The Design of Field Geology Guide Training Combines Spherical Video-Based Virtual Reality (SVVR) and Contextual Clues in Game-Based Learning

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Abstract
Attending field geology class can help learners develop the skills to observe rock layer sequences and infer geological history and tectonics. This training is typically supported by class guides who possess geological expertise and can effectively lead students enhancing learning effect and safety. However, there are variables in the wild field influenced by factors such as unexpected situations faced by students, physical fitness levels, weather conditions, and geological structures that have been affected by weather. These reasons make class guide training crucial. To create a simulation-based online training environment, this study integrates spherical video-based virtual reality (SVVR) to design a field geology situation that showcases the geology of a sea coast in Taiwan. With contextual clues as scaffolding in game-based learning design, learners can thoroughly explore the local geological environment within a safe and controlled immersive setting. Additionally, they can practice responding to unexpected situations that arise for students in various scenarios. It not only enhances their geological knowledge, but also ability of student sudden occurrence and conditions. The study involved 16 participants, and the results indicated that learners demonstrated significant improvements in their learning effectiveness. They exhibited a high level of flow, accompanied by low level of anxiety. In terms of cognitive load, the internal cognitive load assessment was not significantly higher, suggesting that the learning content was moderate. The external cognitive load was not significantly higher, suggesting that the technology was not significantly difficult to operate. This study may provides innovative teaching strategies for geology education but also serves as a reference for research in the geology field of virtual reality educational games.

Keywords: SVVR, game-based learning, geology education, flow

Introduction

With the development of information technology and the improvement of digital literacy, virtual reality (VR) provides an immersive 360 environment, which can effectively enhance learners' conceptual cognition, skill training, and attitude (Chen et al., 2022). In this environment, learners can have a diversified learning experience through the escape room designed with contextual clues (Issock Issock et al., 2024).

To make excellent geohistorical inferences, field geology is one of the most important fields of study in geology (Chris Johnson, 2017). It aims to classify and interpret rock minerals and geological structures in the field, and integrate and analyze the stacked layer upon layer of rock strata about to make logical geohistorical inferences. In addition to the instructor, teaching assistants usually join the group to support the course. However, the actual learning site is outsides, which is susceptible to weather, space capacity, rock weathering, physical fitness, or unexpected conditions of the students not only affecting the learning effectiveness, but also challenging the on-site response of the teaching assistants leading the group, which tends to affect the learning effectiveness and reduce the quality of the learning experience (Balliet et al., 2015).

The purpose of this study is to design a geological teaching game combining Spherical Video-Based Virtual Reality (SVVR) and contextual clues, focusing on the geological features of the Mysterious Coast of Jinshan, Taiwan, for the first time as a geological field assistant for geological class. The VR game is built as real field geological environment, and applies the contextual learning theory (Lave & Wenger, 1991) to the situation in which the assistant support the team. With the Problem-Based Learning (PBL) method, learners are guided to explore and interact with each other in the VR world to complete the geological learning tasks, and to apply their knowledge to complete geohistorical inference to enhance their logical thinking and reasoning skills.

Literature Review

Field Geology and Assistant

Field geology includes mineralogy, petrology, earth structure, earth history, earth tectonics, etc. Among them, field geology is a discipline that integrates the above mentioned studies and applies them to actual field, and it is also an important learning points for geologists (Chris Johnson, 2017). However, the field environment changes continuously with time passing and external forces, it makes students encounter difficulties in inquiry and practice (Grissom et al., 2015), such as: the geological environment will be affected by exogenic phenomena or vegetation cover affecting the observation effect. Also, the weather, physical fitness, students' sudden situations or the size of the space in the lecture environment affect the effectiveness of the learning process, which lead to the inability to focus on the geologic learning itself. These make learner troublesome to focus on the geological learning itself (Balliet et al., 2015). Therefore, the field geology practicum environment requires excellent teaching models and teaching assistants to improve it.

