	Mean	Std. Deviation	Sig. (2-tailed)
25	0.000000	8.511189	0.044

We also conducted a homogeneity test using Levene's test to assess the equality of variances between

the two groups. As shown in Table 5, the significance value (p = 0.388) exceeds the threshold of 0.05, indicating that the data meets the assumption of homogeneity.

Table 5. Homogeneity Test Results (Levene's Test)

Basis for Testing	Levene Statistic	df1	df2	Sig.
Based on Mean	0.760	1	48	0.388
Based on Median	0.771	1	48	0.384
Median with adjusted df	0.771	1	47.366	0.384
Based on trimmed mean	0.569	1	48	0.455

We conducted a paired sample t-test to compare the pretest and posttest scores. The results revealed a statistically significant difference (t (24) = -9.827, p < 0.001), confirming the intervention's positive effect (Table 6).

Table 6. Paired Sample T-Test Results

Pair	Mean Difference	t	df	Sig. (2-tailed)
Pretest-Posttest	-26.00	-9.827	24	0.000

The effect size, calculated using Cohen's d, yielded a value of 2.55, indicating a very large effect and underscoring the substantial impact of the Eco Explorers game on students' problem-solving skills.

Table 7. Descriptive Statistics Results

Test	N	Mean	Std. Deviation
Pretest	25	58.80	12.01
Post-test	25	84.80	8.71

To further quantify the magnitude of improvement, we calculated the effect size using Cohen's d, based on the descriptive statistics in Table 7. The visualization of this effect size is presented in Figure 7.

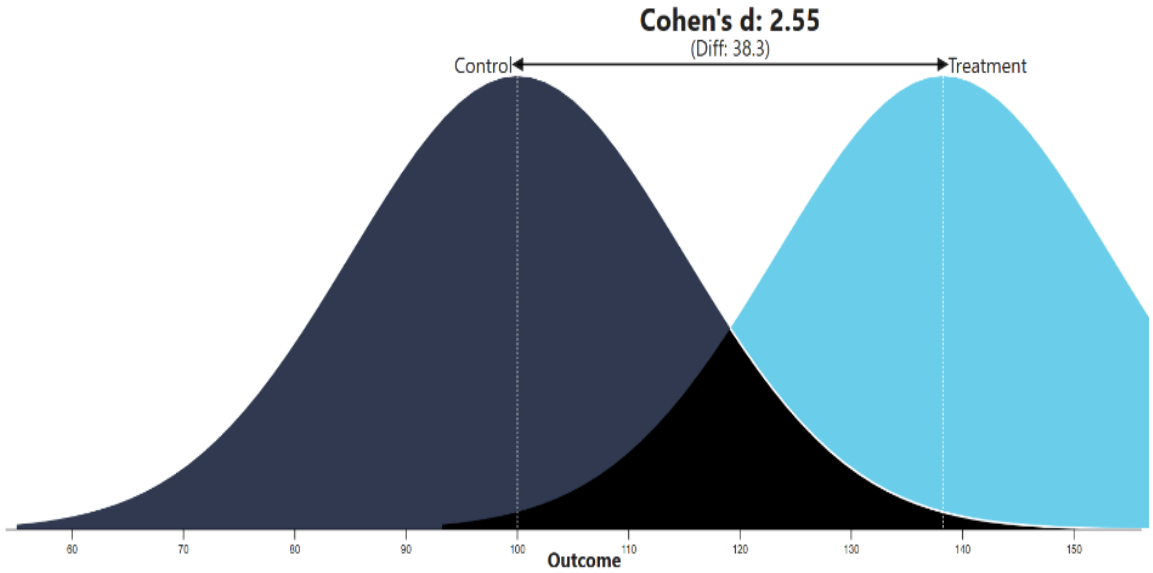


Figure 7. Effect Size Visualization (Cohen's d = 2.55)

These findings reinforce the utility of integrating digital educational games like Eco Explorers with

inquiry-based pedagogies. The consistent upward shift across performance levels, coupled with significant statistical outcomes, provides compelling evidence for its scalability in science education.

Discussion

The findings of this study demonstrate that science learning in primary education benefits significantly when contextualized within students' everyday experiences (Ayotte-Beaudet et al., 2023; Campbell & and Lubben, 2000). Effective instruction requires systematically designed activities that foster interactive, inspiring, engaging, and challenging learning experiences (Czerkawski & Lyman, 2016). These are fundamental characteristics of 21st-century learning, where students are not just passive recipients of information but active agents in their own educational journey (Antonenko et al., 2014; Chalkiadaki, 2018). Such a perspective aligns with the competency-based curriculum and holistic educational approaches promoted by various global educational frameworks.

In this study, the Eco Explorers game was introduced as a digital intervention to support elementary science learning, particularly on the topic of ecosystems. The game's implementation revealed a high level of student engagement and participation. Students were not only motivated to complete the tasks within the game but also exhibited emotional reactions—ranging from excitement upon completing levels to frustration when encountering obstacles. These affective responses, often overlooked in traditional learning environments, are critical components of student motivation and have been associated with increased cognitive engagement and deeper learning outcomes (Li et al., 2021; Pickering, 2017).

The results from this intervention—namely, the significant increase in average scores from the pretest (58.80) to the posttest (84.80)—substantiate the effectiveness of integrating digital game-based learning tools within science instruction. Additionally, the large effect size (Cohen's d = 2.55) provides strong statistical evidence of the magnitude of impact this intervention had on students' problem-solving skills. This corroborates findings from prior studies which assert that educational games enhance critical thinking and problem-solving abilities (Hussein et al., 2019).

