Designing a SVVR Educational Game to Cultivate Environmental Behavior Decision-Making Skills: A Case Study on Tropical Rainforest and Indigenous Issues

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Abstract
Cultivating learners' environmental behavior decision-making skills is important for environmentally sustainable development. General lecture or discussion teaching methods lack realistic scenarios and interactivity in the experience design of environmental behavior decision-making. It is difficult to stimulate learners' motivation and enhance problem-solving abilities, leading to poor transfer of learning. To solve the above problems, this study designed an educational game with a realistic story context. The game employs game-based learning to promote learning motivation, combines Spherical Video-based Virtual Reality (SVVR) to provide realistic environments, and uses Google Forms to enhance interactivity to understand learners' environmental behavior decisions. In this game, learners can talk to non-learner characters (NPCs) in a complex tropical rainforest SVVR and engage in visual and auditory exploration to learn ecological knowledge and understand indigenous culture and challenges. Google Forms were used to solve puzzles and collect information about their personal environmental behavior decisions. An empirical evaluation involving 20 Taiwanese high school students revealed high levels of flow for the game. This indicated that the game could promote learning engagement. After playing the game, learners' academic achievement significantly improved, demonstrating the enhancement of knowledge acquisition. The results of the environmental behavior decision-making and environmental awareness assessments showed that the game effectively combines cognition and action. The learners were highly interested in exploring the rainforest and had negative feelings about the indigenous people's loss of homes. These results indicate that the game's realistic and interactive design can promote deeper understanding and experience and facilitate effective environmental behavior decision-making.

Keywords: Game-based Learning, Educational Games, SVVR, Environmental Behavior Decision-Making Skills, Flow

Introduction

The development of environmental behavior decision-making skills is an important process for strengthening environmental education and maintaining sustainable development. (To elaborate further, in this study, we use the term “environmental behavior decision-making skills” to emphasize the specific decision-making processes related to environmental behaviors.) The purpose of environmental education is not only to transfer knowledge, but also to make students aware of environmental problems' seriousness to promote environmentally friendly behaviors. In addition, environmental knowledge alone is not enough to change an individual's behavior, but also involves other factors such as environmental awareness, psychology and socio-cultural factors (Colombo et al., 2023). However, the lack of experiential learning in which students interact with real-life situations (Kolb, 1984) in general lecture or discussion pedagogies restricts the possibility of applying knowledge in real-life situations, which prevents learners from truly understanding complex environmental problems and behavioral decisions and leads to poor performance in facilitating the transfer of learning. The development of virtual reality technology in environmental education can overcome the time and space constraints of fieldwork and increase the benefits of contextual learning to enhance student engagement and motivation (Cho & Park, 2023). However, past research on virtual reality in education has focused on user experience, with fewer applications in environmental education (Cho & Park, 2023). The simulation and interactive design of environmental behavioral decision-making experiences are insufficient. This makes it difficult to stimulate learners' motivation and limits the enhancement of their problem-solving abilities.

To solve this problem, in addition to virtual reality technology, Lin and Hou (2023) pointed out several advantages of game-based learning. They noted that it not only improves learning effectiveness, motivation, and engagement, but also promotes reflective behaviors. Furthermore, it supports and assists learners through scaffolding guides in the game, as compared to traditional lecture-based instruction. A blended learning approach that combines inquiry-based learning and experiential learning can be effective in improving environmental awareness, students' decision-making skills, and environmental concern (Miyaji & Fukui, 2020). Teaching strategies that combine simulation and problem-oriented learning can improve students' motivation, self-directed learning, and problem-solving skills more than traditional lecture methods (Roh & Kim, 2015). Thus, these strategies can be integrated into the design of virtual reality teaching applications to enhance learning benefits.

