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Empowering Virtual Reality as a Learning Media: A Real Environment to Exploring User Experience

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Abstract: This study aimed to explore students' experiences with VR Geopark Ijen as a learning media for physical environment material, examining the factors influencing these experiences. Employing a survey methodology at Zainul Hasan 1 Senior High School, the sample comprised 82 students from the 11th grade. Data collection involved closed and open-ended questionnaires, with analysis conducted using descriptive statistics based on mean scores. Qualitative data from student responses provided deeper insights into the quantitative findings. Results indicated that VR Geopark Ijen provided a positive and significant experience for students. They rated the media as very good criteria across multiple aspects, including usefulness, pleasantness, entertaining, productivity, novelty, reliability, efficiency, user-friendliness, attractiveness, enjoyment, fulfilment, meaningfulness, engagement, communicativeness, collaborativeness, helpfulness, convincingness, willingness, and recommend. Aspects of feature comprehensiveness, confidence, attentiveness, responsiveness, respectfulness received good criteria. VR Geopark Ijen effectively facilitated contextual and meaningful learning, increased active student engagement, and delivered an enjoyable experience. These findings suggest that VR Geopark Ijen has the potential to be an innovative solution for improving the quality of physical environment learning, addressing access limitations and enhancing student understanding. Further development should consider feature comprehensiveness, bolster student confidence, and integrate VR with the curriculum while providing teacher training.

Keywords: Learning media; Physical environment; User experience; Virtual reality

Introduction

Field trip-based environmental learning is often constrained by limitations in space, time, cost, weather, the number of participants, and instructor resources. For instance, the Ijen Geopark area, which can be utilized to study geological heritage, consisting of geological sites (geosite), biological sites (biosite), and cultural site directly, presents such challenges (Mastika et al., 2023; Putra et al., 2022; Salsabila et al., 2022; Sumarmi et al., 2022). These limitations can hinder in-depth and contextual learning experiences for students (Bachri et al., 2024a; Rizal et al., 2024).

Virtual reality (VR) is one technology offering an innovative solution to the challenges of field trip learning. VR allows students to explore environments virtually and immersively (Oktavianto et al., 2023; Rizal et al., 2024), thus providing realistic experiences corresponding to actual environmental conditions, without the need to travel to physical locations

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(Hermayanti & Setyasto, 2025; Putra et al., 2022). The use of VR can assist students in studying physical phenomena, such as the study of the hydrosphere in Ijen Geopark (Bachri et al., 2024b; Khusna et al., 2022), as illustrated in Figure 1. The use of VR can facilitate contextual learning without being limited by space and time (Asad et al., 2021; Palsdottir, 2024). Furthermore, VR provides opportunities for teachers to create interactive learning experiences tailored to the needs of the material and student characteristics (Ginting et al., 2023; Marougkas et al., 2023; Maulidya & Astuti, 2025).

(a)

(b)

Figure 1. VR simulation view of Ijen Geopark allowing students to interact with the virtual environment (a) for hydrosphere material (b)

Previous research has demonstrated the advantages of VR in the learning process. Research by Bos et al. (2021), Geng et al. (2021), Jong et al. (2020), and Meadows (2020) has shown that VR can have a positive influence on cognitive aspects, such as conceptual understanding and learning outcomes. Furthermore, VR has demonstrated effectiveness in fostering essential 21st-century skills, including critical thinking, problem-solving, creativity, innovation, communication, and collaboration (Putra et al., 2021; Zhao et al., 2020). Although VR possesses advantages, a crucial aspect in VR implementation is the student experience when using VR as a learning media (Alnagrat et al., 2023).

Dimensions of student experience are crucial for enhancing the effectiveness of VR learning media. These dimensions can be categorized as business (economical and technological), human (emotional and cognitive), social (interpersonal and emphatical), and intention to use (Topolewski et al., 2019). Positive experiences can increase student engagement and motivation, leading to learning effectiveness (Lin & Wang, 2021). Conversely, negative experiences can decrease performance and learning interest due to motion sickness, complex displays, and difficult access and navigation (Conner et al., 2022; Xiangming et al., 2024).

The development and implementation of VR learning media often focus solely on cognitive aspects, neglecting student experience data. Student experience is often relegated to supporting data for obtained cognitive results (Hagge, 2021; Hamilton et al., 2021; Shaherani et al., 2022). However, student experience is a fundamental aspect underlying the success of VR in the learning process (Hagge, 2021; Marks & Thomas, 2022; Mystakidis et al., 2021). Without an understanding of how students feel and interact with VR, evaluating the optimization of VR is difficult (Asad et al., 2021; Schott & Marshall, 2021). This indicates a research gap in comprehensively understanding how student experience with VR can influence the learning process and outcomes.

This research aims to analyze student experience with VR as a learning media for Ijen Geopark, based on a multidimensional framework encompassing business (economical and technological), human (emotional and cognitive), social (interpersonal and emphatical), and intention to use dimensions. This research addresses a critical gap in the literature by specifically investigating these dimensions of student experience in the context of physical environment learning using VR, an approach that has not been extensively explored in previous studies. This research is crucial because a comprehensive understanding of student experience provides invaluable feedback for the development and more effective implementation of VR in education. This research contributes by providing in-depth information about student experience in using VR-based learning media within the specific context of Ijen Geopark, identifying areas for improvement to enhance learning media quality and informing best practices for future VR implementations in similar educational settings.

Method

Research Design

This research employs a convergent parallel mixed methods design to concurrently collect quantitative data from a structured questionnaire and qualitative data from open-ended questions. This approach allows for the triangulation of findings from both datasets, providing a more comprehensive and nuanced understanding of students' experiences with VR-based

learning media. Quantitative data from a structured questionnaire and qualitative data from open-ended questions were collected concurrently after students participated in the VR learning session (as depicted in Figure 2). This session lasted 80 minutes, equivalent to two class hours.

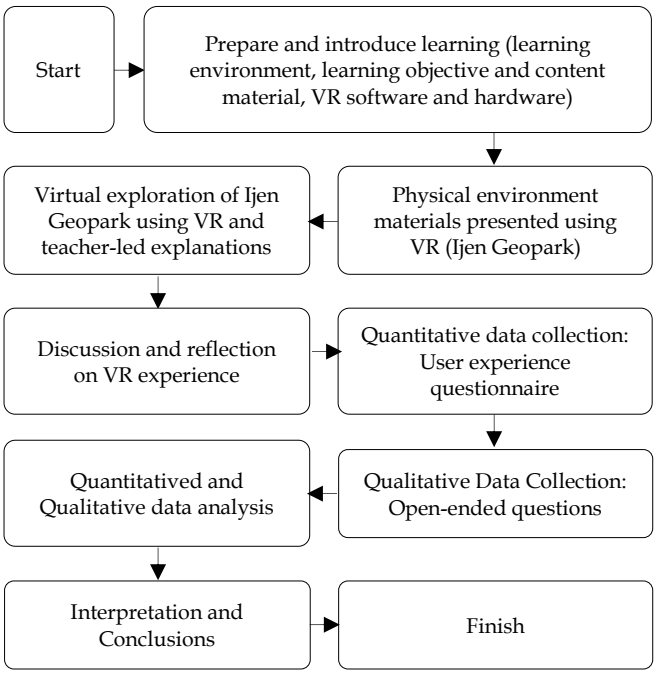

Figure 2. Research flowchart

Research Subject

This research was conducted at Senior High School 1 Zainul Hasan, Genggong, Probolinggo Regency. The population for this study comprised all grade XI students (N = 124). Purposive sampling was employed to select a sample relevant to the research objectives, focusing on students who had prior exposure to physical environment materials in grade X. The specific inclusion criteria were: currently enrolled as a grade XI student at the school; and having completed the physical environment material in Geography curriculum at grade X. A total of 82 students met these criteria and were selected for the study (14 male and 68 female), a number constrained by the available resources computers, VR device, requiring 80 minutes, class schedules, and teacher availability.

Data Collection

The research data was obtained through a questionnaire consisting of closed statements and open-ended questions. The questionnaire comprised 31 items, including 24 closed statements and 7 open-ended questions. The closed statements used a 5-level Likert scale, ranging from scale 1, which means strongly disagree, to scale 5, which means strongly agree. The 24 closed statements were designed to measure user experience, while the 7 open-ended questions aimed to explore students' impressions during their use of virtual reality.

