



Roblox-Based Immersive Learning for Environmental Literacy in Online Science Education

Fathul Zannah*

Universitas Muhammadiyah Palangka Raya
INDONESIA

M Noor Fitriyanto

Universitas Muhammadiyah Palangka Raya
INDONESIA

Kamaliah Kamaliah

Universitas Muhammadiyah Palangka Raya
INDONESIA

Rahmatullah Rahmatullah

Universitas Muhammadiyah Palangka Raya
INDONESIA

Article Info

Article history:

Received: April 17, 2026

Revised: August 10, 2026

Accepted: September 10, 2026

Keywords:

Environmental literacy;
Gamified learning
Immersive learning;
Online science education;
Peatland conservation.

Abstract

Environmental literacy requires learning environments that enable students to explore complex ecosystem interactions and evaluate the consequences of environmental decisions, yet conventional online science learning often provides limited opportunities for such experiences. This study developed and evaluated a Roblox-based immersive learning system designed to support environmental literacy, particularly in the context of peatland conservation. Using a Design-Based Research approach with ADDIE as the development framework, the system integrated virtual forest, peatland, marine, and human-impacted ecosystems with scenario-based problem solving, decision-making, feedback, reflection, and embedded assessment. Junior high school students participated in needs analysis, implementation, practicality evaluation, and pretest-posttest environmental literacy assessment, while experts evaluated the system's validity. The findings demonstrated strong student readiness for interactive digital learning and indicated that the developed system achieved high levels of expert validity and student-rated practicality. Students also showed substantial improvement across environmental literacy outcomes following implementation. These findings provide initial evidence that immersive ecosystem simulation can support environmental knowledge, awareness, attitudes, and pro-environmental behavioral intentions while connecting environmental concepts with contextual decision-making. However, the absence of a control group limits causal interpretation. Further controlled studies across diverse learning contexts are therefore needed to establish its comparative effectiveness and broader applicability.

To cite this article: Zannah, F., Fitriyanto, M. N., Kamaliah, K., Rahmatullah, R. (2026). Roblox-based immersive learning for environmental literacy in online science education. *Online Learning in Educational Research*, 6(3), 81-101. <https://doi.org/10.58524/oler.v6i3.1195>

INTRODUCTION

Environmental challenges, including deforestation, peatland degradation, marine ecosystem damage, and biodiversity loss, highlight the need for learning systems that can represent complex environmental processes in dynamic and interconnected ways (Pacheco-Velázquez et al., 2025). This concern is particularly relevant in Indonesia, which has rich biodiversity and a wide range of ecosystems. Students therefore need to understand not only individual environmental components but also the relationships among ecosystems, environmental changes, and human activities (Demssie et al., 2023). Learning approaches that present these relationships in a connected and dynamic way can help students develop a more

* Corresponding Author

Fathul Zannah, Universitas Muhammadiyah Palangka Raya, INDONESIA ✉ zannah@umpr.ac.id

comprehensive understanding of environmental problems and their implications for sustainable environmental management. Understanding the interconnected environment can be achieved by using appropriate learning media in learning activities. Conventional learning media have been the dominant medium for learning activities. Conventional learning media are limited in visualizing system interactions, temporal changes, and the causal relationships inherent in environmental phenomena (Hosna et al., 2026). As a result, students often struggle to understand environmental systems as integrated and evolving entities.

These limitations highlight the need for learning systems that support environmental literacy by enabling learners to explore interconnected environmental components and observe the consequences of their decisions within complex ecosystems. Recent advances in digital technology have positioned game engines as powerful tools for interactive simulation and system-based media development. Game engines provide real-time rendering, physics-based interaction, and event-driven logic, enabling users to explore virtual environments and receive immediate feedback (Boncu et al., 2022; Ren et al., 2025; Tan & Nurul-Asna, 2023). Accordingly, the integration of game engines into learning media offers a promising approach for developing interactive systems that facilitate environmental literacy through experiential exploration (Garcia et al., 2025).

Environmental literacy is commonly described as a multidimensional construct encompassing environmental knowledge, awareness, attitudes, and pro-environmental behavioral intentions (Winarto et al., 2025). It represents a form of higher-order learning outcome that shapes how individuals understand environmental systems, interpret cause-effect relationships, and make informed decisions regarding environmental issues. Within the context of environmental education, environmental literacy plays a crucial role in enabling learners to identify environmental problems, analyze interactions among ecosystem components, evaluate the consequences of human activities, and determine appropriate actions to address complex environmental challenges (Junaidah et al., 2025; La Hadisi et al., 2025). Therefore, appropriately designed learning approaches are essential to foster environmental literacy as a foundation for meaningful understanding and responsible environmental behavior (Andriana et al., 2025).

In this study, environmental literacy is viewed as a multidimensional construct that extends beyond students' ability to recall environmental information. It involves understanding environmental concepts, recognizing environmental problems and their consequences, developing appropriate responses to environmental issues, and considering actions that contribute to environmental conservation. Based on this perspective, four dimensions were used in the study: environmental knowledge, environmental awareness, environmental attitudes, and pro-environmental behavioral intentions. Environmental knowledge refers to students' understanding of environmental concepts and ecological processes, while environmental awareness concerns their ability to recognize and interpret environmental problems and their impacts. Environmental attitudes reflect how students respond to environmental issues, whereas behavioral intentions represent their tendency to select appropriate actions for environmental conservation. These dimensions were operationalized through context-based and scenario-based assessment items related to ecosystems, environmental problems, and peatland conservation. Specifically, the assessment examined students' understanding of peatland ecosystems and their functions, their ability to identify and interpret environmental damage, their responses to environmental problem situations, and their selection of appropriate conservation actions. In this way, the conceptualization of environmental literacy was directly connected to the indicators and item formats used in the assessment.

Among available digital platforms, Roblox has increasingly been used as a learning environment because its user-generated content, three-dimensional environments, multiplayer features, and cross-platform accessibility allow learners to interact with simulated settings rather than relying solely on conventional digital materials (Faridah & Deng, 2024; Han et al., 2023). These technical features make Roblox suitable not only for entertainment but also for developing immersive and interactive learning environments (Jeong et al., 2024). However, existing Roblox-based educational applications have generally focused on the use of the platform as a medium for delivering learning content or creating engaging virtual experiences. At the same time, its potential as an environment for representing interconnected environmental systems

and supporting environmental literacy has received comparatively limited empirical attention. In particular, it remains unclear how an immersive Roblox environment that combines ecosystem simulation, scenario-based environmental problem-solving, decision-making, feedback, and reflection can be used to support multiple dimensions of environmental literacy. This study addresses this gap by developing a Roblox-based learning system that does not merely present environmental content in a game format, but represents forest, peatland, marine, and human-impacted ecosystems as interactive learning contexts in which students explore environmental conditions, analyze problems, make decisions, observe consequences, and reflect on their actions. The contribution of the study therefore lies in the integration of immersive ecosystem simulation and scenario-based environmental learning within Roblox, with environmental literacy serving as the primary learning outcome.

This study addresses this gap by developing a Roblox-based immersive learning system that integrates representations of local Indonesian ecosystems, including forest, peatland, marine, and human-impacted environments, into science learning. The system incorporates interactive exploration, scenario-based environmental problem-solving, decision-making, feedback, reflection, and embedded assessment activities to support students' environmental literacy. Accordingly, this study had three objectives: (1) to develop a Roblox-based immersive learning system that is valid for use in environmental science learning; (2) to examine the practicality of the developed system based on students' responses during implementation; and (3) to examine changes in students' environmental literacy following the implementation of the learning system. These objectives were addressed through the Analysis, Design, Development, Implementation, and Evaluation stages of the ADDIE model. The study therefore contributes an immersive learning approach that combines ecosystem simulation and scenario-based environmental learning within Roblox, with environmental literacy as the primary learning outcome.

METHOD

Research Design and Purpose

This study employed a Design-Based Research (DBR) approach to develop and evaluate a Roblox-based immersive learning system in an authentic science education context (Nogueras et al., 2026). DBR was selected because the study involved the development, implementation, evaluation, and refinement of an educational intervention in a real learning context. Within this research approach, the ADDIE model was used as the systematic development framework, consisting of five stages: Analysis, Design, Development, Implementation, and Evaluation (Cebrián & Junyent, 2015; Nurjain et al., 2025; Prasasti & Anas, 2023; Suyidno et al., 2025; Widarti et al., 2025; Zannah & Ayatusaadah, 2023). The ADDIE stages provided the procedural structure for developing the learning system. At the same time, the DBR approach guided the iterative refinement of the intervention based on needs analysis, expert feedback, functional testing, and implementation findings.

The research process started with the needs analysis, where the difficulties faced by teachers in teaching environmental concepts, especially peatland conservation, in online learning situations were identified. Stage two entailed the design of the immersive learning environment using the Roblox Studio tool, which included the development of interactive elements like virtual exploration, decision-making through scenarios, and assessment processes. Stage three encompassed the development and functional testing of the system to ensure usability and performance. The last stage involved the evaluation process through expert validation and classroom implementation, followed by reflections.

