GEOGRAPHY
Jurnal Kajian, Penelitian dan Pengembangan Pendidikan
http://journal.ummat.ac.id/index.php/geography
Vol. 12, No. 2, September 2024, Hal. 933-946
e-ISSN 2614-5529 | p-ISSN 2339-2835

DEVELOPMENT OF METAVERSE-BASED VIRTUAL DISASTER GALLERY AS A SUPPORT SYSTEM FOR DISASTER EDUCATION IN GEOGRAPHY LEARNING

Syamsul Bachri[1*], A.Riyan Rahman Hakiki[2], Sumarmi[3], Alfyananda Kurnia Putra[4], Tabita May Hidiyah[5], Nanda Regita Cahyaning Putri[6], Mellinia Regina Heni Prastiwi[7]

[1,2,3,4,5,6,7]Pendidikan Geografi, Universitas Negeri Malang, syamsul.bachri.fis@um.ac.id, ariyan.rahman.2107218@students.um.ac.id, sumarmi.fis@um.ac.id, alfyananda.fis@um.ac.id, tabita.may.2107218@students.um.ac.id, nanda.regita.1907226@students.um.ac.id, mellinia.regina.1907226@students.um.ac.id

ABSTRAK

Abstrak: Pendidikan kebencanaan memainkan peran penting dalam menumbuhkan kesiapsiagaan bencana di kalangan pelajar. Namun, implementasi pendidikan kebencanaan di Indonesia masih memiliki keterbatasan, terutama karena kurangnya media yang interaktif dan kontekstual untuk mendukung proses pembelajaran. Penelitian ini bertujuan untuk mengembangkan Galeri Bencana Virtual Berbasis Metaverse sebagai sistem pendukung pendidikan kebencanaan dalam pembelajaran geografi. Metaverse merupakan teknologi yang mampu menciptakan dunia virtual 3D. Penelitian ini menggunakan model pengembangan 4D, yang meliputi tahapan Define, Design, Develop, dan Disseminate. Media diujicobakan kepada 33 siswa kelas XI di SMAN Pesanggaran untuk menghasilkan media pembelajaran yang layak dan efektif. Temuan penelitian menunjukkan bahwa Galeri Bencana Virtual Berbasis Metaverse sangat valid dan layak sebagai sistem pendukung untuk pendidikan kebencanaan dalam pembelajaran geografi. Hasil penelitian ini dapat dijadikan sebagai sumber dan referensi dalam pengembangan dan penggunaan media berbasis metaverse sebagai upaya pendidikan kebencanaan untuk mengurangi risiko bencana di masa yang akan datang.

Kata Kunci: *bencana; kesiapsiagaan; metaverse; galeri virtual bencana*

Abstract: *Disaster education played a crucial role in fostering disaster preparedness among students. However, the implementation of disaster education in Indonesia had limitations, particularly due to the lack of interactive and contextual media to support the learning process. This study aimed to develop a Metaverse-Based Virtual Disaster Gallery as a supporting system for disaster education in geography learning. The Metaverse is a technology capable of creating a 3D virtual world. This study employed the 4D development model, which included the stages of Define, Design, Develop, and Disseminate. The media was tested on 33 eleventh-grade students at SMAN Pesanggaran to produce feasible and effective learning media. The findings of the study indicated that the Metaverse-Based Virtual Disaster Gallery was highly valid and feasible as a supporting system for disaster education in geography learning. The results of this study can serve as a source and reference in the development and utilization of metaverse-based media as an effort in disaster education to reduce disaster risks in the future.*

Keywords: *disaster; preparedness; metaverse; virtual disaster gallery*

Article History:
Received: 31-08-2024
Revised : 05-09-2024
Accepted: 09-09-2024
Online : 16-09-2024

A. INTRODUCTION

Indonesia is one of the largest archipelagic countries in the world, located between two continents and two oceans, traversed by the equator, and situated at the convergence of three tectonic plates: the Eurasian Plate, the Indo-Australian Plate, and the Pacific Plate (Partuti et al., 2019). Additionally, Indonesia is also traversed by the global mountain belt (Ring of Fire) (Marliyani et al., 2020). These regional characteristics result in Indonesia's geological, geomorphological, climatological, and anthropogenic conditions offering advantages such as abundant natural resources and a large population with diverse ethnicities and cultures. However, on the other side, these conditions also make Indonesia prone to frequent natural disasters such as earthquakes, tsunamis, floods, volcanic eruptions, and landslides, which can cause significant damage and losses, including casualties and property damage (Thouret et al., 2022; Wilopo et al., 2023). Indonesia's vulnerability to disasters must be balanced with disaster preparedness efforts to reduce the impacts of disasters.

Disaster preparedness is a series of actions taken to prepare individuals, communities, and systems to face, respond to, and recover from various types of natural disasters (Hoffmann & Muttarak, 2017). Knowledge is the main factor for preparedness. The knowledge possessed can influence attitudes and awareness towards being ready to anticipate disasters (Bachri et al., 2024; Khusnani et al., 2023). Therefore, disaster education is crucial for building disaster preparedness, especially for students in disaster-prone areas. This is because disasters can occur at any time, and students must be prepared to face emergency situations. Students who have disaster knowledge, such as recognizing signs of an impending disaster, will be able to save themselves and even others, thus reducing disaster risk (Khorram-Manesh et al., 2016; Shah et al., 2020). One strategy to provide disaster knowledge is by integrating into school education through learning materials.