The user experience questionnaire adopted indicators and statements from Topolewski et al. (2019). This questionnaire measured user experience across various aspects, such as business (economic and technological), human (emotional and cognitive), social (interpersonal and empathetic), and intention to use. This questionnaire already implemented by other researchers, such as Maslov et al. (2021), Pallot et al. (2020), and Alao et al. (2022). To ensure the validity and reliability of the instrument in the context of this study, the questionnaire underwent the following validity (pearson's correlations) and reliability (cronbach's α) testing with 35 responses, and shown in Table 1.

Tabel 1. Pearson's correlations and cronbach's α result for validity and reliability instrument

UX property	Pearson's r	P-value	Cronbach's α
Usefulness	0.84	<.00	0.97
Pleasantness	0.70	<.00	0.97
Entertaining	0.74	<.00	0.97
Productivity	0.84	<.00	0.97
Novelty	0.62	<.00	0.97
Reliability	0.88	<.00	0.97
Efficiency	0.85	<.00	0.97
User-friendliness	0.83	<.00	0.97
Attractiveness	0.71	<.00	0.97
Enjoyment	0.70	<.00	0.97
Fulfilment	0.85	<.00	0.97
Comprehensiveness	0.81	<.00	0.97
Meaningfulness	0.93	<.00	0.97
Engagement	0.90	<.00	0.97
Communicativeness	0.80	<.00	0.97
Collaborativeness	0.84	<.00	0.97
Confidence	0.86	<.00	0.97
Attentiveness	0.81	<.00	0.97
Responsiveness	0.85	<.00	0.97
Helpfulness	0.87	<.00	0.97
Respectfulness	0.86	<.00	0.97
Convincingness	0.82	<.00	0.97
Willingness	0.76	<.00	0.97
Recommend	0.77	<.00	0.97
Point estimate	-	-	0.97

Table 1 presents the results of the instrument's validity and reliability tests. Based on the validity test results using Pearson's correlation, all UX properties

showed positive and statistically significant correlation coefficients (r) ($p < .001$), indicating that each UX property had a positive and strong correlation with the overall UX construct. Therefore, it can be concluded that the instrument is valid. Furthermore, the reliability test results using Cronbach's alpha showed a coefficient alpha of 0.96 for the entire instrument. This value exceeds the commonly accepted threshold of 0.70, indicating that the instrument is categorized as reliable.

Data Analysis

Data analysis in this research employed both qualitative and quantitative approaches. Qualitative data analysis was conducted by examining respondents' answers to open-ended questions to obtain a comprehensive and in-depth evaluation of the use of VR Geopark Ijen. The results of this analysis were presented descriptively using NVivo Software. Quantitative data were analyzed descriptive statistical tests using JASP Software, such as mean, standard deviation, and standard error of the respondents' answers to the closed statements regarding user experience (Ubam et al., 2021). The analysis was conducted per indicator to identify factors that significantly affect user experience. The mean analysis per indicator was obtained using the Equation 1.

Tabel 2. User experience criteria

User experience criteria	Mean range
Very good	4.01 to 5.00
Good	3.01 to 4.00
Fair	2.01 to 3.00
Poor	1.01 to 2.00
Very poor	0.00 to 1.00

$$\bar{x} = \frac{\sum X_a + \sum X_b + \cdots \sum X_n}{X_n} \quad (1)$$

Explanation:
$\bar{x}$ = Mean
$\sum X_a$ = Mean per indicator a
$\sum X_b$ = Mean per indicator b
X_n = Number of indicators

The interpretation of user experience analysis is divided into five categories, ranging from Very poor to Very good. The categorization and value ranges are shown in Table 2.

Result and Discussion

Before being given the questionnaire, students participated in a learning process using VR Geopark Ijen as a learning media. This process lasted for 80 minutes in a single session, which included an opening (5 minutes), a lesson on the physical environment materials (10 minutes), VR Geopark Ijen as the learning media (10 minutes), explanation of VR Geopark Ijen features and information (10 minutes), exploration and explanation of material at each geosite (20 minutes), discussion (10 minutes), reflection and evaluation through the user experience questionnaire (10 minutes), and a closing session (5 minutes). Documentation of the use of VR Geopark Ijen in the learning process is shown in Figure 3 below.

(a) (b)

Figure 3. Documentation of the learning process using VR Geopark Ijen, desktop version (a) and VR mode using head-mounted display (b)

User Experience Using VR Geopark Ijen

The results of the user experience analysis show that VR Geopark Ijen can provide positive experiences,

perceptions, and responses for students. This result is based on the average score of the user experience questionnaire which obtained an average of 4.29, and each dimension exceeded 4.01: business (mean = 4.43), human (mean = 4.40), social (mean = 4.05), and intention to use (mean = 4.30), which is categorized as very good. The user experience analysis results are shown in Table 3.

Overall, ux properties show results with very good categories, for example attractiveness (mean = 4.66), pleasantness (mean = 4.65), and enjoyment (mean = 4.61) which get the highest scores. There are only four ux properties are categorized as good, namely confidence (mean = 3.82), attentiveness (mean = 3.85) and responsiveness (mean = 3.95) on the emphatical factor, and respectfulness (mean = 3.84) on the intention to use dimension.

Standard deviation is a measure of the variation in user responses to different ux properties. A low standard deviation indicates consistent user perceptions, while a high standard deviation indicates significant differences in opinion. For example, pleasantness has a standard deviation of 0.55 which indicates a small variation, while attentiveness has a standard deviation of 1.06 which indicates a large variation.

Tabel 3. Statistical analysis of user experience for each UX property

UX dimension	UX factor	UX property	Response distribution					Mean	Std. error	Category
			1	2	3	4	5			
Business	Economical	Usefulness	0	0	6	45	31	4.31	0.60	Very good
		Pleasantness	0	0	3	23	56	4.65	0.55	Very good
		Entertaining	0	0	2	30	50	4.56	0.54	Very good
		Productivity	0	0	4	37	41	4.45	0.59	Very good
	Technological	Novelty	0	1	7	21	53	4.54	0.71	Very good
		Reliability	0	0	7	42	33	4.32	0.63	Very good
		Efficiency	0	0	5	33	44	4.48	0.61	Very good
		User-friendliness	0	2	14	37	29	4.13	0.78	Very good
Human	Emotional	Attractiveness	1	0	2	20	59	4.66	0.65	Very good
		Enjoyment	0	0	3	26	53	4.61	0.56	Very good
		Fulfilment	1	0	8	39	34	4.28	0.74	Very good
	Cognitive	Comprehensiveness	2	4	10	42	24	4.00	0.92	Good
		Meaningfulness	1	0	2	37	42	4.45	0.67	Very good
		Engagement	0	0	3	44	35	4.39	0.56	Very good
Social	Interpersonal	Communicativeness	2	1	8	36	35	4.23	0.86	Very good
		Collaborativeness	0	2	6	37	37	4.33	0.72	Very good
		Confidence	3	4	20	33	22	3.82	1.01	Good
	Emphatical	Attentiveness	2	8	16	30	26	3.85	1.06	Good
		Responsiveness	3	2	12	44	21	3.95	0.91	Good
		Helpfulness	0	1	11	36	34	4.26	0.73	Very good
		Respectfulness	2	5	20	32	23	3.84	0.99	Good
Intention to Use		Convincingness	1	2	11	44	24	4.07	0.80	Very good
		Willingness	2	0	5	37	38	4.33	0.80	Very good
		Recommend	0	0	6	29	47	4.50	0.63	Very good

Business Dimension

The data analysis results for the economical factors show that VR Geopark Ijen is considered a usefulness, pleasantness, entertaining, and productivity learning media. The usefulness aspect of VR Geopark Ijen allows students to complete assigned tasks (strongly agree responses = 31, mean = 4.31). VR Geopark Ijen is equipped with various features, such as learning goals, material information, geosite distribution maps, multimedia hotspots, and exercises (Putra et al., 2023b).

These features have a positive impact on student productivity (strongly agree responses = 41, mean = 4.45), as students can study material from various geosite points by interacting with the available virtual objects (Putra et al., 2023c). This is evidenced by student comments such as, "*VR Geopark Ijen can visualize an object without having to visit the actual location, overcoming distance limitations and aiding my understanding*," or "*VR Geopark Ijen enables contextual learning by exploring and interacting with various elements within it*."