The study population included 100 seventh-grade students at a junior high school in Palangka Raya, Indonesia, with the purposive sampling method. The learners had digital literacy skills and experience using the online learning platform; however, they had not used immersive game-based learning platforms like Roblox. Such circumstances were ideal for the feasibility and practicality evaluation of the system as an alternative interactive learning platform for teaching environmental concepts, especially peatland conservation.

Research Procedure

The research process was done through the five phases of ADDIE. The first phase of ADDIE is the Analysis, wherein the students' learning needs were analyzed, as well as their digital capabilities and the problems they encountered in learning environmental topics, especially regarding peatland conservation, in online learning situations. The second phase, the Design, was devoted to creating the learning objectives, content, ecosystem scenarios, interaction process, and the form of assessment. In the Development phase, the design of the immersive learning environment using Roblox was created, together with the inclusion of interaction tools, scenario activities, feedback, reflective activities, assessment, and function testing and validation by experts. The Implementation phase was conducted by implementing the created learning system among 100 Grade 7 students and gathering information regarding students' perceptions of practicality and their environmental literacy through pretest and posttest assessments.

Research Subjects

Participants of this study include two different groups of people: expert validators and student participants. In the first group, six expert validators validated the validity of the developed Roblox based immersive learning system where there were two science subject-matter experts, two instructional media experts, and two language experts validating the validity of the developed Roblox-based immersive learning system. In the second group, 100 seventh graders from a junior high school in Palangka Raya, Indonesia, were selected to implement a limited application of the developed learning system in terms of its practicality, usability, and effectiveness in an actual online learning environment. In this study, environmental literacy was considered as the dependent variable, which has four important dimensions; namely, environmental knowledge, environmental awareness, environmental attitude, and pro-environmental behavioral intentions (Winarto et al., 2025).

Research Instrument

Four research tools were employed in this study to gather data in the various phases of the research process, namely the needs analysis questionnaire, expert validation form, student practicality questionnaire, and environmental literacy test. A needs-analysis questionnaire was first conducted among the 100 Grade 7 students at the beginning of the study process. The needs analysis questionnaire aimed at gathering information regarding students' access to and preparedness in terms of digital technology, exposure to digital games, prior use of games in education, and students' response to interactive simulation-based learning. The information gathered through this questionnaire was utilized as the basis for determining the students' learning needs and technological preparedness before developing the Roblox-based learning environment.

Second, an expert validation sheet was employed to check for the validity and reliability of the developed Roblox-based immersive learning system. The tool had three components, which included instructional media, science content, and language. This tool contained 11 questions, which were rated using a five-point Likert scale. Six experts were used in the process of validating the tool, where each component was assigned two experts: two instructional media experts, two science subject-matter experts, and two language experts. The questions focused on the appropriateness of the media, scientific content, functionality, interactivity, visual appeal, and the clarity of language used in the learning system.

Third, a student practicality questionnaire was filled out by the 100 Grade 7 students during the implementation phase. This was meant to measure students' perception of their experience when using Roblox-based environmental learning media. The questionnaire considered many aspects regarding the learning experience, such as usability, attractiveness, engaging nature, interactivity, clarity of content, feedback received, and the general experience with the learning system.

Fourth, an environmental literacy assessment was used to examine changes in students' environmental literacy before and after the implementation of the learning system. The assessment was developed around four dimensions of environmental literacy: environmental knowledge, environmental awareness, environmental attitudes, and pro-environmental

behavioral intentions (see Table 1 and Table 3). The items were presented in contextual and scenario-based situations related to ecosystems, environmental problems, and peatland conservation.

The environmental knowledge dimension addressed students' understanding of peatland ecosystems, their functions, and the effects of environmental changes. Environmental awareness focused on students' ability to recognize and interpret environmental problems and their impacts. The environmental attitude dimension addressed students' responses to environmental problems, whereas the behavioral intention dimension focused on students' selection of appropriate actions related to environmental conservation. The environmental literacy assessment was administered as a pretest before the learning activities and as a posttest after the implementation of the Roblox-based learning system. The resulting scores were then used to examine changes in students' environmental literacy following the learning intervention.

Table 1. Environmental Literacy Operational Indicators

Dimension	Operational indicator	Item format
Environmental knowledge	Understanding peatland ecosystems, their functions, and impacts	Context-based item
Environmental awareness	Identifying and interpreting environmental damage and its impacts	Scenario-based item
Environmental attitude	Selecting appropriate responses toward environmental problems	Scenario-based item
Behavioral intention	Selecting appropriate conservation actions	Scenario-based item

Data Analysis Techniques

The needs-analysis data were analyzed descriptively using frequency and percentage distributions. The percentage of students selecting each response was calculated by dividing the frequency of students who selected a particular response by the total number of respondents and multiplying the result by 100. The formula used was ($P = (f/N) \times 100\%$), where (P) represents the percentage, (f) represents the frequency of responses, and (N) represents the total number of respondents. In this study, the needs analysis involved 100 Grade 7 students; therefore, the reported percentages were calculated using (N = 100) as the denominator.

The validity of the Roblox-based immersive learning system was analyzed using the descriptive qualitative technique (Hashish et al., 2024). Score validation results were evaluated by validators and grouped into 4 categories (see Table 2). Final score validation results for every aspect are determined based on the average score of the validators.

Table 2. Level Validity

Interval Score	Criteria	Information
$3.25 < P \leq 4.00$	Very valid	Can be used without revision
$2.5 < P \leq 3.25$	Valid	Can be used with slight revision
$1.75 < P \leq 2.5$	Quite valid	Can be used with lots of revision
$1.0 < P \leq 1.75$	Less valid	Can be used and still needs consultation

The practicality data obtained from the student questionnaire were analyzed using descriptive statistics, including mean scores and percentage distributions. The results were interpreted based on predetermined criteria to categorize the level of practicality in terms of usability, engagement, and ease of understanding within the online learning environment.

Table 3. Environmental Literacy Indicators

Indicator	Description
Environmental knowledge	Identifying the concept of peat ecosystems, their functions and impacts
Environmental awareness	Determining the impact of environmental damage in a case
Environmental attitude	Choosing the right attitude towards environmental problems
Behavioral intention	Selecting appropriate conservation actions

To evaluate the effectiveness of the Roblox-based immersive learning system, students' environmental literacy scores were analyzed using a pretest–posttest design. The normality of the score distribution was assessed to determine whether the assumption required for parametric analysis was met. Improvements in environmental literacy were quantified using normalized gain (N-gain) and classified into three categories: low ($g < 0.3$), moderate ($0.3 \leq g < 0.7$), and high ($g \geq 0.7$).

In addition, the paired-samples t-test was performed in order to identify the statistically significant differences between pretest and posttest results. The level of significance was set at $\alpha = 0.05$. To estimate the practical significance of the experiment, Cohen's d statistic was calculated to estimate the effect size, which is categorized as small ($d = 0.2$), medium ($d = 0.5$), and large ($d \geq 0.8$).

RESULTS AND DISCUSSION

The development of the Roblox-based immersive environmental learning system was done to create an interactive online learning tool that will improve the environmental knowledge of the students, especially concerning ecosystem interactions and environmental changes in junior high school science learning. The development of the Roblox-based learning system was done following the ADDIE framework in the Design-Based Research methodology. These five ADDIE phases, which are Analysis, Design, Development, Implementation, and Evaluation, were utilized to guide the development and evaluation of the Roblox-based learning system.

Analysis

The first stage of the development of the proposed Roblox immersive learning system focused on defining the key issues related to Natural Science subject teaching in junior high schools and, specifically, the students' environmental literacy concerning their comprehension of ecosystems, environmental interactions, and environmental change. The analysis of the current practices showed that science lessons were mainly based on theoretical explanations and static media that hindered the students' ability to connect scientific knowledge to the real-life environment. This resulted in the students' inability to understand cause-and-effect relationships in environmental systems and led to their low environmental literacy in terms of awareness, attitude, and intentions for environmentally friendly behavior. As a solution to these issues, an interactive learning medium was developed using the Roblox game engine as an immersive environment for learning about the environment. The system represents science learning in the context of virtual local Indonesian ecosystems like forests, peatlands, and marine areas connected with the problem of environmental degradation.

The study participants were Indonesian junior high school students who had the basics of digital literacy and were accustomed to using digital devices in their daily routines. According to initial results, the majority of the subjects had their own digital devices, as more than 85% of them owned a smartphone or had access to computers, and about 78% knew about digital games. Nevertheless, only about 22% of them had some experience in using digital games for educational purposes, which means that game-based learning is not commonly integrated into formal education. Nonetheless, there was a high interest in simulation and exploratory digital learning among the participants, with nearly 81% of them having a positive attitude towards interactive learning (refer to Figure 1). This fact demonstrates the great potential for using Roblox-based immersive learning in order to facilitate learning of environmental literacy in online science classes.