The game was purposefully designed to align with indicators of problem-solving competency. Four main aspects were embedded into the game mechanics: (1) problem understanding, where students identify challenges and gather relevant information to overcome them; (2) diagnosing problems, as students interpret gameplay outcomes and recognize errors (e.g., losing lives due to incorrect decisions); (3) developing alternative strategies, where learners devise ways to optimize their performance based on prior experiences; and (4) evaluation, which involves reflecting on the results and making adjustments accordingly. These stages are closely aligned with Jonassen (2000) model of problem-solving in learning environments and have been effectively translated into the Eco Explorers game context.

The resemblance between Eco Explorers and commercial digital games such as Mario Bros. was also strategically employed. Maryani et al (2025) found that games with progressive challenges and immediate feedback loops tend to enhance students' perseverance and self-regulation. By leveraging familiar mechanics, Eco Explorers created a bridge between recreational gaming and formal learning, particularly beneficial for the digitally native Generation Alpha students who interact with technology daily.

The thematic content of the game—ecosystems and their components—was also essential to its success. Students explored biotic and abiotic elements, food chains and webs, and environmental threats in a simulated setting. This immersive experience promoted not only conceptual understanding but also environmental awareness. The gamified format facilitated experiential learning, a method shown to be effective in environmental education (Huang et al., 2016; Tan & Nurul-Asna, 2023).

Observational data further confirmed that students showed increased curiosity and enthusiasm during learning sessions. As noted in (Neo & Neo, 2004), creative instructional media—especially those incorporating multimedia and interactivity—can enhance student autonomy and encourage deeper exploration. Students were seen reflecting on their actions during gameplay, discussing strategy with peers, and even relating in-game challenges to real-world environmental issues. These observations are supported by Sun et al (2025), who emphasized the role of collaborative, game-based tasks in promoting interpersonal and intrapersonal intelligence.

Furthermore, the structure of the problem-solving skill assessment reinforced the game's effectiveness. The four components—understanding the problem, diagnosing causes, formulating strategies, and evaluating results—were measurable both within the game and through supplementary tools (e.g., worksheets and quizzes). Students who initially scored low on pretests demonstrated significant improvement in these dimensions, particularly in the ability to formulate strategies and evaluate outcomes. This indicates that the game not only improved academic knowledge but also fostered cognitive flexibility.

In addition to the statistical results, qualitative data—such as student reflections, teacher observations, and worksheet analyses—supported the conclusion that the Eco Explorers game fostered both engagement and learning. Students expressed enjoyment and pride in their achievements, and teachers reported higher levels of participation compared to conventional lessons. Such feedback highlights the socio-emotional benefits of game-based learning, echoing the conclusions of Woo (2014), who noted that digital games increase students' willingness to take on cognitive challenges.

The implications of these findings are multifaceted. From a pedagogical perspective, Eco Explorers showcases how educational games can serve as an effective medium for conveying complex scientific content. The ability to simulate ecological interactions in a game-based format allows for more meaningful learning compared to traditional lecture-based methods. For curriculum developers, this

research supports the integration of digital tools into science units, particularly when aligned with inquiry-based approaches like Problem-Based Learning (PBL).

From a technological standpoint, this study emphasizes the importance of user-centered design in educational games. Elements such as intuitive navigation, immediate feedback, and goal-based progression contributed to the game's effectiveness. Future iterations of Eco Explorers could incorporate adaptive learning paths based on student performance, ensuring individualized pacing and support. This aligns with the Universal Design for Learning (UDL) framework, which promotes flexibility in educational technology to accommodate diverse learner needs.

It is also worth noting that while the intervention was successful, its implementation was resource-intensive. Teachers needed training not only in operating the digital tool but also in integrating it meaningfully into instruction. As pointed out by Maryani et al (2025), teacher readiness is a critical factor in the success of any educational technology initiative. Therefore, scalability of such programs requires systemic support, including professional development, infrastructure, and access to devices. The relevance of this study extends beyond local contexts. As environmental education becomes increasingly urgent, tools like Eco Explorers offer a replicable model for cultivating ecological literacy and problem-solving skills among young learners. International frameworks such as UNESCO's Education for Sustainable Development (ESD) promote precisely this kind of integrated, skills-based approach to science education.

The integration of the Eco Explorers game into science instruction has proven to be an effective strategy for enhancing elementary students' problem-solving abilities and engagement with ecosystem content. The significant improvement in learning outcomes, coupled with strong affective responses and active participation, underscores the game's potential as both a pedagogical and technological innovation. Future research could expand on these findings by examining long-term retention of concepts, scalability across different schools, and integration with other STEM domains. Ultimately, this study contributes valuable insights into the design and application of game-based learning environments in primary education, supporting the development of competent, curious, and environmentally conscious learners.

CONCLUSION

This study investigated the effectiveness of the Eco Explorers game in enhancing problem-solving skills among fifth-grade students during ecosystem learning. The findings demonstrate that the integration of game-based learning significantly improves students' ability to understand, diagnose, strategize, and evaluate problems. The statistical results, including a large effect size (Cohen's $d = 2.55$), confirm the strong impact of the intervention on students' cognitive development. The game's interactive features and alignment with problem-based learning principles fostered engagement and supported

higher-order thinking. Students were actively involved in learning through exploration, decision-making, and reflection—core components of 21st-century education. The observed improvements reinforce the value of educational games as tools not only for knowledge acquisition but also for developing critical competencies in elementary science education. Importantly, this study contributes to the growing body of evidence supporting the pedagogical potential of digital learning environments. It highlights the importance of intentional game design that links curricular content with authentic problem-solving experiences. Given these results, educators are encouraged to adopt game-based strategies as part of their instructional approach. Future research should explore the long-term effects, scalability, and adaptability of such interventions across diverse educational contexts and age groups. By integrating meaningful gameplay into the classroom, schools can better prepare students to face real-world challenges with creativity, resilience, and confidence.

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