In terms of pleasantness and entertaining, students find VR Geopark Ijen very exciting and fun to use (strongly agree responses = 56, mean = 4.65) and perceive it as entertaining during the learning process (strongly agree responses = 50, mean = 4.56). This is demonstrated by students' expressions of joy and amusement while using the VR Geopark Ijen (Alfarizi et al., 2024; Warouw et al., 2024). VR Geopark Ijen is capable of visualizing the real environment of the geopark, albeit virtually, and provides students with an immersive experience (Rachmadian et al., 2024). Their comments, "*Using VR Geopark Ijen in the learning process is very enjoyable, interesting, exciting, and memorable because it allows direct exploration of the material*," or "*I am amazed by VR Geopark Ijen because it can visualize the real environment, making it feel like being in the actual setting*."

The data analysis results for the technological factors show that VR Geopark Ijen is a media that offers novelty, reliability, efficiency, and user-friendliness. Using VR Geopark Ijen in the Geography learning process is a new experience for students (strongly agree responses = 53, mean = 4.54). This experience is also supported by other factors, such as the reliability of VR VR Geopark Ijen (strongly agree responses = 33, mean = 4.32), the efficiency of the learning process (strongly agree responses = 44, mean = 4.48), and its ease of understanding even for users who have never used VR Geopark Ijen before (strongly agree responses = 29, mean = 4.13). The teaching of physical geography using conventional learning media, such as PowerPoint text, has been found to be inadequate in facilitating student comprehension (Leh et al., 2021). The utilization of VR Geopark Ijen in the study of physical environment offers a more engaging, efficient, and accessible approach to material delivery (Rachmadian et al., 2024). These results are supported by student comments such as, "*VR Geopark Ijen provides a new, more efficient learning experience because it allows studying the physical environment material without leaving the classroom*," or "*VR Geopark Ijen makes learning easier for me anytime and anywhere*."

Although the response is positive, some challenges were encountered by students, particularly new users. These challenges are indicated by student comments such as, "*I had difficulty using the VR device*," or "*I was a bit confused by the many features in VR*." These challenges can be addressed by extending the duration of the VR Geopark Ijen orientation session with more detailed explanations (Albus et al., 2021). The orientation session should also include demonstrations on how to use the VR Geopark Ijen device with a more personal approach (Asad et al., 2021). VR Geopark Ijen supports the use of VR headsets, also known as head-mounted displays, as it features a "VR mode" (Putra et al., 2023c). However, the VR headset is merely a tool to enhance the immersive experience and not the primary device for accessing VR Geopark Ijen (Sedlák et al., 2022; Shen, 2022). Additionally, the use of a manual book plays an important role in explaining the features of VR Geopark Ijen and addressing other basic technical issues (Kaplan et al., 2021).

Furthermore, students also reported symptoms of cybersickness, or motion sickness, characterized by dizziness and nausea, following prolonged use of VR Geopark Ijen. These sensations arose when students used the VR headsets for extended periods, often due to improper adjustment of the headsets, such as incorrect interpupillary distance, inadequate focus, or low frame and refresh rates (Kim et al., 2022; Martirosov et al., 2022). Proper adjustment of the VR headset prior to use is crucial, as individual user preferences vary (Pardini et al., 2022). These symptoms are indicated by comments like, "*Using VR Geopark Ijen for too long makes me dizzy*," or "*VR Geopark Ijen can cause dizziness and nausea if not adjusted properly*." These issues can be mitigated by providing rest breaks and limiting VR Geopark Ijen usage to 5-7 minutes (Kourtesis et al., 2023). Students should also understand the early symptoms of cybersickness to receive faster treatment (Mareta et al., 2022).

Human Dimension

The data analysis results for the emotional factors show that VR Geopark Ijen provides positive emotional effects for users, including attractiveness, enjoyment, and fulfilment. Visually, VR Geopark Ijen is very attractive (strongly agree responses = 59, mean = 4.66), enjoyable (strongly agree responses = 53, mean = 4.61), and supports task completion, leading to a sense of satisfaction (strongly agree responses = 34, mean = 4.28). VR Geopark Ijen facilitates self-directed learning, empowering students with autonomy over their learning process (Marougkas et al., 2023; Putra et al., 2022). This self-directed learning requires students to actively engage within the virtual environment, for example by accessing learning materials, exploring geosites, answering questions, and interacting with supplementary visual aids (Bachri et al., 2024a; Putra et al., 2023c). This is supported by student comments such as, "*VR Geopark Ijen is very attractive because it can*

visualize the real environment as if being in the actual location." Additionally, the learning experience using VR Geopark Ijen is more interesting and enjoyable compared to conventional methods (Pane et al., 2024). VR Geopark Ijen represents an innovative learning media, presenting a realistic environment for the authentic study of physical environment material content (Bos, 2022). Student comments, "*VR Geopark Ijen is more meaningful because it makes it easier for me to understand the physical environment material*."

Students also feel that using VR Geopark Ijen provides its own satisfaction because it can help complete tasks efficiently. The tasks within VR Geopark Ijen can be completed through exploration and direct explanation (Harknett et al., 2022). This provides students with a feeling of satisfaction as they are able to complete tasks effectively and efficiently (Carbonell-Carrera et al., 2021). Students commented, "*VR Geopark Ijen makes it easier to complete tasks because it allows direct exploration of the physical environment material*." The exploration process can facilitate students' understanding as they can see and interact with virtual objects (Pratiwi et al., 2024; Yuendita & Dina, 2024). Students noted, "*The interesting visualization, informative material, and direct learning experience help me remember the material better*."

The data analysis results for cognitive factors show that VR Geopark Ijen has a positive impact on students' cognition. This positive impact is due to VR Geopark Ijen having comprehensive features (strongly agree responses = 24, mean = 4.00), providing meaningful learning experiences (strongly agree responses = 42, mean = 4.45), and active student engagement in the learning process (strongly agree responses = 35, mean = 4.39). VR Geopark Ijen integrates various media, including infographics, photos, and videos, which allows learning content to be presented in a simplified format (Putra et al., 2023b). This simplified presentation of material can assist students in comprehending more complex concepts (Ozdemir & Ozturk, 2022). Students commented, "*VR Geopark Ijen can simplify difficult concepts because they can be studied directly*."

VR Geopark Ijen supports active and independent learning. Students can explore the virtual environment and study the presented content (Harknett et al., 2022). This process is a personalized learning experience, as it can be tailored to the different grasping speeds and interests of students (Abdjul et al., 2024; Ilma et al., 2024). This aligns with students' comments, "*VR Geopark Ijen provides a personalized learning experience, according to each student's pace*." The interactive nature of VR and student engagement can increase students' learning motivation and have a linear impact on understanding the material (Haeratunisah et al., 2024; Vesga et al., 2021).

The comprehensiveness of VR Geopark Ijen features shows the lowest aspect compared to other aspects in the cognitive factor because it does not have direct communication features. VR Geopark Ijen incorporates features such as a "help" section containing usage instructions, an "information" section providing material content, and other multimedia features (Putra et al., 2022; Putra et al., 2023c). However, these features are considered insufficient, as students require additional explanation from teachers (Hagge, 2021). This affects the need for teachers to act as direct facilitators in the exploration process, especially in explaining more detailed material (Young et al., 2020). Teachers play a role in delivering the material, so they do not only rely on the presented infographics (Wiriasto et al., 2024; Yildirim et al., 2020). Students commented, "*I feel the need for direct communication with the teacher to explain more complex concepts*" or "*the presence of the teacher as a facilitator is very important to explain the material in more detail and to address technical issues that arise*."

Social Dimension

The data analysis results for interpersonal factors show that VR Geopark Ijen strongly emphasizes communicative (strongly agree responses = 35, mean = 4.23) and collaborative aspects (strongly agree responses = 37, mean = 4.33). This indicates that VR Geopark Ijen supports communication and collaboration during the learning process, as reflected in the students' comments, "*I can also collaborate with friends to discuss the study physical environment material*." Student-to-student collaboration occurred outside the virtual environment, through group discussions (Hagge, 2024). This was due to limitations in VR Geopark Ijen's multiplayer features, as it lacked messaging capabilities or open mic and camera functionality (Putra et al., 2023b). Students can discuss and work together to complete assigned tasks directly, despite the limitations of live chat or video call features in VR Geopark Ijen (Pirker & Dengel, 2021).