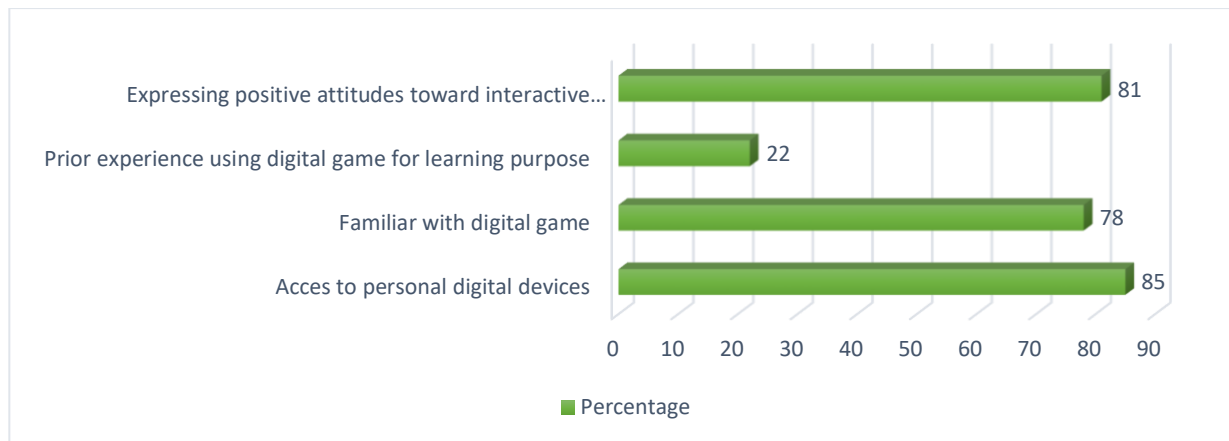


Figure 1. Digital Readiness and Learning Motivation of Junior High School Students

The analysis of context also considered the accessibility and readiness of technological infrastructure. Most of the students possessed Android- or iOS-based devices that could facilitate the use of cloud-based applications and allow the creation of a learning system that is accessible on multiple platforms without requiring high-quality hardware specifications. This factor allows implementing the proposed approach based on Roblox in the online learning process. The educational content was centered around science-related topics such as ecosystems, biodiversity, environmental pollution, and the effects of human activity, especially those related to the conservation of peatlands. The content was presented via immersive simulations, scenario interactions, embedded quizzes, and feedback options.

The results obtained during the analysis include (i) identification of learning needs and problems associated with the environmental literacy of students, particularly concerning environmental issues, (ii) evaluation of the readiness of students for digital learning as well as their attitude toward immersive and simulated learning approaches, and (iii) determination of the environmental literacy, including knowledge, awareness, attitudes, and intentions towards actions aimed at environmental protection as the main goal of the system.

Design

In the design stage of this study, the design of the immersive learning environment within Roblox was considered as the means for science learning, simulating environmental contexts. In this regard, the design stage of the study was carried out on the basis of need analysis, taking into account the characteristics and preferences of the learners. The main purpose of this learning design was to promote environmental literacy through ecosystem concepts, analysis of environmental problems, and decision-making.

Scenario Design and Game Storyboard

The design was done in a way that helps connect the gameplay process to the learning goals of junior high school science, especially developing environmental literacy among the students by making them learn about the environment, interactions between the components of the environment, and the impact of human beings on the balance of the environment (Fig. 2). Learning activities were conducted in the form of missions and challenges in the Roblox virtual environment where the students had to examine the environment and take actions for the provided situations. In each scenario, students were expected to analyze environmental issues, evaluate the consequences of the issues, and make decisions in relation to the situations.

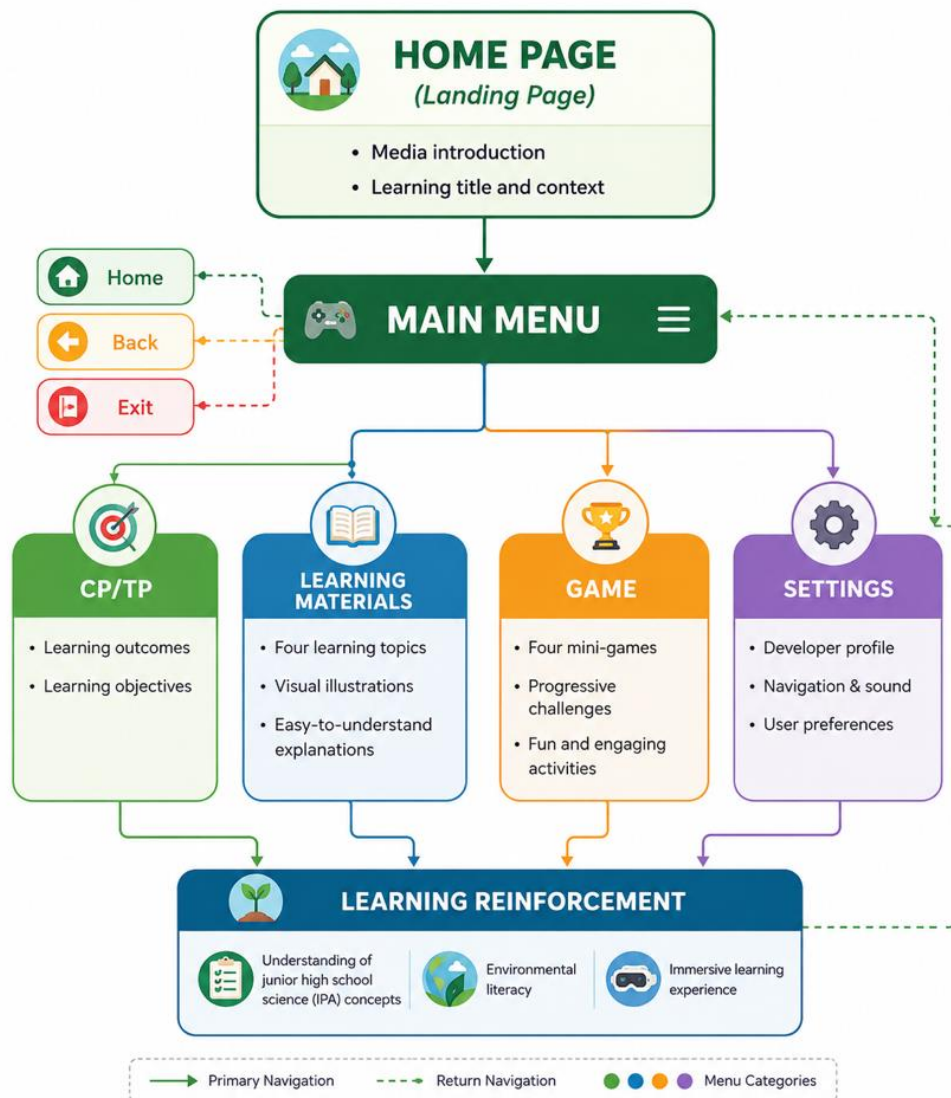


Figure 2. Content Structure

Each case is an abstraction of the environmental scenario in reality. It can be a forest ecosystem, peatland environment, aquatic ecosystem, or the residential environment. The learners take the role of the main character in the case, observe the environmental scenario, identify problems in the scenario such as pollution or habitat destruction, and make decisions to ensure environmental balance in the ecosystem. This helps the learners not only gain knowledge but also understand the environmental problem, evaluate its consequences, and choose the action needed, thereby building environmental literacy.

The storyboards were created to illustrate the connections between the game objects, learning objectives, learners' activities, and the feedback from the system. In each segment of the game, the specific learning indicators are considered. These learning indicators stress the importance of building up environmental knowledge, awareness, responsible attitude, and pro-environmental behavior intentions.

Game Flowchart

The game design process involved the use of a flow chart as the basis for describing the sequence of interactions between the learners and the Roblox immersion learning system. The first step involves orientation, in which the learners are oriented towards the learning goals that revolve around environmental literacy, the context of the simulated environment, and the roles that the learners play as key participants in observing, analyzing, and responding to environmental issues (Figure 3).