SVVR Integration Into Learning

One of the theoretical foundations of VR learning is situated learning (Lave & Wenger, 1991), which aims that with contextual designing, learners can effectively invest and migrate the experience to enhance decision-making abilities in actual situations (Kimhi et al., 2016) such as natural sciences (Chan et al., 2023), however, it is constrained by the cost of immersive VR , the technological barrier, technical design content and substantial finance (Jong, 2023), which has led to the widespread use of low-cost and easy-to-develop SVVR technology in education. For example, geography and spatial thinking (Jong, 2023) and language learning (Jong, 2023). In summary, this study aims to enhance the ability of geological field teaching assistants to conduct courses through SVVR.

Game-Based Learning

Game-based learning (GBL) is an educational approach referring to a type of learning that deeply integrates computer games with educational content (Prensky, 2001), which can stimulate intrinsic motivation, enhance interest, aid memory, provide training and feedback, and promote higher-order thinking (Hogle, 1996). By helping learners to reduce cognitive load and improve learning outcomes through their work in multimedia education (Mautone & Mayer, 2001), games have been shown to have a positive impact on pedagogical applications (Latorre-Cosculluela et al., 2025).

Research Questions

The research questions for this study are as follows:

(1) Were learners making significant progress in their learning effectiveness?
(2) What were the anxiety, flow and cognitive load of the learners?

Research Method

Participants and Procedure

This study was conducted in a high school in Taiwan with a total of 16 participants, with an average age of 16 years old, who had not participated in any camps or trainings for field geology investigation. In this study, four questionnaires were collected, including one-group pretest-posttest design for learning effectiveness and anxiety levels, and the one-sample test for flow and cognitive load. Since the sample size was less than 30, Wilcoxon signed-rank was used for statistical purposes.

Before the game begins, a pretest on learning effectiveness and anxiety levels was conducted. Participants then entered the game platform, which started with a story introduction and an interface tutorial. Following this, they proceeded to the geological SVVR tour of Mysterious Coastline in Jinshan. The detailed design will be explained in Section 3.3. After completing the game, the posttest of learning effectiveness, anxiety levels, flow, and cognitive load was conducted to statistical analysis.

Table 1: Research Procedure

Procedure	Session time	Description
Pretest	20 minutes	Measuring learning effectiveness and anxiety.
Game introduction and setup	10 minutes	Entering the SVVR game.
Game start	60 minutes	Explore the Mysterious Coast of Jinshan.

Instruments

Learning Effectiveness. The pretest and posttest in this study used the same set of questions, with the items randomly arranged to ensure a different order between the two tests. The test consisted of 14 multiple-choice questions and 1 inference question, covering topics such as identifying types of rocks, geological and sedimentary structures, historical geological inference, and analysis of local geological photos. All questions were developed by professional geology teachers and verified by the researchers to ensure alignment with the content of the VR model.

Anxiety Levels. It was based on the "Affective Filter Hypothesis" scale developed by Krashen (1982). Specifically, the study utilized the activity anxiety dimension and adapted the content to design a game-related anxiety questionnaire tailored to the research context. The questionnaire comprised 8 questions and was based on five-point Likert scale.

Flow. To analyze learners' engagement in the activity, this study utilized the flow questionnaire translated by Hou & Chou (2012), originally developed by Kiili (2006). The questionnaire consists of 23 questions, divided into two main dimensions: Flow Antecedents and Flow Experience. A five-point Likert scale was used for the evaluation.

Game-Based Learning. The Cognitive Load Scale (Klepsch et al., 2017) was adapted from Leppink's scale (2013). The scale has three dimensions with a total of 8 questions, two on internal cognitive load, three on external cognitive load, and three on related cognitive load on a 5-point Likert scale.

Game Design

This game is set in Taiwan's Jinshan Mysterious Coast, with an actual path of approximately 500 meters. On-site guided tours typically take 3 to 6 hours. 360-degree panoramic photos were captured using a RICOH THETA camera and uploaded to the ThingLink platform to construct scenes and provide knowledge descriptions, as shown in Figure 1. Students can click on icons to view and read the content. During the game, different paths and explorations can be generated based on their willingness to explore.