The confidence aspect is the lowest in the interpersonal factor (strongly agree responses = 21, mean = 3.82). Students lack confidence when using VR Geopark Ijen in the learning process due to unfamiliarity with the technology, devices, and available VR Geopark Ijen (Taçgın, 2020). Students expressed hesitation in trying VR Geopark Ijen, particularly with the VR headsets (Mohring & Brendel, 2021). This unfamiliarity with the technology led to a lack of confidence, as students were unaccustomed to and unsure how to use the equipment (Roelofsen, 2022). Students commented, "*The challenges I faced included unstable internet connection, inadequate devices, and intensive training needed to understand VR Geopark Ijen features*." Orientation efforts can address technical issues and thereby enhance students' confidence "*The success of VR Geopark Ijen*

depends on infrastructure, teacher training, and the development of quality content".

The data analysis results for empathical factors show that VR Geopark Ijen received relatively low ratings, especially in responsiveness (strongly agree responses = 21, mean 3.95), respectfulness (strongly agree responses = 23, mean = 3.84), and attentiveness (strongly agree responses = 26, mean = 3.85). Students tended to focus more on the visualization presented by VR Geopark Ijen (Fahmi et al., 2022). Student saying, "*I am amazed by VR because it can visualize the real environment as if I am actually there*," thus neglecting the directions and explanations from the researcher. This highlights the importance of designing instructional plans in VR-based learning that integrate technological aspects and teacher-student interactions (Alam & Mohanty, 2023).

The helpfulness aspect received higher ratings compared to other aspects (strongly agree responses = 34, mean = 4.26). VR Geopark Ijen aids the learning process and facilitates understanding of the material through virtual field exploration (Putra et al., 2023c). This is supported by VR Geopark Ijen ability to present realistic visualizations, interact with virtual objects, integrate other media, and support active and independent learning (Korkut & Surer, 2023). The active and independent learning afforded by VR Geopark Ijen contributes to students' comprehension of material content by presenting the material contextually (Putra et al., 2023c). Students commented, "*VR Geopark Ijen allows contextual learning and interaction with various presented elements*."

Intention to Use Dimension

The data analysis results for the intention to reuse VR Geopark Ijen show that the convincingness aspect received the lowest score (strongly agree responses = 24, mean = 4.07). Convincingness is influenced by several factors, including the limitations of VR Geopark Ijen hardware and software, as well as the instructional design used by teachers (Dubovi, 2023). Students face limitations with VR hardware and the lack of VR software containing Geography learning materials (Checa & Bustillo, 2020). This is indicated by student comments, "*I had difficulty using the VR device*." Additionally, teachers face challenges in designing and providing learning experiences using VR (Alalwan et al., 2020). Students noted, "*VR is a new media and can provide a new learning experience for me*."

Although the confidence to reuse VR Geopark Ijen is relatively low, students showed high willingness (strongly agree responses = 38, mean = 4.33) and recommend (strongly agree responses = 47, mean = 4.50) aspects. This indicates interest and enthusiasm for using VR Geopark Ijen due to the meaningful and memorable learning experiences it provides (Putri et al., 2024). Students commented, "*VR Geopark Ijen provides new and memorable learning experiences, increasing my interest in learning*." Additionally, students also felt the benefits of VR Geopark Ijen learning media compared to conventional learning media (Putra et al., 2023a).

The high recommendation aspect shows the positive experiences students gained from VR Geopark Ijen learning media. Students are willing to recommend VR Geopark Ijen usage to teachers or other students in the learning process (Bower et al., 2020). Students stated, "*VR Geopark Ijen can be accessed again, the material can be further developed, and it can be used as a learning media at the high school level*." Recommendations for teachers can be more deeply explored because they relate to teachers' ability to provide VR Geopark Ijen learning experiences (Khukalenko et al., 2022). Students commented, "*VR Geopark Ijen should be used to broaden students' perspectives and simulate the material presented by the teacher*."

User Responses to VR Geopark Ijen

Tabel 4. User responses to VR Geopark Ijen

User responses	Category	Indicator	Word count frequency
User experience	Positive	Accessibility	4
		Enthusiasm	1
		Features	4
		Informative	1
		Surprise	1
		Engaging	84
		Entertaining	1
		Enjoyable	84
		Interest	2
		Motivation	4
		Spirit	1
		Excitement	7
		Amazed	6
		Impressed	18
	Neutral	Curiosity	5
		Novel experience	33
	Negative	Cost	5
		Adoption	1
		Confusion	3
		Device	27
		Network	21
		Nausea	1
		Dizziness	1
		Difficulty	7
		Challenged	1
		Update	2

Learning aspect	Learning effectiveness	27
	Learning efficiency	14
	Learning interactivity	24
	Learning practicality	5
	Learning engagement	12
	Ease of learning	72
	Collaborative learning	3
	Contextual learning	51
	Direct learning	29
	In-depth learning	11

The analysis of coding and word clouds using NVivo revealed a variety of user responses to the use of VR Geopark Ijen. The results of this analysis are shown in Table 4, with a word cloud visualization in Figure 4. User responses can be divided into two categories: user experience and perceived benefits in the learning aspect. User experience is divided into three categories: positive, neutral, and negative. The benefits in the learning aspect perceived by users include learning effectiveness, learning efficiency, learning interactivity, learning practicality, learning engagement, ease of learning, collaborative learning, contextual learning, direct learning, in-depth learning.

Figure 4. Word cloud from user responses

The qualitative analysis using NVivo revealed that the words "interesting" and "enjoyable" had the highest frequency (84 times), indicating that VR Geopark Ijen provides a positive experience in the learning process. These findings suggest that VR Geopark Ijen can evoke positive emotions to facilitate the learning process (Putra et al., 2023c; Putri et al., 2024). The enjoyment and interest generated can increase focus, motivation, and learning interest, which leads to ease in understanding the material (Shen, 2022). Moreover, an engaging and enjoyable learning process can provide a memorable learning experience (Bos et al., 2021).

The use of VR Geopark Ijen as a learning media can provide a new experience for students (33 times). VR Geopark Ijen is a virtual-based learning media that takes students to the geopark environment without having to go directly (Putra et al., 2023c). This media allows students to explore and interact with virtual objects directly, making it easier to understand the concepts of Geography and the environment (Alnagrat et al., 2023; Ozdemir & Ozturk, 2022). The near-realistic environment and the use of assistive devices in the form of VR glasses allow students to experience an immersive experience or as if they were in the actual location (Birenboim et al., 2021).

In addition to being interesting, fun, and providing a new experience, VR Geopark Ijen can also generate a spectrum of other positive emotions, such as excitement (7 times) and amazement (6 times). The emotion of amazement shows that the visualization of VR Geopark Ijen is able to amaze students (Putra et al., 2022), and the impressed emotion shows that students appreciate the ability of VR Geopark Ijen in presenting information and providing a unique learning experience (Putri et al., 2024). These two emotions are closely related to students' intrinsic motivation to explore and learn the material content further (Brůža et al., 2021; Wang et al., 2023).

These findings align with previous research demonstrating that VR learning media can provide positive learning experiences in Geography. Studies by Ozdemir & Ozturk (2022) have shown that VR can enhance student engagement and motivation in Geography learning. Research by Putra et al (2023c) indicated that VR Geopark Ijen can provide an immersive and meaningful experience compared to conventional methods. Furthermore, research by Li et al. (2022) has shown that interactive and narrative VR can improve student understanding of Geography concepts.

The use of VR Geopark Ijen as a learning media offers various benefits to students. Qualitative data indicate that the ease of learning aspect is the data with the highest frequency (72 times). This indicates that VR Geopark Ijen helps the understanding of material in an easier way than conventional methods (Putri et al., 2024). This is due to the attractive visualization, interaction with virtual objects, and immersive experience as if being directly in the geopark environment (Putra et al., 2022; Rachmadian et al., 2024). In addition, VR Geopark Ijen also allows contextual learning (51 times), by presenting the environment in a real context although virtually. This learning helps students connect theory with practice, so they gain a deeper understanding (Putra et al., 2023c; Rahman et al., 2023).