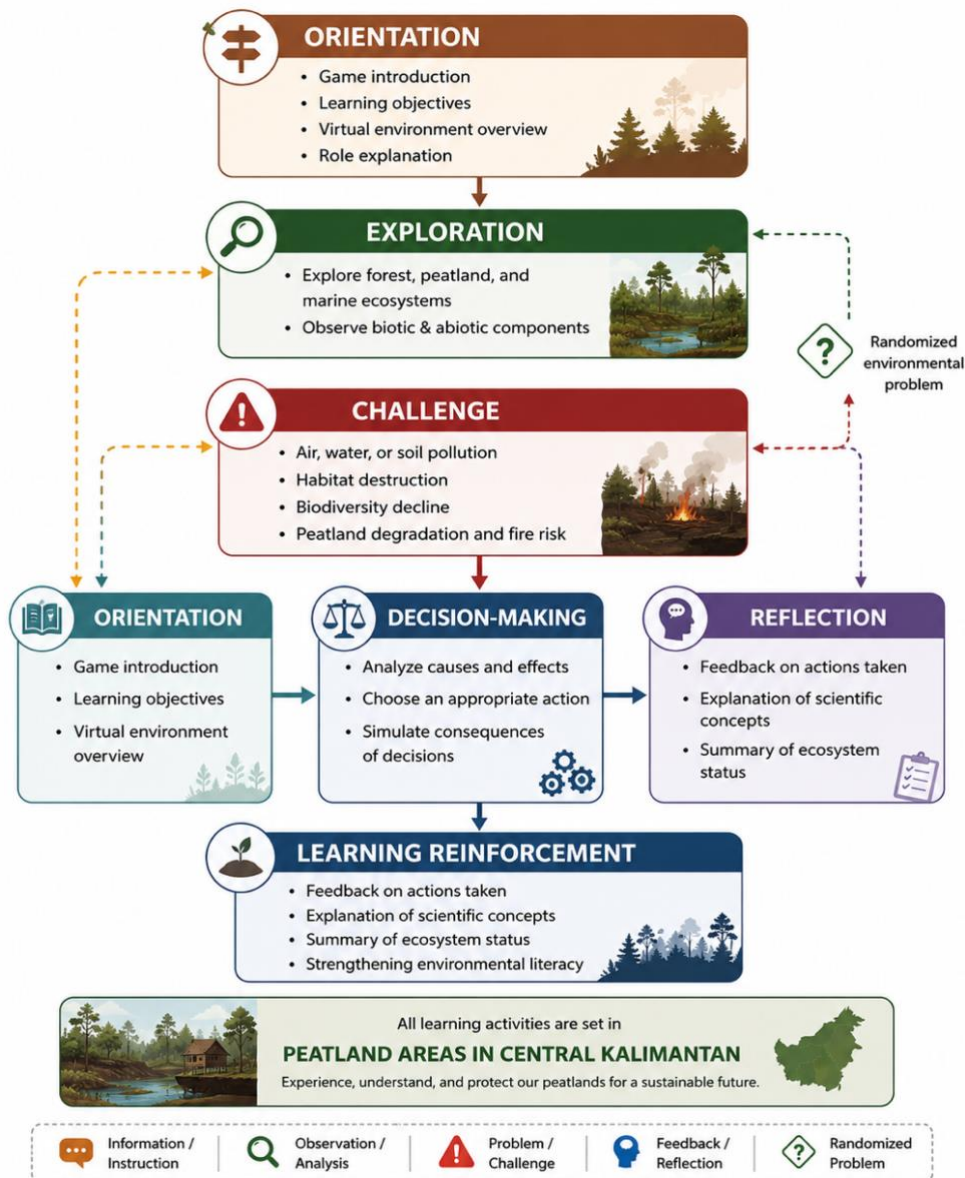


Figure 3. Game Flowchart of the Roblox-Based Environmental Learning System

Students further advance to the stage of environmental exploration in which they explore biotic and abiotic elements and analyze interactions between these elements in the ecosystem. This virtual environmental exploration will help the students gain a lot in terms of increasing awareness and knowledge about their environment through observing conditions in the environment and analyzing relationships between different components in the ecosystem. Scenario-based problems, including environmental degradation such as poor water quality, deforestation, destruction of peatlands, and loss of biodiversity, are also included in this virtual environmental exploration program. Students are required to analyze the problems, identify the cause of each problem, the consequence of each of them, and select an appropriate response from the options given. This will make the students think critically about environmental issues and develop awareness and responsibility to solve environmental problems. Students will see the consequence of each of their responses in the virtual environment to understand how each action can influence the environmental conditions.

The gameplay concludes with a reflection phase, where students receive feedback in the form of scores, explanations of relevant science concepts, and a summary of the cause-effect relationships encountered during the gameplay. This phase reinforces students' understanding and supports the integration of environmental knowledge, awareness, attitudes, and behavioral intentions. Overall, the gameplay flow is designed not only as a game-based experience but also

as a pedagogically structured learning process that supports the development of environmental literacy in junior high school science education.

Development

Development involved the implementation of the proposed Roblox immersive learning system according to the completed design and structure of the game determined in the design stage. In this stage, a functional interactive learning system that was developed from the conceptual framework aimed at developing environmental literacy was developed using Roblox Studio and Lua programming. Much emphasis was placed on the integration of features that would enable the development of environmental literacy, including interactive environmental scenarios, decision-making challenges, feedback, and assessment features. These features were incorporated to help the learners understand environmental concepts, raise environmental awareness, and develop environmental attitudes and behavioral intention.

Implementation of Core System and User Interface

The learning system was designed based on Roblox Studio as the main platform. The learning system starts from the first game menu as the access point for users and allows the user to access the main learning system. After the user accesses the game, the main menu room will be accessed as the navigation menu (Figure 4). Using this system allows students to choose the learning modules and environmental scenarios (e.g., forest, peatland, water, and urban environment), and allows the learners to go through a learning process systematically. Such a design for the navigation system facilitates the learning process to develop environmental literacy among the students through a series of learning activities.

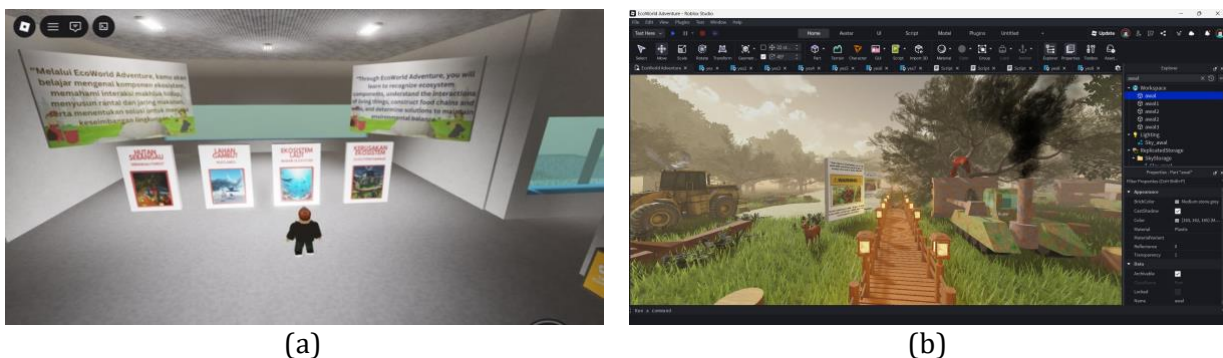


Figure 4. Roblox-Based Environmental Learning System: (a) user interface and main menu; (b) environmental map module design.

The main menu was designed as a structured virtual space that provides intuitive access to the learning activities. Clear navigation features and visual cues were incorporated to facilitate movement between sections and support a smooth and user-friendly interaction flow.

Development of Environmental Map Modules

Based on the documented structure, the system includes multiple environmental map modules representing different ecosystem conditions. Users can select specific maps corresponding to various environmental contexts, including:

- 1) Forest ecosystem (Sebangau forest), representing natural forest conditions and biodiversity balance.
- 2) Peatland ecosystem, focusing on environmental risks such as land degradation and fires.
- 3) Marine ecosystem, emphasizing biodiversity interactions and human impacts on coastal and marine environments.
- 4) Ecosystem damage scenarios, illustrating degraded environmental conditions caused by unsustainable human activities.

The use of the Sebangau ecosystem in Central Kalimantan, Indonesia, an area renowned for its high biodiversity, as a contextual reference was to ensure that the learning setting was similar

to the learners' immediate environment and consequently enhance their learning through environmental awareness and a conservationist attitude (Zannah et al., 2017).

Each of the maps was created as a three-dimensional explorable environment where users would interact with the environmental elements and objects in relation to the situation presented. These were designed to allow the changing of the visual environment and system state depending on the decisions made by the user. To illustrate the various game components and their roles, Table 4 gives an overview of the major modules of the environmental learning system created using Roblox.

Table 4. Game Modules and Their Functions in the Roblox-Based Environmental Learning System

Module	Function
Main Menu	Serves as the primary navigation hub, allowing users to access learning modules, select environmental maps, and start the learning sequence.
Environment Selection	Enables users to choose specific ecosystem maps (forest, peatland, marine, and damage scenarios) for contextualized learning.
Forest Ecosystem (Sebangau)	Simulates forest ecosystem dynamics and biodiversity balance, allowing users to observe ecological interactions and environmental changes.
Peatland Ecosystem	Represents peatland environments and associated environmental risks, such as land degradation and fire hazards, to support risk analysis.
Marine Ecosystem	Provides interactive exploration of marine biodiversity and human impacts on coastal and marine environments.
Ecosystem Damage Scenario	Illustrates cause-effect relationships resulting from unsustainable human activities, supporting environmental problem analysis.
Interaction & Decision Module	Allows users to make decisions and interact with environmental elements, triggering dynamic system responses.
Reflection Module	Guides users to reflect on their decisions and analyze outcomes in relation to science concepts and environmental systems.
Feedback System	Provides immediate explanations and corrective feedback for user actions and quiz responses to reinforce conceptual understanding.
Final Quiz	Evaluates users' understanding of ecosystem concepts, environmental issues, and solution strategies after completing all modules.
Scoring and Ranking System	Summarizes learning performance through scores and rankings to provide formative feedback and enhance learning motivation.