The storyline revolves around a novice geology teaching assistant leading a group to explore and learn. Students engage with contextual clues to study and collect geological data while completing tasks on Google Docs, such as capturing screenshots of photos, classifying structures, and conducting geological history analysis and inference as Figure 2.

During the game, students encounter scenarios such as straying from the group or shopping, requiring them to make situational choices. Correct answers earn points, while incorrect answers prompt feedback and comments, providing immediate responses, as shown in Figure 3. The images used in the scenarios were generated using Bing AI.

Figure 1: Actual Situation of the Scene

Figure 2: After Clicking the Icon, It Can Display Instructions and Correspond to Learning Tasks

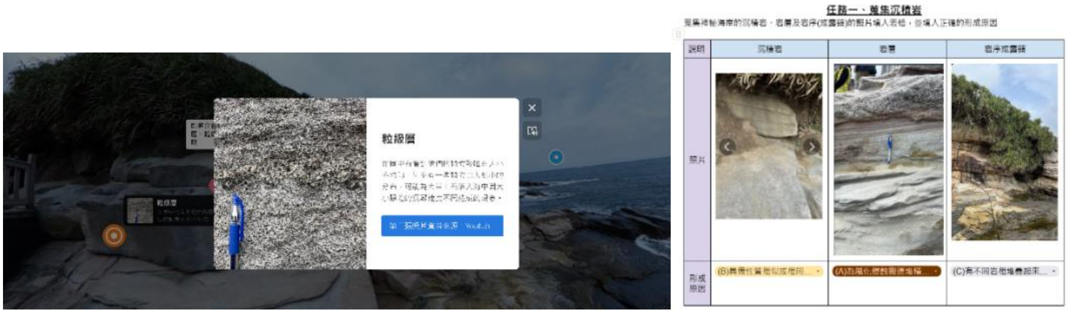
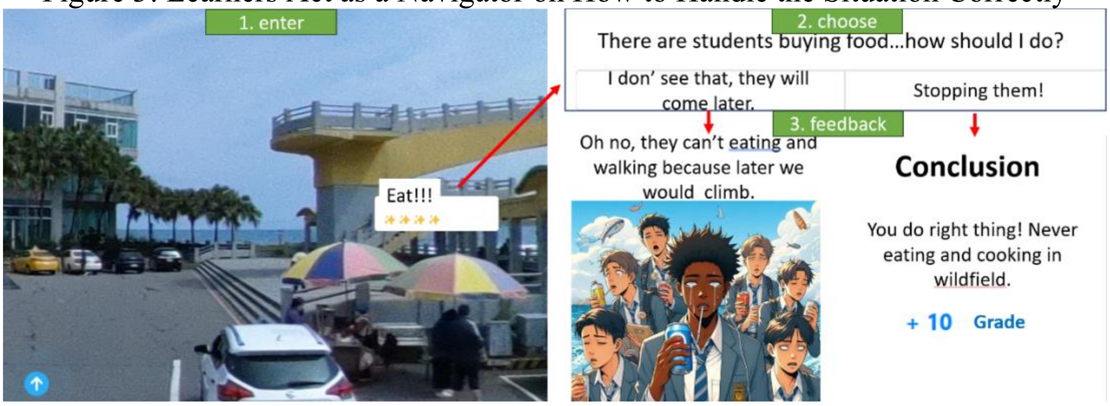


Figure 3: Learners Act as a Navigator on How to Handle the Situation Correctly



Results and Discussion

Learning Effectiveness

The scores of learning effectiveness showed a significant improvement (t = -2.84, p = .002 < .01), indicating the effectiveness of learning field geology in identifying rock types and interpreting geological structures. Furthermore, learners were able to describe the history of rock strata based on their observations.