In addition, Spherical Video-based Virtual Reality (SVVR) technology and equipment are easier to popularize in teaching and learning (Wu et al., 2022) and can bring more self-regulation and exploration experiences (Wang et al., 2023). Tropical rainforests are rich in both biological diversity and cultural diversity, and the close connection between indigenous cultures and ecosystems is one of their characteristics. However, current environmental education focuses on scientific data and ignores the traditional ecological wisdom of indigenous peoples (Ardoin et al., 2020). By focusing on the relationship between indigenous people and the rainforest, we can promote a deeper understanding of the complex interactions between people and nature, providing valuable lessons for addressing modern environmental challenges (Malone, 2022).

In summary, this study aims to design and evaluate an educational game that combines SVVR technology and game-based learning to promote learners' environmental behavior decision-making skills on the topic of rainforests and indigenous peoples. The study

measured academic achievement, flow, environmental awareness, and environmental decision-making behaviors. Through simulated storytelling scenarios in virtual reality, learners were able to better understand environmental problems on both emotional and cognitive levels and explore effective solutions. This approach will serve as a reference for environmental educators in developing innovative pedagogical approaches.

Methods

This study adopted a one-group pre- and post-test design with a 40-minute gameplay session. The participants were 20 high school students aged 15-16 years old who had not recently completed any courses related to the study topic.

In this study, we designed the "Love Rainforest" SVVR game, in which learners are led by a Penan guide into the Borneo rainforest. The game aims to teach about the five vertical layers of the rainforest, explore the relationship between the rainforest and the lives of the indigenous people, and understand the impacts of corporate deforestation on these communities.

The game incorporates various challenges. For example, learners must interact with the tour guide and identify specific plant or animal sounds to progress. In another scenario, when indigenous people face dilemmas due to corporate deforestation, learners are guided by a rainforest conservator to choose actions that can support the indigenous people's livelihoods. These challenges not only help learners understand the relationship between rainforest ecology and indigenous life but also enhance their problem-solving and critical-thinking skills.

The game was developed using the Thinglink VR platform, as shown in Figure 1. It consists of one rainforest entrance scene (with five rainforest vertical layered sub-scenes) and three indigenous life scenes. Learners interact with five non-learner characters (NPCs) that reflect the crises encountered by indigenous people, their voices, and key figures that can help learners make decisions to enhance their understanding of environmental issues.

The game design follows the principles of virtual reality and simulation, combining 360-degree photographs, visual and auditory elements, and digital game-based learning (Çatak et al., 2020; Prensky, 2003; Wu et al., 2022). The scenarios are designed to guide users step-by-step through exploration, connecting relevant knowledge points and creating an environmentally interactive link between indigenous life and the tropical rainforest. Interaction and decision-making behaviors are facilitated through Google Forms.

Upon completion of the game, learners will have gained an understanding of the challenges faced by indigenous people in the rainforest and developed related environmental behavioral decision-making skills.

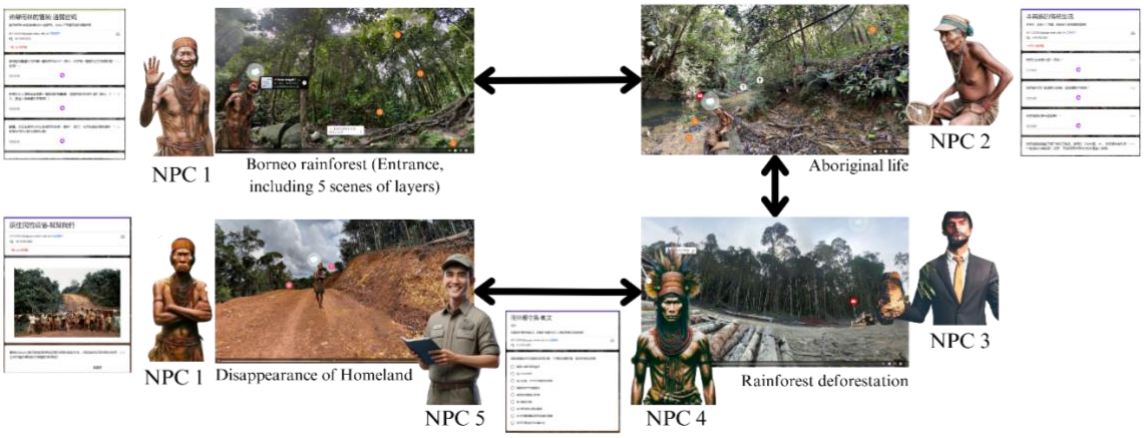

Figure 1: SVVR Game Scenes and NPCs in "Love Rainforest" Using Google Forms for Interaction