The direct learning aspect (29 times) is also one of the benefits felt by students. VR Geopark Ijen allows students to learn about the environment directly, even in a virtual environment (Bachri et al., 2024b). This learning also increases student engagement in the learning process (24 times), as students must independently explore the environment to gain knowledge. This interaction requires students to be active during learning, not just passively receiving information. In addition (Marougkas et al., 2023), VR Geopark Ijen also supports collaborative learning with the lowest frequency (3 times). This shows that VR Geopark Ijen has not been able to facilitate collaboration between students and teachers in a virtual environment, which is an evaluation aspect in the next development (Jochecová et al., 2022).

Theoretical Contribution

This research provides a theoretical contribution to the field of Geography education, specifically on the use of VR technology in the study of the physical environment by utilizing the Ijen Geopark. It enriches the literature on the evaluation of experiences with VR Geopark Ijen learning media using a comprehensive framework, namely the user experience indicators from the research by Topolewski et al. (2019). The findings offer a methodological contribution that can be utilized by other researchers.

The research identifies and outlines various factors influencing user experience. The dimensions that impact user experience, in order of significance, are the business dimension, the human dimension, the intention-to-use dimension, and the social dimension. Overall, VR Geopark Ijen is found to be an engaging, entertaining, and enjoyable learning media. VR Geopark Ijen functions effectively and provides a positive experience to users, despite some challenges related to complex features. The social dimension has the lowest score, influenced by the limitations of VR Geopark Ijen features, such as the absence of live chat or video call options.

This research also addresses the potential and advantages of VR Geopark Ijen in supporting contextual learning processes. VR Geopark Ijen can create real-life environments and integrate content according to the context being studied. Such environments allow students to explore and interact with virtual objects to learn the available material content. From a theoretical perspective, the findings of this research can serve as a reference for further research in evaluating user experience with VR Geopark Ijen learning media.

Practical Implications

The practical implications of this research contribute to teachers, educational technology developers, and education policymakers. The findings can assist teachers in designing, implementing, and evaluating VR Geopark Ijen learning media. Teachers can use user experience variables as a basis for evaluation to provide an engaging, memorable, and meaningful learning experience. Such learning experiences positively affect students' comprehension, retention, and understanding, optimizing the use of VR Geopark Ijen in the learning process.

This research demonstrates that integrating VR Geopark Ijen into the curriculum can overcome spatial and temporal limitations in conducting field-based learning. VR Geopark Ijen content aligned with the curriculum allows students to achieve learning outcomes effectively and efficiently. Students can conduct virtual field explorations without leaving the classroom, thereby supporting contextual learning. This approach not only enhances understanding but also increases students' motivation and interest in learning.

The findings also contribute to the development of educational technology. These results offer insights to developers on the importance of designing user-friendly VR devices that are easily accessible to teachers and students. Issues encountered, such as complex features and a lack of virtual interaction, highlight gaps in further development. Developers might consider incorporating features like live chat or video calls to enhance the social dimension of VR learning media.

The research also contributes to education policymakers by highlighting the need for investment in VR technology and supporting infrastructure in educational institutions. Supportive policies for VR learning media, such as the provision of VR hardware and software content aligned with the curriculum, are essential. Additionally, investment may include capacity building for teachers through specialized training to implement VR-based learning, as an effort to enhance the quality of education.

Conclusion

This research demonstrates that students' experiences and responses to VR Geopark Ijen were overwhelmingly positive and significant. In general, students reported a highly favorable experience with VR Geopark Ijen, particularly regarding its usefulness, enjoyability, and capacity to enhance learning productivity. Aspects such as user-friendliness, novelty, and technological reliability also received excellent ratings. Nevertheless, certain areas require further attention, including feature comprehensiveness, students' confidence in using the device, and attentiveness and respectful behavior during VR Geopark Ijen use. This suggests that while overall experiences with VR Geopark Ijen are highly positive,

further development should address these aspects to optimize the user experience. VR Geopark Ijen has proven to provide a contextual and meaningful learning experience. Students can explore the virtual space and learn material content within the context of the real world, facilitating conceptual understanding and promoting active engagement in the learning process. The use of VR also has a positive impact on students' emotional state, such as increasing interest and motivation, and providing an enjoyable experience. Furthermore, VR Geopark Ijen demonstrates effectiveness and efficiency in achieving learning outcomes, enabling field-based learning without the need to leave the classroom. These findings have significant implications for education, particularly in the context of physical geography learning at Ijen Geopark. The utilization of VR Geopark Ijen can serve as an innovative solution to overcome access limitations and improve the quality of learning about the geopark's physical environment. Future software development should focus on integrating VR with the curriculum, providing teacher training in VR utilization, and ensuring relevant and high-quality content. Further research could examine the long-term impact of VR use on student comprehension and explore VR's potential for collaborative learning and the development of other skills.

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The authors declare no conflict of interest.

References

Abdjul, T., Odja, A. H., & Nurhayati, N. (2024). Effectiveness of Virtual Laboratory-Based Interactive Learning Media Through a Differentiated Approach to Students' Scientific Literacy. *Jurnal Penelitian Pendidikan IPA*, *10*(11), 9838–9838. https://doi.org/10.29303/jppipa.v10i11.9253

Alalwan, N., Cheng, L., Al-Samarraie, H., Yousef, R., Alzahrani, A. I., & Sarsam, S. M. (2020). Challenges and Prospects of Virtual Reality and Augmented Reality Utilization Among Primary School Teachers: A Developing Country Perspective. *Studies in Educational Evaluation*, *66*, 100876. https://doi.org/10.1016/j.stueduc.2020.100876

Alam, A., & Mohanty, A. (2023). Implications of Virtual Reality (VR) for School Teachers and Instructional Designers: An Empirical Investigation. *Cogent Education*, *10*(2). https://doi.org/10.1080/2331186X.2023.2260676

Alao, O. D., Priscilla, E. A., Amanze, R. C., Kuyoro, S. O., & Adebayo, A. O. (2022). User-Centered/User Experience Uc/Ux Design Thinking Approach for Designing a University Information Management System. *Ingenierie Des Systemes d'Information*, *27*(4), 577–590. https://doi.org/10.18280/isi.270407

Albus, P., Vogt, A., & Seufert, T. (2021). Signaling in Virtual Reality Influences Learning Outcome and Cognitive Load. *Computers and Education*, *166*(April 2020), 104154. https://doi.org/10.1016/j.compedu.2021.104154

Alfarizi, A., Suciati, S., & Yamtinah, S. (2024). Analyzing Spatial Ability Outcomes and Students' Responses of E-Module Inquiry Learning Integrated Virtual Laboratory (IL- VIL) on Human Cardiovascular Concept. *Jurnal Penelitian Pendidikan IPA*, *10*(12), 10245–10254. https://doi.org/10.29303/jppipa.v10i12.9375

Alnagrat, A. J. A., Ismail, R. C., & Idrus, S. Z. S. (2023). The Opportunities and Challenges in Virtual Reality for Virtual Laboratories. *Innovative Teaching and Learning Journal*, *6*(2), 73–89. https://doi.org/10.11113/itlj.v6.91

Asad, M. M., Naz, A., Churi, P., & Tahanzadeh, M. M. (2021). Virtual Reality as Pedagogical Tool to Enhance Experiential Learning: A Systematic Literature Review. *Education Research International*, . https://doi.org/10.1155/2021/7061623

Bachri, S., Hakiki, A. R. R., Putra, A. K., Hidiyah, M. T., Putri, N. R. C., & Prastiwi, M. R. H. (2024a). Development of Metaverse-Based Virtual Disaster Gallery as a Support System for Disaster Education in Geography Learning. *Geography: Jurnal Kajian, Penelitian, dan Pengembangan Pendidikan*, *12*(2), 933–946. https://doi.org/10.31764/geography.v12i2.26431

Bachri, S., Hakiki, A. R. R., Wibowo, N. A., Sumarmi, S.,

Amini, R., Yosritzal, Y., & Nursaribilah, E. (2024b). Developing an Education Support System for Disaster Management Through an Ethnoscience-Based Digital Disaster Learning Module. *International Journal of Disaster Risk Reduction*, *100*(December 2023), 104214. https://doi.org/10.1016/j.ijdrr.2023.104214