Integration of Learning Tasks, Reflection, and Feedback

In the process of each environmental map, there was provision for the inclusion of some learning activities and problems for the purpose of making the learners see the environmental problems and the factors associated with them. After visiting all the different ecosystem environments, the learners would be taken to the reflection component where they could reflect on the decisions they had made and relate the results they saw to some science principles. The system also gave immediate feedback in case of wrong answers being chosen by the learners. This feedback came in the form of short scientific explanations aimed at addressing any misconceptions as well as some concepts about ecosystem interactions and the environment.

Final Assessment and Performance Summary

After going through all environmental modules, students were asked to complete a final task or quiz that would measure their understanding of the concepts and environmental problems discussed in the game. The topics covered in the test included the concepts of ecosystems, the environmental problems, and the methods that could be used to solve the problems. Students got their scores through a performance and ranking system, which would display their scores and achievement level. The ranking aspect of the system was meant to motivate students.

System Deployment and Iterative Refinement

The finalized learning media were then published through Roblox's cloud platform, where the students can use the learning environment through various devices, such as PC and mobile

devices. In the development phase, tests were done to determine the functionality of the navigation system, event trigger, feedback response, and assessment systems. All identified issues were later fixed through script improvements, improved interface elements, and better interactions to improve functionality and stability. Generally, the development stage yielded a fully formed Roblox environmental learning system featuring menus, ecosystem simulation maps, feedback and reflection systems, and a final performance assessment that ranks performance. The system implements the design principles created earlier and serves as a technical basis for future validation and evaluation of the learning system.

In validating the learning media, media, subject matter, and language experts were employed to evaluate the feasibility, suitability, and quality of the Roblox immersive learning system (see Table 5). Validation areas include interface, functionality, interactivity, content accuracy and relevance, learning objective to activity alignment, environmental literacy representation, and language. The validation process provided structured feedback to ensure that the learning media met the required standards for instructional design, scientific content, and language appropriateness before student implementation.

Table 5. Expert Validation Results of the Roblox-Based Learning Media

No.	Validation Aspect	Indicator Description	Mean Score	Validity Category
Media Expert Validation	Interface Design	Clarity of layout, consistency of visual elements, and ease of navigation	4.50	Very Valid
	System Functionality	Accuracy of system responses, event triggering, and menu transitions	4.45	Very Valid
	Interactivity	Responsiveness of user interaction and feedback mechanisms	4.65	Very Valid
	Technical Performance	System stability, loading time, and cross-platform compatibility	4.45	Very Valid
Content Expert Validation	Content Accuracy	Scientific correctness of ecosystem and environmental concepts	4.60	Very Valid
	Content Relevance	Alignment with junior high school science curriculum	4.55	Very Valid
	Learning Objectives	Consistency between objectives, activities, and assessment	4.50	Very Valid
	Environmental System Representation	Representation of cause-effect relationships in environmental systems	4.60	Very Valid
Language Expert Validation	Language Clarity	Readability and clarity of instructions and explanations	4.55	Very Valid
	Language Appropriateness	Suitability of language level for junior high school students	4.55	Very Valid
	Terminology Consistency	Consistent use of scientific and instructional terms	4.50	Very Valid
Overall Mean Score			4.55	Very Valid

Expert validation confirmed that the learning media developed using Roblox technology had fulfilled the requirements for being used as an interactive learning environment. Media, content, and language validations by the experts demonstrated excellent performance in relation to the evaluated aspects, which were interface, system, scientific, interactive, and language. The validation results were rated as very valid, indicating that the system was functional and provided appropriate environmental concepts and language for junior high school students. Additionally, the experts made positive evaluations of the interactive and ecosystem simulation aspects, especially their ability to present the relationship between environmental conditions, human behavior, and its consequences. The interactive and ecosystem simulation aspects were important as they related to the intended development of environmental literacy in that they provided a platform to present environmental concepts and cause-and-effect relationships in contextualized learning settings.

Implementation

Implementation involved the use of the developed Roblox-based environmental learning media in a real junior high school learning situation to evaluate its usability, instructional implementation, and alignment with the learning objectives. This process was done after ensuring the functional stability of the system through internal testing procedures. The purpose of this process was to assess how the students used the learning system and its practicality and effectiveness in helping them develop environmental literacy.

Prior to the learning activity, the students were taken through an orientation process involving the learning objectives, design of the Roblox-based learning system, and navigation controls. This process helped the students learn how to operate the system without experiencing any challenges due to unfamiliarity with the system. During the implementation process, the students accessed the learning media using their personal computers and mobile phones on the Roblox cloud-based platform. The students moved through the different virtual environments by first going through the main menu to the various ecosystems. In each ecosystem, the students navigated the virtual environment, identified the biotic and abiotic factors, and responded to the different learning and environmental challenges.

Students had to solve various environmental scenarios through decision-making in the virtual environment. Decisions taken by the learners brought about responses from the system in the form of visual effects, message responses, and the scientific rationale behind the concept being addressed. This way, students were able to experience cause-and-effect relations in the environment, thereby analyzing environmental issues and taking conservation measures. As the students completed the activities within each module on the ecosystems, reflection and quiz activities built into the learning system were completed by the students. This allowed them to reflect on their actions, understand the impact of their actions, and connect their experiences to related scientific concepts. After completion of the learning activities, the students took the final in-game assessment, and the system automatically produced performance reports in the form of scores and rankings.

During implementation, observations were made to find usability problems, navigation challenges, and the level of engagement of the students with the learning system. In addition, feedback from the students was sought to discover areas that needed further improvements in terms of system navigation and flow, and the clarity of learning content. The results were used to refine the learning media before evaluation. Generally, implementation of the study showed that it is possible to use the learning system within Roblox in an authentic junior high school learning environment.

Evaluation

The performance of the immersive learning approach through Roblox was tested based on a pretest-posttest design among 100 seventh-grade students. The students' knowledge of their environment was measured before and after they engaged in the learning process through Roblox. The results of the pretest and posttest were analyzed using descriptive statistics, normalized gain (N-Gain), and a paired samples t-test. Cohen's d was also used to quantify the effect size (see Table 6).

Table 6. Descriptive Statistics of Environmental Literacy Scores

Measure	N	Mean	SD	Minimum	Maximum
Pretest	100	55.82	9.18	35	77
Posttest	100	79.15	11.86	41	99

The findings indicated a significant boost in the level of environmental literacy among the learners after the adoption of the Roblox virtual learning environment. The average score rose from 55.82 (SD = 9.18) in the pretest to 79.15 (SD = 11.86) in the posttest, a rise of 23.33 points on average. The normalized gain score was 0.53, which is moderate (see Table 7).

Table 7. Paired Samples Test and Effect Size

Statistic	Value
Mean difference	23.33
95% CI	21.57–25.09
<i>t</i>	26.35
df	99
<i>p</i>	< .001
Cohen's <i>d</i>	2.63
N-Gain	0.53
N-Gain category	Moderate

The paired-samples *t*-test revealed a statistically significant difference between the pretest and posttest means, $t(99) = 26.35$, $p < .001$. The confidence interval for the mean difference at the 95% level of significance was 21.57 to 25.09. Additionally, Cohen's *d* of 2.63 revealed a very large effect. Therefore, the results revealed empirical evidence that there was a substantial improvement in the environmental literacy of the students after exposure to the Roblox environment.

At this stage of the research, an evaluation of the implementation of the Roblox-based environmental learning media was carried out by investigating students' interactions with the learning process. The evaluation involved assessing how the students used the system, how they interacted with the simulation, and how the learning media helped the students develop environmental literacy. This was done through observation of student interactions with the system, analyzing generated system responses, and collecting data about students' perceptions concerning the usability, clarity, and relevance of the learning experience. This evaluation not only sought to establish how well the students understood the concepts of ecosystems but also how they perceived the learning experience in a game engine-based learning system.

Students' responses to the implementation of the Roblox-based environmental learning media were collected from 100 Grade 7 junior high school students who participated in a limited classroom implementation, and the summary of their responses is presented in Table 8.

Table 8. Student Responses to the Implementation of the Roblox-Based Environmental Learning Media

Evaluation Aspect	Statement Indicator	Mean Score	Response Category
System Usability	The learning media is easy to use and navigate	4.41	Very Positive
Interface Design	Visual appearance and layout are clear and attractive	4.35	Very Positive
Learning Engagement	The game-based environment makes learning more engaging	4.48	Very Positive
Content Clarity	Environmental and ecosystem concepts are easy to understand	4.32	Very Positive
Interactivity	Interactive features support active exploration	4.45	Very Positive
Feedback Mechanism	Feedback helps me understand mistakes and correct them	4.38	Very Positive
Environmental responsibility	Determining appropriate attitudes and actions towards environmental issues	4.30	Very Positive
Environmental Understand	Understanding the concept of ecosystems and environmental issues (including peat)	4.34	Very Positive
Motivation	The learning media motivates me to learn science topics	4.47	Very Positive
Overall Experience	Overall, the learning experience is enjoyable and meaningful	4.50	Very Positive
Overall Mean Score		4.40	Very Positive

As presented in Table 8, Grade 7 students demonstrated very positive responses to the Roblox-based environmental learning media, especially with regard to its usability, level of engagement, and capacity to facilitate environmental literacy and environmental problem-solving during the limited implementation.