Table 2: Summary Table of Learning Effectiveness (n = 16)

	Pretest		Posttest			
	M	*SD*	*M*	*SD*	*Z*	*p*
Learning Effectiveness	34.25	12.12	44.25	11.69	-2.84	.002**

$^{**}p < .01$, $^{***}p < .001$

Anxiety Levels

Statistics revealed a significant decrease after the game in anxiety ($t = -2.84$, $p = .002 < .01$), inferred to be a result of game-based learning, as well as the controllability of the environment and the possibility of repetition to learn or understand knowledge or thinking related to field geology.

Table 3: Summary Table of Anxiety Levels (n = 16)

	Pretest		Posttest			
	M	*SD*	*M*	*SD*	*Z*	*p*
Anxiety Levels	3.73	1.40	2.76	1.07	-2.84	$.002^{**}$

$^{**}p < .01$, $^{***}p < .001$

Flow

Overall flow reached significance ($p < .001$), indicating that participants were quite engaged. While the loss of self-consciousness did not reach significance ($p = .067 > .05$), possibly due to the need for sustained focus on logical reasoning, which may have influenced this aspect of the experience.

Table 4: Summary Table of Flow (n = 16)

	M	*SD*	*p*	*V*
Overall flow	3.699	0.768	$< .001^{***}$	91.000
Flow antecedents	3.650	0.776	0.001^{**}	89.000
Challenge	3.625	0.806	0.007^{**}	36.000
Goal	3.656	0.831	0.006^{**}	52.500
Feedback	3.594	0.841	0.010^{*}	42.500
Control	3.750	0.856	0.003^{**}	63.500
Playability	3.625	0.885	0.009^{**}	42.500
Flow experience	3.740	0.784	$< .001^{***}$	102.500
Concentration	3.766	0.834	0.002^{**}	76.000
Time distortion	3.688	0.814	0.004^{**}	63.000
Autotelic experience	3.859	0.811	0.002^{**}	66.000
Loss of self-consciousness	3.500	1.211	0.067	50.000

$^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$

Cognitive Load Scale

The analysis results showed no significant differences across the three dimensions. The intrinsic cognitive load ($p = 1.0 > .05$) suggests that the difficulty level of learning field geology was moderate and appropriate. The extraneous cognitive load ($p = .09 > .05$) indicates that the game interface and operations were reasonably balanced, presenting some challenges but remaining within an acceptable range. As for the germane cognitive load ($p = .887 > .05$), the learning aids and support interfaces did not show a statistically significant effect.

Table 5: Summary Table of Cognitive Load Scale (n = 16)

	M	*SD*	*p*	*V*
intrinsic cognitive load	2.938	1.124	1.000	27.000
extraneous cognitive load	2.917	1.092	0.090	16.500
germane cognitive load	2.604	0.809	0.887	5.500

$^{*}p$ <.05, test value = 3

Conclusions

The study results confirmed the feasibility of SVVR and game-based learning in field geology education, demonstrating improvements in learning effectiveness. Student feedback, such as "an enjoyable way of learning" and "hoping for more similar activities in the future," reflect low levels of anxiety during the experience and high flow states. As for cognitive load, the findings indicate a moderate level, suggesting an appropriate balance for effective learning.

Based on the above discussion, the limitations and future development of this study are as follows:

(1) Factor Interaction
The factors influencing learning effectiveness are diverse and complex. While this study demonstrates the effectiveness of SVVR in enhancing learning effectiveness, it does not clarify the relationships between factors or identify potential underlying variables. For instance, the study did not measure learners' attitudes toward learning or distinguish the specific contributions of SVVR and gamification to learning effectiveness. Additionally, the possibility of other mediating factors influencing the outcomes remains unexplored, warranting further investigation.

(2) System Development
System Development: Immersive design has promoted geological thinking and decision-making skills, offering opportunities for experiential transfer to real-world fieldwork. However, research by Sureephong et al. (2024) indicates that while gamified VR can enhance student engagement and motivation, it does not guarantee ideal learning transfer. Given that the goal of the game is to facilitate experiential transfer during actual fieldwork, this study should further analyze differences in higher-order learning achievements and conduct field-based studies to evaluate the transfer effects. This would help clarify the effectiveness of such experiential transfer.

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