Birenboim, A., Bloom, P. B-N., Levit, H., & Omer, I. (2021). The Study of Walking, Walkability and Wellbeing in Immersive Virtual Environments. In *International Journal of Environmental Research and Public Health*, *18*(2). https://doi.org/10.3390/ijerph18020364

Bos, D. (2022). Using Virtual Reality (VR) for Teaching and Learning in Geography: Fieldwork, Analytical Skills, and Employability. *Journal of Geography in Higher Education*, *46*(3), 479–488. https://doi.org/10.1080/03098265.2021.1901867

Bos, D., Miller, S., & Bull, E. (2021). Using Virtual Reality (VR) for Teaching and Learning in Geography: Fieldwork, Analytical Skills, and Employability. *Journal of Geography in Higher Education*, *00*(00), 1–10. https://doi.org/10.1080/03098265.2021.1901867

Bower, M., DeWitt, D., & Lai, J. W. M. (2020). Reasons Associated with Preservice Teachers' Intention to Use Immersive Virtual Reality in Education. *British Journal of Educational Technology*, *51*(6), 2214–2232. https://doi.org/10.1111/bjet.13009

Brůža, V., Byška, J., Mičan, J., & Kozlíková, B. (2021). VRdeo: Creating Engaging Educational Material for Asynchronous Student-Teacher Exchange using Virtual Reality. *Computers & Graphics*, *98*, 280–292. https://doi.org/10.1016/j.cag.2021.06.009

Carbonell-Carrera, C., Saorin, J. L., & Díaz, D. M. (2021). User VR Experience and Motivation Study in an Immersive 3D Geovisualization Environment Using a Game Engine for Landscape Design Teaching. *Land*, *10*(5). https://doi.org/10.3390/land10050492

Checa, D., & Bustillo, A. (2020). Advantages and Limits of Virtual Reality in Learning Processes: Briviesca in the Fifteenth Century. *Virtual Reality*, *24*(1), 151–161. https://doi.org/10.1007/s10055-019-00389-7

Conner, N. O., Freeman, H. R., Jones, J. A., Luczak, T., Carruth, D., Knight, A. C., & Chander, H. (2022). Virtual Reality Induced Symptoms and Effects: Concerns, Causes, Assessment & Mitigation. *Virtual Worlds*, *1*(2), 130–146. https://doi.org/10.3390/virtualworlds1020008

Dubovi, I. (2023). Learning with Virtual Reality Simulations: Direct Versus Vicarious Instructional Experience. *Interactive Learning Environments*, *31*(10), 6627–6639. https://doi.org/10.1080/10494820.2022.2042313

Fahmi, M. R., Putra, A. K., Handoyo, B., & Sumarmi, S. (2022). Development of Web-Based Virtual Reality as Media Learning for Baluran Conservation Area with Geographical Characteristics. *Proceedings of the 2nd International Conference on Social Knowledge Sciences and Education (ICSKSE 2022)*, 332–346. https://doi.org/10.2991/978-2-494069-63-3_30

Geng, J., Chai, C. S., Jong, M. S. Y., & Luk, E. T. H. (2021). Understanding the Pedagogical Potential of Interactive Spherical Video-Based Virtual Reality from the Teachers' Perspective Through the ACE Framework. *Interactive Learning Environments*, *29*(4), 618–633. https://doi.org/10.1080/10494820.2019.1593200

Ginting, F. W., Sakdiah, H., Widya, W., & Unaida, R. (2023). Analysis of the Need for Development of Virtual Reality-Based Learning Media to Build Technological Pedagogical and Content Knowledge (TPACK) Competencies for Prospective Physics Teachers. *Jurnal Penelitian Pendidikan IPA*, *9*(12), 12098–12103. https://doi.org/10.29303/jppipa.v9i12.6163

Haeratunisah, H., Doyan, A., & Taufik, M. (2024). The Effect of Using Virtual Laboratories Using the Guided Discovery Learning Model on Students' Conceptual Understanding of Static Electricity Material. *Jurnal Penelitian Pendidikan IPA*, *10*(10), 8015–8022. https://doi.org/10.29303/jppipa.v10i10.8682

Hagge, P. (2021). Student Perceptions of Semester-Long in-Class Virtual Reality: Effectively Using "Google Earth VR" in a Higher Education Classroom. *Journal of Geography in Higher Education*, *45*(3), 342–360. https://doi.org/10.1080/03098265.2020.1827376

Hagge, P. D. (2024). Metaverse in in the Geography Lecture Classroom? Evaluating 'Group VR' Possibilities using the Multiplayer 'Wooorld' VR App. *Journal of Geography in Higher Education*, *48*(5), 864–872. https://doi.org/10.1080/03098265.2024.2333290

Hamilton, D., McKechnie, J., Edgerton, E., & Wilson, C. (2021). Immersive Virtual Reality as a Pedagogical Tool in Education: A Systematic Literature Review of Quantitative Learning Outcomes and Experimental Design. *Journal of Computers in Education*, *8*(1). https://doi.org/10.1007/s40692-020-00169-2

Harknett, J., Whitworth, M., Rust, D., Krokos, M., Kearl, M., Tibaldi, A., Bonali, F. L., Vries, B. V. W. D., Antoniou, V., Nomikou, P., Reitano, D., Falsaperla, S., Vitello, F., & Becciani, U. (2022). The Use of Immersive Virtual Reality for Teaching Fieldwork Skills in Complex Structural Terrains. *Journal of Structural Geology*, *163*, 104681. https://doi.org/10.1016/j.jsg.2022.104681

Hermayanti, F., & Setyasto, N. (2025). Development of E-Learning Materials Assisted by Augmented

Reality on the Material of the Form of Matter and Its Changes to Improve Learning Outcomes of Elementary School Students. *Jurnal Penelitian Pendidikan IPA*, *11*(1), 329–341. https://doi.org/10.29303/jppipa.v11i1.10218

Ilma, A. Z., Istiandaru, A., & Ritasari, N. S. (2024). Implementing Discovery Learning Model Using Virtual Laboratory: An Insight to Differentiation Learning Strategies. *Jurnal Penelitian Pendidikan IPA*, *10*(4), 2110–2117. https://doi.org/10.29303/jppipa.v10i4.5784

Jochecová, K., Černý, M., Stachoň, Z., Švedová, H., Káčová, N., Chmelík, J., Brůža, V., Kvarda, O., Ugwitz, P., Šašinková, A., Fořtová, N. C., & Šašinka, Č. (2022). Geography Education in a Collaborative Virtual Environment: A Qualitative Study on Geography Teachers. *ISPRS International Journal of Geo-Information*, *11*(3). https://doi.org/10.3390/ijgi11030180

Jong, M. S.-Y., Tsai, C.-C., Xie, H., & Wong, F. K.-K. (2020). Integrating Interactive Learner-Immersed Video-Based Virtual Reality into Learning and Teaching of Physical Geography. *British Journal of Educational Technology*, *51*(6), 2063–2078. https://doi.org/10.1111/bjet.12947

Kaplan, A. D., Cruit, J., Endsley, M., Beers, S. M., Sawyer, B. D., & Hancock, P. A. (2021). The Effects of Virtual Reality, Augmented Reality, and Mixed Reality as Training Enhancement Methods: A Meta-Analysis. *Human Factors*, *63*(4), 706–726. https://doi.org/10.1177/0018720820904229

Khukalenko, I. S., Kaplan-Rakowski, R., An, Y., & Iushina, V. D. (2022). Teachers' Perceptions of Using Virtual Reality Technology in Classrooms: A Large-Scale Survey. *Education and Information Technologies*, *27*(8), 11591–11613. https://doi.org/10.1007/s10639-022-11061-0

Khusna, N. I., Sumarmi, S., Bachri, S., Astina, I. K., Nurhayati, D. A. W., & Shresthai, R. P. (2022). New Technologies for Project-Based Empathy Learning in Merdeka Belajar (Freedom to Learn): The Use of inaRISK Application and Biopore Technology. *International Journal of Interactive Mobile Technologies*, *16*(22), 94–110. https://doi.org/10.3991/ijim.v16i22.36153

Kim, Y. S., Won, J., Jang, S.-W., & Ko, J. (2022). Effects of Cybersickness Caused by Head-Mounted Display--Based Virtual Reality on Physiological Responses: Cross-sectional Study. *JMIR Serious Games*, *10*(4), e37938. https://doi.org/10.2196/37938