Student Responses and Practicality of the Roblox-Based Learning Media

The implementation of the Roblox-based environmental learning media received very positive responses from the Grade 7 students. As presented in Table 8, the overall mean response was 4.40, which was categorized as very positive. The highest responses were found for overall learning experience (4.50), learning engagement (4.48), motivation (4.47), and interactivity (4.45), followed by system usability (4.41) and feedback mechanism (4.38). These results indicate that students generally found the learning environment easy to use, engaging, and suitable for supporting active participation during the limited implementation.

The positive responses are generally in line with previous research suggesting that digital and game-based learning environments can create more active and engaging learning experiences (Ding & Xue, 2025; Hendarman et al., 2026; Maier & Klotz, 2025; Monazam-Tabrizi et al., 2024; Muflihah et al., 2025; Vasz kun & Mihalkov Szakács, 2025). Nevertheless, the current results provide a more concrete background, given that the media for learning was constructed using Roblox and was based on learning activities concerning the environment and ecosystems. Other studies carried out on Roblox have also yielded positive learning outcomes in various subjects. Although these studies were done in various subjects, they all prove that Roblox has the potential to be an interactive learning medium.

The current results extend this evidence to environmental science education. Rather than employing Roblox merely as a vehicle for content presentation, the developed system provided students with an opportunity to immerse themselves in the virtual ecosystem environment and participate in the environmental problem situation. It is crucial to note here that the learning activities were designed in such a way that students' actions would be linked to environmental situations and their possible consequences. High ratings obtained by engagement and interactivity indicators imply that students appreciated this type of interaction. Still, these perceptions can hardly be treated as direct evidence of the platform's positive influence on the learning process.

It is also necessary to distinguish between the student questionnaire and the environmental literacy assessment. While the former was meant to gather data on students' perceptions of the tool's usability, attractiveness, engagement, interactivity, content clarity, feedback, and learning experience, the latter measured students' environmental knowledge, awareness, attitude, and intentions to act in a pro-environmental manner before and after the learning activity. Therefore, 4.40 score represents evidence of practicality and acceptance, while pretest-posttest results represent evidence of change in environmental literacy directly.

Changes in Environmental Literacy

The environmental literacy results showed a substantial increase after the implementation of the learning system. The mean score increased from 55.82 (SD = 9.18) in the pretest to 79.15 (SD = 11.86) in the posttest, representing an increase of 23.33 points. The paired-samples t-test showed a statistically significant difference, $t(99) = 26.35$, $p < .001$, while Cohen's d was 2.63. The N-Gain score was 0.53, which was categorized as moderate. These results indicate that students demonstrated considerable improvement in environmental literacy following participation in the Roblox-based learning activities.

The finding is consistent with recent empirical research on digital game-based environmental learning. Crilly (2026) and Demssie et al. (2023) found that a serious game improved students' understanding of the urban water cycle and supported learning related to water protection. These studies are closely related to the present research because they examined environmental learning outcomes rather than focusing only on students' enjoyment or perceptions of digital learning media. The present study therefore provides additional evidence that game-based learning can be used to support measurable changes in environmental learning outcomes.

At the same time, the present study differs from these earlier studies in the type of learning environment and environmental content used. The developed system incorporated forest, peatland, marine, and human-impacted ecosystem representations, together with scenario-based activities, feedback, reflection, and embedded assessment. Environmental literacy was also assessed through four dimensions: environmental knowledge, environmental awareness, environmental attitudes, and pro-environmental behavioral intentions. The assessment items were presented in contextual and scenario-based situations related to ecosystems, environmental problems, and peatland conservation. Therefore, the present study extends previous evidence by combining a Roblox-based immersive environment with a multidimensional environmental literacy outcome.

The observed improvement may also be related to the way environmental systems were represented in the learning media. Environmental systems involve interactions between biotic and abiotic components, changes over time, and relationships between environmental conditions and human activities (Demssie et al., 2023; Paniagua-Avila et al., 2026). These characteristics can be difficult to represent fully through static learning materials. In the present system, students could explore ecosystem components, observe environmental conditions, respond to environmental problems, and receive feedback following their decisions. Such characteristics provide a possible explanation for the learning improvement because students were given opportunities to interact with environmental situations rather than only reading or viewing information about them. Nevertheless, the present study did not examine these mechanisms independently, so their individual contributions cannot be determined (Paniagua-Avila et al., 2026).

Contextualization and Environmental Problem-Based Learning

Another characteristic of the present learning system was the use of contextual environmental settings. The Sebangau ecosystem in Central Kalimantan was incorporated into the learning environment to connect environmental concepts with local biodiversity and conservation issues. Previous studies have emphasized the importance of contextual and local environmental knowledge in making environmental learning more meaningful (Angelelli et al., 2023; Zannah et al., 2017). In the present study, this contextualization was combined with interactive exploration and environmental problem scenarios.

The combination is relevant to the nature of environmental literacy assessed in this study. Environmental literacy involves more than recalling information about ecosystems. It requires students to recognize environmental problems, understand relationships among environmental components, consider possible consequences, and identify appropriate responses. The assessment used in this study reflected this perspective by including items concerning environmental knowledge, awareness, attitudes, and behavioral intentions. The use of scenario-based situations in both the learning activities and assessment therefore provided a closer connection between what students experienced during gameplay and what was subsequently assessed.

This approach is also consistent with the broader literature on environmental serious games. (Tan & Nurul-Asna, 2023) identified immersive experience, meaningful engagement, learning-by-doing, simulation of real-world environmental problems, and decision-making as important characteristics of serious games used in environmental education. The present learning system incorporated several of these characteristics through ecosystem exploration, environmental scenarios, decision-making, feedback, and reflection. The findings therefore support the relevance of these design principles in an environmental learning context, while the present study applies them specifically within a Roblox-based learning environment.

The local context may have helped students relate the environmental problems represented in the system to recognizable ecosystem conditions. However, this interpretation needs to remain cautious. Because the study did not compare the contextualized version of the system with a non-contextualized version, it is not possible to determine whether the local environmental context itself was responsible for the improvement. Contextualization should therefore be understood as one component of the overall instructional design rather than as an independently tested factor.

Immersive and Interactive Features of the Learning Environment

The interactive characteristics of Roblox provide another possible explanation for the positive learning experience observed in this study. Roblox enables the development of three-dimensional environments, interactive system logic, and user participation within virtual settings. These characteristics have contributed to its increasing use as a learning environment rather than merely as an entertainment platform (Doviggi Meyer et al., 2026; Suyidno et al., 2025). In the present study, these technical possibilities were used to create ecosystem representations and environmental scenarios in which students could explore, interact, make decisions, and receive feedback.

The use of simulation is particularly relevant to environmental learning because environmental processes often involve relationships that are difficult to observe directly. Interactive and simulation-based representations can provide opportunities for students to identify patterns, examine changes, and consider relationships within complex systems (Liou, 2025). Similar arguments have been made regarding the use of interactive technologies for representing ecological and environmental processes (Madani et al., 2017; Pombo & Marques, 2020). The present study applies this principle through a game-based environment in which ecosystem conditions and environmental problems were presented as interactive situations.

The high student ratings for engagement (4.48), interactivity (4.45), and motivation (4.47) are consistent with previous research reporting positive engagement in game-based and simulation-driven learning environments (Hashish et al., 2024; Troiano et al., 2025; Wolf et al., 2025). Nevertheless, these results cannot be interpreted in such a way that the factor of immersion alone accounts for the increase in the level of environmental literacy. The teaching technique involved a number of components simultaneously, such as context-related materials, interactive learning experience, environmental situations, feedback, and reflection. Consequently, the current research design does not allow separating the influence of individual components in the learning system.

It is especially significant due to the fact that there is emerging scientific evidence showing the necessity of a more restrained attitude to the relation between immersion and learning. For instance, according to Guerriero et al. (2026), a VR serious game led to an increase in spatial presence and awe. Yet, the expected improvement in learning outcomes or pro-environmental policy support did not happen. Thus, it seems possible that the use of immersive technology does not have to result in effective learning if there is no proper process of instruction. The current research is consistent with the described theory because the Roblox environment was not used for immersion itself.

Relationship to Previous Evidence

Taken together, the findings of the present study are broadly consistent with previous research while also providing a more specific application of game-based learning to environmental education. The improvement in environmental literacy is consistent with empirical studies showing positive effects of digital games and serious games on environmental knowledge and related learning outcomes (Chuang et al., 2025; Garcia et al., 2025). The positive student responses are also in line with previous studies showing that Roblox and other game-based environments can promote engagement and active participation (Jin, 2024; Toopmongkol et al., 2025). In addition, the design of the learning system reflects characteristics previously associated with environmental serious games, particularly simulation, learning-by-doing, environmental problem scenarios, and decision-making (Tan & Nurul-Asna, 2023).