Results and Discussions

The results of this study showed that the mean pre-test score and the mean post-test score for academic achievement in the Love Rainforest SVVR game were 52.90 (*SD*=16.29) and 65.90 (*SD*=16.25), respectively, reflecting an improvement of 13.00 points (Table 1). A paired-samples t-test revealed a significant difference between pre-test and post-test scores (t=4.036, p=0.001). These results suggest that the game is effective in enhancing learners' academic achievement, demonstrating significant pedagogical benefits.

Table 1: Academic Achievement in the Love Rainforest SVVR Game: Cognitive Test Results

Dimension	**post-test (N=20)**		**pre-test (N=20)**			
	M	*SD*	*M*	*SD*	*t*	*p*
Overall	65.9	16.254	52.9	16.293	4.036**	0.001

***p <0.01, ***p <0.001*

In the "Indigenous People's Problems - Help Us!" game questionnaire, learners demonstrated a significant awareness of indigenous people's challenges and decision-making skills regarding environmental actions. The results are as follows:

- Awareness of indigenous people's life difficulties: 74 points (mean score=37.0 out of 50 possible points)
- Decision-making on environmental actions to help indigenous people: 74 points (mean score=37.0 out of 50 possible points)
- Overall performance: 74 points (mean score=74.0 out of 100 possible points)

These results indicate that most learners gained increased awareness of the challenges faced by indigenous people after participating in the game. Moreover, learners actively engaged in problem-solving processes related to environmental issues affecting these communities.

Analysis of open-ended responses revealed that learners primarily considered factors such as education, economy, resources, and ecosystem in relation to indigenous peoples. Learners generally perceived their decisions as reasonable and potentially impactful.

The game appeared to foster empathy among learners, as evidenced by their engagement with the game's narrative. This led to increased awareness of rainforest ecosystems and indigenous livelihoods. Furthermore, learners demonstrated reflective thinking about the impact of their own actions on environmental protection.

In terms of environmental awareness, the present study adapted measures from Han & Lin (2012) to assess the level of environmental exposure and affect. The results of the analyses (Table 2) showed that, when comparing the scores of each dimension with the median of the scale (i.e., 3), the mean value of the item "I like the tropical rainforest" was significantly higher. This indicated that learners generally had a high level of interest in exploring the tropical rainforest environment. However, the mean value of the item "I am familiar with the tropical rainforest" was relatively low (M=3.25) and not significantly higher than the median of the scale (p=0.262).

This discrepancy may be attributed to the fact that the high interest in the tropical rainforest stemmed from the visual and experiential appeal of the game. However, due to the limited scope of the game (focusing only on the rainforest of Borneo) and the time constraints of the game experience, participants' familiarity with tropical rainforests remained relatively low.

Table 2: Results of One-Sample t-Test Analysis for Environmental Exposure and Affective Level

Dimension	***(N=20)***				
	M	***SD***	***t***	***P***	***ES***
Environmental Exposure and Affective Level	3.53	0.77	3.053**	0.007	0.53
I am familiar with the tropical rainforest	3.25	0.97	1.157	0.262	0.25
I like the tropical rainforest	3.80	0.77	4.660***	0.000	0.80