Korkut, E. H., & Surer, E. (2023). Visualization in Virtual Reality: A Systematic Review. *Virtual Reality*, *27*(2), 1447–1480. https://doi.org/10.1007/s10055-023-00753-8

Kourtesis, P., Linnell, J., Amir, R., Argelaguet, F., & MacPherson, S. E. (2023). Cybersickness in Virtual Reality Questionnaire (CSQ-VR): A Validation and Comparison Against SSQ and VRSQ. *Virtual Worlds*, *2*(1), 16–35. https://doi.org/10.3390/virtualworlds2010002

Leh, F. C., Anduroh, A., & Huda, M. (2021). Level of Knowledge, Skills and Attitude of Trainee Teachers on Web 2.0 Applications in Teaching Geography in Malaysia Schools. *Heliyon*, *7*(12), e08568. https://doi.org/10.1016/j.heliyon.2021.e08568

Li, Y., Ying, S., Chen, Q., & Guan, J. (2022). An Experiential Learning-Based Virtual Reality Approach to Foster Students' Vocabulary Acquisition and Learning Engagement in English for Geography. *Sustainability*, *14*(22). https://doi.org/10.3390/su142215359

Lin, Y. J., & Wang, H. chun. (2021). Using Virtual Reality to Facilitate Learners' Creative Self-Efficacy and Intrinsic Motivation in an EFL Classroom. *Education and Information Technologies*, *26*(4), 4487–4505. https://doi.org/10.1007/s10639-021-10472-9

Mareta, S., Thenara, J. M., Rivero, R., & Tan-Mullins, M. (2022). A Study of the Virtual Reality Cybersickness Impacts and Improvement Strategy towards the Overall Undergraduate Students' Virtual Learning Experience. *Interactive Technology and Smart Education*, *19*(4), 460–481. https://doi.org/10.1108/ITSE-10-2021-0193

Marks, B., & Thomas, J. (2022). Adoption of Virtual Reality Technology in Higher Education: An Evaluation of Five Teaching Semesters in a Purpose-Designed Laboratory. *Education and Information Technologies*, *27*(1), 1287–1305. https://doi.org/10.1007/s10639-021-10653-6

Marougkas, A., Troussas, C., Krouska, A., & Sgouropoulou, C. (2023). Virtual Reality in Education: A Review of Learning Theories, Approaches and Methodologies for the Last Decade. *Electronics*, *12*(13). https://doi.org/10.3390/electronics12132832

Martirosov, S., Bureš, M., & Zítka, T. (2022). Cyber Sickness in Low-Immersive, Semi-Immersive, and Fully Immersive Virtual Reality. *Virtual Reality*, *26*(1), 15–32. https://doi.org/10.1007/s10055-021-00507-4

Maslov, I., Nikou, S., & Hansen, P. (2021). Exploring User Experience of Learning Management System. *International Journal of Information and Learning Technology*, *38*(4), 344–363. https://doi.org/10.1108/IJILT-03-2021-0046

Mastika, I. K., Harsono, S. S., Khristianto, W., Oktawirani, P., & Hutama, P. S. (2023). Creative Strategies of Local Resources in Managing Geotourism in the Ijen Geopark Bondowoso, East Java, Indonesia. *International Journal of Geoheritage*

and Parks, *11*(1), 149–168. https://doi.org/10.1016/j.ijgeop.2023.01.002

Maulidya, D. R., & Astuti, T. (2025). The Influence of Interactive Learning Media on the Learning Outcomes and Motivation of Grade V Students in the Science Subject. *Jurnal Penelitian Pendidikan IPA*, *11*(1), 63–70. https://doi.org/10.29303/jppipa.v11i1.9393

Meadows, M. E. (2020). Geography Education for Sustainable Development. *Geography and Sustainability*, *1*(1), 88–92. https://doi.org/10.1016/j.geosus.2020.02.001

Mohring, K., & Brendel, N. (2021). Producing Virtual Reality (VR) Field Trips -- A Concept for a Sense-Based and Mindful Geographic Education. *Geographica Helvetica*, *76*(3), 369–380. https://doi.org/10.5194/gh-76-369-2021

Mystakidis, S., Berki, E., & Valtanen, J. P. (2021). Deep and Meaningful E-Learning with Social Virtual Reality Environments in Higher Education: A Systematic Literature Review. *Applied Sciences*, *11*(5). https://doi.org/10.3390/app11052412

Oktavianto, D. A., Utaya, S., Sumarmi, S., & Taryana, D. (2023). Implementing Fieldwork Based on Blended Learning Using Geo-Inquiry Approach: Will It Work During the Covid-19 Pandemic? *International Research in Geographical and Environmental Education*, *33*(2), 125–138. https://doi.org/10.1080/10382046.2023.2214043

Ozdemir, D., & Ozturk, F. (2022). The Investigation of Mobile Virtual Reality Application Instructional Content in Geography Education: Academic Achievement, Presence, and Student Interaction. *International Journal of Human-Computer Interaction*, *38*(16), 1487–1503. https://doi.org/10.1080/10447318.2022.2045070

Pallot, M., Pawar, K., Krawczyk, P., Topolewski, M., Lecossier, A., & Razek, A. R. A. (2020). Evaluating User eXperience as a Means to Reveal the Potential Adoption of Innovative Ideas. *2020 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC)*, 1–11. https://doi.org/10.1109/ICE/ITMC49519.2020.9198368

Palsdottir, A. (2024). Activating Teenagers' Learning in Geography using Virtual Reality: Student Enquiry of Local School Environment in Iceland. *International Research in Geographical and Environmental Education*, *0*(0), 1–17. https://doi.org/10.1080/10382046.2024.2349427

Pane, E. P., Lubis, N. F., & Simarmata, G. (2024). Application of Interactive Virtual Lab Media Based on a STEM Approach in Improving Students' Scientific Literacy and Learning Motivation. *Jurnal Penelitian Pendidikan IPA*, *10*(12), 10736–10744. https://doi.org/10.29303/jppipa.v10i12.8589

Pardini, S., Gabrielli, S., Dianti, M., Novara, C., Zucco, G. M., Mich, O., & Forti, S. (2022). The Role of Personalization in the User Experience, Preferences and Engagement with Virtual Reality Environments for Relaxation. *International Journal of Environmental Research and Public Health*, *19*(12). https://doi.org/10.3390/ijerph19127237

Pirker, J., & Dengel, A. (2021). The Potential of 360° Virtual Reality Videos and Real VR for Education - A Literature Review. *IEEE Computer Graphics and Applications*, *41*(4), 76–89. https://doi.org/10.1109/MCG.2021.3067999

Pratiwi, M. R., Hakim, R., Zen, Z., Rayendra, J, F. Y., & Hardika, J. (2024). Development of Virtual Laboratory in Physics Subject for Senior High School Phase-F. *Jurnal Penelitian Pendidikan IPA*, *10*(12), 11197–11203. https://doi.org/10.29303/jppipa.v10i12.9406

Putra, A. K., Khalidy, D. A., Handoyo, B., & Thang, H. V. (2023a). Construction of Immersive Experiences: Development of Virtual Reality Technology to Facilitate Physical Geography Learning. *International Journal of Emerging Technologies in Learning*, *18*(19), 47–60. https://doi.org/10.3991/ijet.v18i19.40859

Putra, A. K., Purwanto, P., Islam, M. N., Hidayat, W. N., & Fahmi, M. R. (2022). Development of Mobile Virtual Field Trips in Ijen Crater Geosites Based on 3600 Auto Stereoscopic and Geospatial Technology As Geography Learning Media. *Geojournal of Tourism and Geosites*, *41*(2), 456–463. https://doi.org/10.30892/GTG.41216-850

Putra, A. K., Rizal, S., Alam, M., Sustika, L., Huda, I. A. S., & Yembuu, B. (2023b). Volcano Tourism in Volcanic Risk Areas: Exploration of the Higher Experience in Mount Semeru – Indonesia. *GeoJournal of Tourism and Geosites*, *46*(1), 99–107. https://doi.org/10.30892/gtg.46111-1005