The present study adds to these findings by bringing the different elements together within a single Roblox-based environmental learning system. The system combined multiple ecosystem representations with contextual environmental problems, interactive exploration, decision-making, feedback, and reflection, while environmental literacy was used as the main learning outcome. This provides an example of how Roblox can be used not only to increase engagement but also to represent environmental relationships and support learning about environmental problems.

At the same time, the findings should be interpreted within the methodological boundaries of the study. The one-group pretest-posttest design does not allow the improvement to be

attributed exclusively to the Roblox intervention, and there was no comparison with conventional instruction or another digital learning condition. The large Cohen's d value should therefore be interpreted as the magnitude of change within the participating students rather than as evidence that Roblox is more effective than other learning approaches. In addition, the implementation was limited to a single school and a relatively short period. Consequently, the findings provide promising initial evidence rather than definitive evidence of the long-term effectiveness of Roblox-based environmental learning.

This difference becomes especially significant when speaking about the behavioral component of environmental literacy. While the test had questions related to environmental behavioral intentions, the research was unable to prove any changes in the actual conservation behavior of students following the intervention. At the same time, high levels of practicality show the students' positive perception of the educational process, but there is no proof that it will persist in the future. Thus, future research should be devoted to the sustainability of changes in environmental literacy and attitudes.

LIMITATIONS

There are several important limitations in the interpretation of the findings in the present study. Firstly, the intervention was conducted among 100 Grade 7 students in only one junior high school in Palangka Raya, Indonesia. Thus, the results obtained cannot be easily generalized to other students at different schools, in different regions, of various ages, or in other learning situations. Secondly, the effectiveness was tested using a one-group pretest-posttest design without a comparison group. Even though there is a significant difference between pretest and posttest scores and a large effect size indicating an improvement, there may be some other possible factors that caused this change. Thirdly, the effectiveness evaluation was conducted in relation to short-term changes in environmental literacy after the implementation of the learning system. The study does not consider the sustainability of this result and whether there was any change in the behavior of the participants later. Finally, the effectiveness of the learning system was assessed with the help of the evaluation by experts, students' feedback, and environmental literacy scores. Future research should use bigger samples, comparison groups, longitudinal design, and behavioral measures to confirm its effectiveness.

CONCLUSION

In this research, an immersive learning platform in Roblox was created for online science learning involving interactive simulations of ecosystems, scenario-based decision-making, feedback, reflection, and assessment, with contextual relevance to peatlands preservation. It was found that the platform has very high validity in terms of content and design because of its expert validation and was perceived as very practical, enjoyable, interactive, and meaningful by the students. Environmental literacy scores of the students have significantly increased from the pretest to the posttest, with a medium N-Gain and a statistically significant pretest-posttest difference, along with a large standard difference.

This evidence suggests that there is an indication of improvement in the environmental knowledge of students as a result of engaging in Roblox-based learning activities. It therefore supports the feasibility of employing an immersive game-based environment for environmental science learning. Nonetheless, given the fact that the study has used a one-group pretest-posttest design and there was no control or comparison group used in the study, the improvement that has been observed cannot be taken as conclusive evidence of the causal effectiveness of the Roblox-based intervention. Future studies need to apply controlled or comparative designs, larger sample sizes, and longer assessment periods to determine if there is improvement or change in students' environmental attitudes and conservation practices.

AUTHOR CONTRIBUTIONS

FZ was involved in conceptualization, methodology, research design, investigation, data curation, formal analysis, writing original draft, writing review and editing, project administration, and supervision. MNF was involved in methodology, investigation, data collection, data curation,

formal analysis, and writing, review, and editing. K was involved in investigation, data collection, validation, data curation, and writing, review, and editing. R was involved in software development, investigation, data collection, visualization, and writing, review, and editing. All authors were involved in the interpretation of results, manuscript review, and approval of the final manuscript.

ACKNOWLEDGMENT

The authors gratefully acknowledge Universitas Muhammadiyah Palangka Raya, Indonesia, for providing institutional support and research facilities for this study. The authors also express their sincere appreciation to the Ministry of Higher Education, Science, and Technology of the Republic of Indonesia (Kemdiktisaintek) for providing financial support through the 2026 Research Downstreaming Program (Program Hilirisasi Riset Prioritas – Pengujian Model dan Prototipe), under Grant No. 138/DST/C4/AL.04.00/2026. The financial support provided through this grant contributed to the implementation and completion of this research.

REFERENCES

- Andriana, I., Zamroni, M. A., Thamrin, K. M. H., Kalsum, U., Fuadah, L. L., Rifanka, N. S., Chaidir, K. S. K., & Usman, F. (2025). Awakening environmental responsibility in youth through Islamic values in green governance education. *Munaddhomah: Jurnal Manajemen Pendidikan Islam*, 6(4), 650–660. <https://doi.org/10.31538/munaddhomah.v6i4.2263>
- Angelelli, C. V., Ribeiro, G. M. de C., Severino, M. R., Johnstone, E., Borzenkova, G., & da Silva, D. C. O. (2023). Developing critical thinking skills through gamification. *Thinking Skills and Creativity*, 49. <https://doi.org/10.1016/j.tsc.2023.101354>
- Boncu, Ștefan, Candel, O. S., & Popa, N. L. (2022). Gameful green: A systematic review on the use of serious computer games and gamified mobile apps to foster pro-environmental information, attitudes and behaviors. *Sustainability (Switzerland)*, 14(16). <https://doi.org/10.3390/su141610400>
- Cebrián, G., & Junyent, M. (2015). Competencies in education for sustainable development: Exploring the student teachers' views. *Sustainability (Switzerland)*, 7(3), 2768–2786. <https://doi.org/10.3390/su7032768>
- Chuang, T.-Y., Tsai, S.-K., & Lu, Y.-H. (2025). Technology-enhanced digital game-based learning for environmental literacy: Catalyzing attitude change in learners. *Frontiers in Education*, 10, 1629670. <https://doi.org/10.3389/feduc.2025.1629670>
- Crilly, N. (2026). Critical thinking, creative thinking, systems thinking and many more: A comparative bibliometric analysis of prevalence and distribution. *Thinking Skills and Creativity*, 59. <https://doi.org/10.1016/j.tsc.2025.102014>
- Demssie, Y. N., Biemans, H. J. A., Wesselink, R., & Mulder, M. (2023). Fostering students' systems thinking competence for sustainability by using multiple real-world learning approaches. *Environmental Education Research*, 29(2), 261–286. <https://doi.org/10.1080/13504622.2022.2141692>
- Ding, Z., & Xue, W. (2025). Navigating anxiety in digital learning: How AI-driven personalization and emotion recognition shape EFL students' engagement. *Acta Psychologica*, 260. <https://doi.org/10.1016/j.actpsy.2025.105466>
- Doviggi Meyer, N., Machado, M., Da Trindade Viegas, M., Tonetto Londero, F., Lehnhart Vargas, C., & Jobim Benedetti, F. (2026). Primeiras refeições: Serious game to improve infant feeding knowledge. *International Journal of Serious Games*, 5–18. <https://doi.org/10.17083/j9g34329>
- Faridah, I., & Deng, C. (2024). Approach and application of the Roblox application as a learning medium. *Sciencetechno: Journal of Science and Technology*, 3(3), 263–281. <https://doi.org/10.70177/sciencetechno.v3i3.1395>
- Garcia, X., Domene, E., Goenaga, X., Rodriguez-Benitez, A., Satorras, M., Acuña, V., Martínez-Ruiz, A., Boada, I., & Corominas, L. (2025). Evaluating the effectiveness of a serious game to educate children about the urban water cycle. *British Journal of Educational Technology*, 56(6), 2367–2386. <https://doi.org/10.1111/bjet.13578>
- Guerriero, J. G., Sajjadi, P., Swim, J. K., Klippel, A., DeCoster, J., & Bagher, M. M. (2026). Virtual reality serious games for promoting environmental systems thinking and pro-environmental policy