**p <0.05, **p <0.01, ***p <0.001*

In addition, none of the nine scenarios preferred by learners in the storyline exceeded 50%, demonstrating a high level of diversity in scenario preferences. The most favored scenes were the entrance to the primary rainforest and the emergent layer (20% each). Furthermore, the entrance to the primary rainforest was considered by learners to be the most representative of the tropical rainforest (30%). In contrast, the least preferred scene was the one depicting the indigenous people's loss of home (45%), suggesting that learners had a strong emotional response to the negative emotions evoked by this scene. This result reflects that the study successfully designed scenarios to evoke emotional responses in learners, helping them understand the complexity of environmental issues and the impact of human activities from an emotional perspective, which in turn encourages reflection and action on environmental behaviors. Overall, the analysis indicated that learners were highly interested in the tropical rainforest, although their familiarity with it was low. Additionally, the diversity of scene designs was significant, especially as the scene portraying the loss of the indigenous people's home evoked a particularly strong negative emotional response.

The results of the analysis of the Flow Questionnaire (Hou & Li, 2014) in this study showed that the overall flow (M=3.95, SD=0.60) and the mean scores of all sub-dimensions were significantly higher than the median of the scale (i.e., 3) (p<0.001), as presented in Table 3. This indicates that the game could effectively enhance both learning motivation and effectiveness. Among these, the highest mean value for overall flow experience (M=3.96) suggests that learners generally experienced a stronger flow state during gameplay. This

implies that the game design was effective in promoting learners' entry into a flow state, maintaining a high level of concentration and engagement. Notably, the highest mean value (*M*=4.25) for the "Autotelic experience" sub-dimension indicated that learners set and pursued personal goals during gameplay. This clear goal orientation helped learners overcome challenges and achieve a sense of success and satisfaction, which in turn deepened their flow experience, making it easier for them to remain in the desired learning or gaming state.

Table 3: Results of One-Sample t-Test Analysis for Learners' Flow ***(N=20)***

	M	***SD***	***t***	***p***	***ES***
Overall Flow	3.95	0.60	7.138***	0.000	0.95
Flow antecedents	3.88	0.67	5.824***	0.000	0.88
Challenge-skill balance	3.90	0.75	5.339***	0.000	0.90
Goals of an activity	4.03	0.91	5.037***	0.000	1.03
Unambiguous Feedback	3.83	0.73	5.051***	0.000	0.83
Control	3.80	0.78	4.559***	0.000	0.80
Playability	3.83	0.83	4.437***	0.000	0.83
Flow experience	3.96	0.58	7.360***	0.000	0.96
Concentration	4.00	0.73	6.126***	0.000	1.00
Time distortion	4.00	0.83	5.407***	0.000	1.00
Autotelic experience	4.25	0.72	7.754***	0.000	1.25
Loss of self-consciousness	3.58	0.94	2.748*	0.013	0.58

*p <0.05, **p <0.01, ***p <0.001

Conclusion and Limitations

This study utilized SVVR technology and game-based learning theory to develop the "Love Rainforest" educational game, which was applied to tropical rainforest and indigenous peoples' issues to cultivate learners' environmental behavioral decision-making skills. The results showed that the SVVR game significantly improved learners' learning effectiveness and effectively enhanced their awareness of the indigenous people's living difficulties as well as their decision-making abilities regarding environmental behaviors. Learners expressed a high level of interest and emotional connection to the rainforest environment, although there remains room for improvement in their familiarity with it. The diversity of scenarios in the game design elicited various emotional responses from learners, especially the scene depicting the indigenous people's loss of home, which triggered strong negative emotions. The game's performance in fostering a flow experience with autotelic experience was outstanding, demonstrating a high level of self-directed learning engagement. This study highlights the potential of SVVR technology in environmental education and provides a preliminary reference for environmental educators to develop innovative teaching methods. Future research could increase the sample size and include a control group to enhance reliability and validity. Additionally, extending the duration of the game may improve learners' familiarity with the tropical rainforest environment, and deepening the game design with relevant psychological factors could strengthen the assessment of attitudinal and behavioral changes.

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