Putra, A. K., Sumarmi, A. S., Fajrilia, A., Islam, M. N., & Yembuu, B. (2021). Effect of Mobile-Augmented Reality (MAR) in Digital Encyclopedia on The Complex Problem Solving and Attitudes of Undergraduate Student. *International Journal of Emerging Technologies in Learning*, *16*(7), 119–134. https://doi.org/10.3991/ijet.v16i07.21223

Putra, A. K., Sumarmi, Bachri, S., Khalidy, D. A., & Huda, I. A. S. (2023c). Spatial Acumen in the Digital Age: The Transformative Power of STEM-Enriched Mobile Textbooks in Geography. *International Journal of Interactive Mobile Technologies (IJIM)*, *17*(23), 153–167. https://doi.org/10.3991/ijim.v17i23.45949

Putri, G. B., Putra, A. K., Romero, D. C. A., & Samsul, S. (2024). Student Perceptions About the Use of

Immersive Media Virtual Field Learning Study of Ijen Geosite Geopark on Interests in Studying Banyuwangi Geography. *Future Space: Studies in Geo-Education*, *1*(2), 145–163. https://doi.org/10.69877/fssge.v1i2.17

Rachmadian, R. H., Putra, A. K., Sumarmi, S., & Masruroh, H. (2024). Developing Interactive Virtual Reality as a Tech-Based Learning Media to Improve Students' Geoheritage Comprehension. *International Journal of Learning Technology*, *19*(3), 332–351. https://doi.org/10.1504/IJLT.2024.142510

Rahman, A. R., Sumarmi, S., Bachri, S., & Mkumbachi, R. L. (2023). Pengembangan Media Pembelajaran Progressive WEB APP Berbasis Environmental Learning untuk Meningkatkan Ecoliteracy Siswa. *Jurnal Pendidikan Ilmu Sosial*, *10*(1), 1–20. http://dx.doi.org/10.15548/20995

Rizal, S., Sumarmi, S., Bachri, S., Mutia, T., & Ismail, A. S. (2024). Potensi Kawasan Segara Anakan sebagai Sarana Fieldwork pada Pembelajaran Geografi Materi Lingkungan Estuari. *J-PIPS (Jurnal Pendidikan Ilmu Pengetahuan Sosial)*, *10*(2), 78–97. https://doi.org/10.18860/jpips.v10i2.23568

Roelofsen, M. (2022). Virtual Reality as a Spatial Prompt in Geography Learning and Teaching. *Geographical Research*, *60*(4), 625–636. https://doi.org/10.1111/1745-5871.12551

Salsabila, T. I., Putra, A. K., & Matos, T. (2022). Mobile Virtual Field Trip and Geography Education: Potential Exploration of Complex Problem Solving and Spatial Intelligence Capabilities. *International Journal of Interactive Mobile Technologies*, *16*(24), 21–31. https://doi.org/10.3991/ijim.v16i24.36157

Schott, C., & Marshall, S. (2021). Full-Immersion Virtual Reality for Experiential Education: An Exploratory User Experience Analysis. *Australasian Journal of Educational Technology*, *37*(1), 96–110. https://doi.org/10.14742/ajet.5166

Sedlák, M., Šašinka, Č., Stachoň, Z., Chmelík, J., & Doležal, M. (2022). Collaborative and Individual Learning of Geography in Immersive Virtual Reality: An Effectiveness Study. *PLoS ONE*, *17*(10 October), 1–18. https://doi.org/10.1371/journal.pone.0276267

Shaherani, N., Putra, A. K., Soelistijo, D., & Yembuu, B. (2022). The Development of Mobile Geography Virtual Laboratory for Rock and Soil Practicum Studies. *International Journal of Interactive Mobile Technologies*, *16*(22), 142–156. https://doi.org/10.3991/ijim.v16i22.36163

Shen, Y. (2022). An Empirical Study of Geography Learning on Students' Emotions and Motivation in Immersive Virtual Reality. *Frontiers in Education*, *7*. https://doi.org/10.3389/feduc.2022.831619

Sumarmi, S., Bachri, S., Purwanto, P., Sholiha, A. W., Zubaidah, S., & Shrestha, R. P. (2022). Assessing Bedul Mangrove Ecotourism Using Green and Fair Strategy Empowerment to Fulfill SDGs 2030 Agenda for Tourism. *Environmental Research, Engineering and Management*, *78*(2), 73–87. https://doi.org/10.5755/j01.erem.78.2.31006

Taçgın, Z. (2020). The Perceived Effectiveness Regarding Immersive Virtual Reality Learning Environments Changes by the Prior Knowledge of Learners. *Education and Information Technologies*, *25*(4), 2791–2809. https://doi.org/10.1007/s10639-019-10088-0

Topolewski, M., Lehtosaari, H., Krawczyk, P., Pallot, M., Maslov, I., & Huotari, J. (2019). Formative Measurement Model of User eXperience. *Proceedings - 2019 IEEE International Conference on Engineering, Technology and Innovation, ICE/ITMC 2019*, *June*. https://doi.org/10.1109/ICE.2019.8792617

Ubam, E., Hipiny, I., & Ujir, H. (2021). User Interface/User Experience (UI/UX) Analysis & Design of Mobile Banking App for Senior Citizens: A Case Study in Sarawak, Malaysia. *2021 International Conference on Electrical Engineering and Informatics (ICEEI)*, 1–6. https://doi.org/10.1109/ICEEI52609.2021.9611136

Vesga, J. B., Xu, X., & He, H. (2021). The Effects of Cognitive Load on Engagement in a Virtual Reality Learning Environment. *Proceedings - 2021 IEEE Conference on Virtual Reality and 3D User Interfaces, VR 2021*, *September*, 645–652. https://doi.org/10.1109/VR50410.2021.00090

Wang, M., Wu, J., An, N., & Lin, M. (2023). The Effect of Emotional Experiences in Fieldwork: Embodied Evidence from a Visual Approach. *Journal of Geography in Higher Education*, *47*(2), 188–209. https://doi.org/10.1080/03098265.2021.2005002

Warouw, Z. W. M., Wekes, W. C. A., Harahap, F., Tumewu, W. A., & Wola, B. R. (2024). Development of STEM-Based Virtual Laboratory on Global Warming Topic for Junior High School Student. *Jurnal Penelitian Pendidikan IPA*, *10*(5), 2309–2321. https://doi.org/10.29303/jppipa.v10i5.6403

Wiriasto, G. W., Misbahuddin, M., Rachman, A. S., Harahap, I. L., Akbar, L. S. I., Iqbal, M. S., & Fikriansyah, M. (2024). Study on the Development of a Virtual Reality Application for Skeletal Anatomy Learning Using Rapid Application Development (RAD). *Jurnal Penelitian Pendidikan IPA*, *10*(8), 5726–5733. https://doi.org/10.29303/jppipa.v10i8.8722

Xiangming, L., Wang, K., Wang, Y., He, J., & Zhang, J. (2024). Assessing User Experiences in Virtual Reality Learning Environments. *Asia-Pacific Education Researcher*, *33*(5), 1149–1160. https://doi.org/10.1007/s40299-023-00785-3

Yildirim, B., Topalcengiz, E. S., Arikan, G., & Timur, S. (2020). Using Virtual Reality in the Classroom: Reflections of STEM Teachers on the Use of Teaching and Learning Tools. *Journal of Education in Science, Environment and Health*, *6*(3), 231–245. https://doi.org/10.21891/jeseh.711779

Young, G. W., Stehle, S., Walsh, B. Y., & Tiri, E. (2020). Exploring Virtual Reality in the Higher Education Classroom: Using VR to Build Knowledge and Understanding. *Journal of Universal Computer Science*, *26*(8), 904–928. https://doi.org/10.3897/jucs.2020.049

Yuendita, D., & Dina, D. (2024). Development of Chemical Literacy Book on Local Wisdom of Madura Culture Based on Augmented Reality (AR). *Jurnal Penelitian Pendidikan IPA*, *10*(1), 346–359. https://doi.org/10.29303/jppipa.v10i1.5689

Zhao, J., LaFemina, P., Carr, J., Sajjadi, P., Wallgrun, J. O., & Klippel, A. (2020). Learning in the Field: Comparison of Desktop, Immersive Virtual Reality, and Actual Field Trips for Place-Based STEM Education. *2020 IEEE Conference on Virtual Reality and 3D User Interfaces (VR)*, 893–902. Atlanta, GA, USA. https://doi.org/10.1109/vr46266.2020.00012