- support. *Computers & Education*, 247, 105575. <https://doi.org/10.1016/j.compedu.2026.105575>
- Han, J., Liu, G., & Gao, Y. (2023). Learners in the metaverse: A systematic review on the use of Roblox in learning. *Education Sciences*, 13(3). <https://doi.org/10.3390/educsci13030296>
- Hashish, E. A. A., Al Najjar, H., Alharbi, M., Alotaibi, M., & Alqahtany, M. M. (2024). Faculty and students perspectives towards game-based learning in health sciences higher education. *Heliyon*, 10(12). <https://doi.org/10.1016/j.heliyon.2024.e32898>
- Hendarman, H., Sudiantini, D., Mayadi, M., Mirnawati, M., Desianti, L. C., & Abdullah Aji, Y. (2026). Gamification and adaptive learning innovations for enhancing students' critical thinking and creativity at an Islamic boarding school in Indonesia. *Nazhruna: Jurnal Pendidikan Islam*, 9(2), 518–535. <https://doi.org/10.31538/nzh.v9i2.414>
- Hosna, R., Idawati, K., Hanifudin, H., Mahsun, A., Budiarti, E. M., Ilahiyah, I. I., & Mustaji, M. (2026). Development of artificial intelligence-based Akidah Akhlak teaching materials for Islamic senior high schools in Indonesia. *Nazhruna: Jurnal Pendidikan Islam*, 9(1), 207–226. <https://doi.org/10.31538/nzh.v9i1.355>
- Iskandar, B., Saidah, Kurnia, A. A., Jauhari, A., & Zannah, F. (2024). Modeling land cover change using MOLUSCE in Kahayan Tengah Forest Management Unit, Kalimantan Tengah. *Jurnal Sylva Lestari*, 12(2), 242–257. <https://doi.org/10.23960/jsl.v12i2.865>
- Jeong, Y., Lee, Y., Byun, G., & Moon, J. (2024). Navigating the creation of immersive learning environments in Roblox: Integrating generative AI for enhanced simulation-based learning. *Immersive Learning Research - Practitioner*, 1(1), 16–19. <https://doi.org/10.56198/5M1RHT9ZJ>
- Jin, S. (2024). Experiential learning through the Roblox metaverse platform: Investigating its effect on English language learners' learning flow and academic achievement. *English Language & Literature Teaching*, 30(2), 153–172. <https://doi.org/10.35828/etak.2024.30.2.153>
- Junaidah, J., Mahardika, N. P., & Ma'arif, M. A. (2025). Promoting green madrasa as environmental education program: How to implement and maintain it. *Munaddhomah: Jurnal Manajemen Pendidikan Islam*, 6(1), 39–54. <https://doi.org/10.31538/munaddhomah.v6i1.1572>
- La Hadisi, L., La Fua, J., Dirman, D., Assingkily, M. S., Harson, H., & Harisatyma, N. K. A. (2025). The role of spiritual leadership in internalizing environmental values in Islamic eco-madrasah. *Nazhruna: Jurnal Pendidikan Islam*, 8(3), 732–748. <https://doi.org/10.31538/nzh.v8i3.141>
- Liou, C. F. (2025). Determining the developmental pathway of system thinking in undergraduate nursing students using a simulation education program. *Nurse Education in Practice*, 89. <https://doi.org/10.1016/j.nepr.2025.104626>
- Madani, K., Pierce, T. W., & Mirchi, A. (2017). Serious games on environmental management. *Sustainable Cities and Society*, 29, 1–11. <https://doi.org/10.1016/j.scs.2016.11.007>
- Maier, U., & Klotz, C. (2025). Students ignore their mistakes: Elaborated error feedback processing in a digital learning system. *Contemporary Educational Psychology*, 82, 102395. <https://doi.org/10.1016/j.cedpsych.2025.102395>
- Monazam-Tabrizi, N., Kurt, Y., & Kang, W. I.-K. (2024). Navigating learning disruptions: The role of digital learning platforms in student motivation, feedback and emotion. *Computers & Education*, 2(2).
- Muflihah, M., Hanifah, U., Thoha, M., & Haji Abdullah, H. R. binti. (2025). Management of developing interactive multimedia-based Arabic teaching materials: Enhancing learning for diverse students at Indonesian Islamic universities. *Munaddhomah: Jurnal Manajemen Pendidikan Islam*, 6(1), 82–98. <https://doi.org/10.31538/munaddhomah.v6i1.1469>
- Nogueras, C., Verstegen, D., Landa, C., López, Y., Moreno, M., Manjón, H., Oropeza, V., & Miralles, R. (2026). How can a micro-level communication training intervention help medical students learn about patient-centered care and empathy? Qualitative results of a design-based research. *Educacion Medica*, 27, 101135. <https://doi.org/10.1016/j.edumed.2025.101135>
- Nurjain, A., Nurjain, L. R., Fajriah, Y. N., Nurjain, A. K., & Nugraha, I. (2025). Developing and evaluating an augmented reality (AR) digital storytelling video to foster multimodal literacy and narrative comprehension. *Journal of Engineering Science and Technology*, 20(4), 919–956.

- Pacheco-Velázquez, E. A., Rodés-Paragarino, V., & Ramírez-Echeverri, S. A. (2025). Student's experience in using simulators for the development of complex skills in logistics education: Assessing enjoyment of learning. *Smart Learning Environments*, 12(1). <https://doi.org/10.1186/s40561-025-00372-7>
- Paniagua-Avila, A., Branas, C., Kane, J., Para La, A., Paniagua-Avila, A., Sapalú, D., Tz'utujil, M., Pieters, M., Petzey, A., Paniagua, K., Tellez, A., Fort, M., Branas, C., Susser, E., & Kane, J. (2026). Integrating systems thinking with global implementation science to co-learn and co-create mental health interventions and strategies with Maya Indigenous community partners. *Lancet Glob Health*, 14. [https://doi.org/10.1016/S2214-109X\(25\)00495-4](https://doi.org/10.1016/S2214-109X(25)00495-4)
- Pombo, L., & Marques, M. M. (2020). The potential educational value of mobile augmented reality games: The case of edupark app. *Education Sciences*, 10(10), 1–20. <https://doi.org/10.3390/educsci10100287>
- Prasasti, R. D., & Anas, N. (2023). Pengembangan media digital berbasis flipbook untuk meningkatkan kemampuan berpikir kritis pada peserta didik. *Munaddhomah: Jurnal Manajemen Pendidikan Islam*, 4(3), 694–705. <https://doi.org/10.31538/munaddhomah.v4i3.589>
- Ren, J., Tan, Y. H., & Guo, J. (2025). Scientific mapping of research on metaverse in education. *International Journal of Technology in Education*, 8(1), 1–21. <https://doi.org/10.46328/ijte.986>
- Suyidno, S., Mastuang, M., Komariyah, L., Misbah, M., Qamariah, Q., & Syarkowi, A. (2025). Augmented reality, artificial intelligence and local wisdom-based renewable energy learning media to improve student' 5C skills. *Journal of Engineering Science and Technology*, 20(6).
- Tan, C. K. W., & Nurul-Asna, H. (2023). Serious games for environmental education. *Integrative Conservation*, 2(1), 19–42. <https://doi.org/10.1002/inc3.18>
- Toopmongkol, W. A., Jaihuek, S. B., & Saiyee, N. C. (2025). Evaluating the impact of Roblox-based interactive media on English learning outcomes and engagement at Chiang Rai Rajabhat University. *International Journal of Information and Education Technology*, 15(11), 2436–2440. <https://doi.org/10.18178/ijiet.2025.15.11.2439>
- Troiano, G. M., Abdollahi, A., Cassidy, M., Puttick, G., Machado, T., & Harteveld, C. (2025). Leveling the computational playing field: Inquiring about factors predicting computational thinking in constructionist game-based learning. *Computers and Education*, 237. <https://doi.org/10.1016/j.compedu.2025.105347>
- Vaszkun, B., & Mihalkov Szakács, K. (2025). Looking for student success factors outside of the educators' scope: The effect of digital literacy, personal skills, and learning habits and conditions on self-evaluated online learning effectiveness in management education. *International Journal of Management Education*, 23(2). <https://doi.org/10.1016/j.ijme.2025.101188>
- Widarti, H. R., Wiyarsi, A., Yamtinah, S., Shidiq, A. S., Sari, M. E. F., Fauziah, P. N., & Rokhim, D. A. (2025). Analysis of content development in chemical materials related to ethnoscience: A review. *Journal of Education and Learning*, 19(1), 422–430. <https://doi.org/10.11591/edulearn.v19i1.21210>
- Winarto, Rosana, D., Wibowo, W. S., Rahayu, D. P., Pradana, P. W., & Shidiq, G. A. (2025). The impact of STEM-EfSD games on enhancing students' creative thinking and environmental literacy. *European Journal of STEM Education*, 10(1), 1–9. <https://doi.org/10.20897/ejsteme/17354>
- Wolf, M., Herstätter, P., Rantschl, M., Ramsauer, C., & Magana, A. J. (2025). Immersive learning factories for promoting experiential manufacturing education and STEM competency development. *Computers & Education: X Reality*, 7, 100125. <https://doi.org/10.1016/j.cexr.2025.100125>
- Zannah, F., Amin, M., Suwono, H., & Lukiati, B. (2017). Phytochemical screening of *Diplazium esculentum* as medicinal plant from Central Kalimantan, Indonesia. *AIP Conference Proceedings*, 1844(May). <https://doi.org/10.1063/1.4983439>
- Zannah, F., & Ayatusaadah. (2023). Effectivity of medicinal plant based on local wisdom of Dayak community textbook development on improving student learning outcome. *Jurnal Penelitian Pendidikan IPA*, 9(7), 5398–5405. <https://doi.org/10.29303/jppipa.v9i7.2615>