Disaster material is highly relevant and important given Indonesia's vulnerability to various types of natural disasters. One such material is disaster mitigation. Disaster mitigation material is included in the high school geography curriculum in Indonesia (Endah Sudarmilah et al., 2019; Wang et al., 2022). The aim of the disaster mitigation material in the geography curriculum is to provide students with a comprehensive understanding of the various strategies that can be used to reduce the risks and impacts of natural disasters (Setiawan et al., 2020). The disaster mitigation material is comprehensive and practical, covering in-depth

understanding of the types of disasters, their distribution, causes, and processes, as well as emphasizing mitigation measures (Johnson et al., 2016; Shoji et al., 2020). It incorporates a holistic approach that combines theory and practice, focusing on developing skills that can be applied in real-world contexts. Therefore, its implementation requires contextual learning to enhance the relevance and understanding of students.

However, existing disaster mitigation materials in schools have not been maximally delivered to students. Implementation is often disrupted by the lack of adequate learning media, which has a significant impact on teaching effectiveness and student understanding (Bachri et al., 2024; Yusuf et al., 2022). This is because the disaster learning process is not interesting and difficult to understand, resulting in reduced student engagement in the learning process. In addition, existing learning materials are often limited to textbooks that are not regularly updated or contextualized to the local situation (Kusumandari et al., 2019; Zainudin & Widjayanti, 2019). As a result, students do not get a clear view of how to deal with emergency situations or implement effective mitigation measures. The lack of learning media also makes it difficult for teachers to deliver materials in an interactive and engaging manner, which is useful for increasing students' awareness and preparedness for disasters (Paul et al., 2021). Thus, it is necessary to develop innovative learning media that can increase student engagement, and is contextualized.

Metaverse is the latest technology that can be utilized as innovative media in the learning process. Metaverse is a 3D virtual world that combines the real world into a virtual world with avatars as a representative display so that it looks real and users can interact with each other (Rasyida et al., 2023). The utilization of metaverse in education brings great innovation by creating a more interactive, immersive and collaborative learning environment (Karapakdee & Wannapiroon, 2023). Students can access virtual classrooms that allow them to interact with teachers and classmates without space and time constraints (Karapakdee & Wannapiroon, 2023; Mirza-Babaei et al., 2022). The integration of Virtual reality (VR) and Augmented Reality (AR) on the metaverse, allows for more immersive learning experiences, such as virtual exploration of disaster sites, laboratory simulations, or visualization of abstract concepts in three-dimensional form. By utilizing the metaverse, it can offer more engaging and relevant learning experiences, increase student engagement, and expand access to previously unreachable educational resources.

Various studies have shown that the metaverse has great potential to transform education by increasing student engagement and understanding through VR and AR technologies. VR simulations in scientific learning improved students' concept understanding better than traditional methods through a more immersive and interactive experience (Ma, 2021), (Di & Zheng, 2022). Virtual classrooms enable global collaboration that enriches the learning experience (Rafiq et al., 2022). The inclusivity of the metaverse, providing greater access for students with special needs (Rajabi et al., 2022), Project-based learning in the

metaverse improved critical and collaborative thinking skills (Jiawei & Mokmin, 2023). However, research focusing on the development of metaverse-based learning media in geography lessons, particularly on disaster mitigation material, remained limited.

This research was designed to address the issues and gaps in integrating metaverse technology into education, which had not yet been commonly used as a learning media for geography, particularly in disaster mitigation material. The metaverse could enhance students' learning experiences through immersive environments. It also allowed students to access a broader range of learning resources than those previously limited to real life. Therefore, this research aimed to develop a metaverse-based virtual disaster gallery as a support system for disaster education in geography learning. The results of this research could be utilized as a support tool and learning media in disaster education, initiating innovative learning in geography education.

B. METHOD

1. Development model

This study was a type of research and development (R&D). Development research consisted of a series of actions used to validate and develop a product (Hajar et al., 2023). This method helped in producing a product that met standards of effectiveness and quality (Sari & Setiawan, 2018). The use of models in R&D served as stages in the implementation of specific and accountable development (Haryati, 2012). This research referred to the 4D development model. This model was chosen because it had a comprehensive and structured approach, allowing for more effective, efficient, and user-oriented product development (Hajar et al., 2023; Wardani et al., 2019; Zulhelmi et al., 2023). The model was flexible enough to be adapted to various types of development projects, from curriculum development to learning media (Vivien Pitriani et al., 2023). The 4D model consisted of four stages: Define, Design, Develop, and Disseminate (Kersten et al., 2017; Wardani et al., 2019). The development stages were presented in Table 1.

Table 1. Stages of the 4D Development Model

Procedure	Activity	Output
Define	- Analyze student characteristics - Material analysis - Analyze concepts and learning objectives	Conditions related to problems and needs in the field
Design	- Designing the prototype - Developing materials - Designing the instrument	Prototype, materials, and instrument sheet
Develop	- Developing the product - Expert validation test - Product trial on students	Valid and feasible learning media to use
Disseminate	- Dissemination of product utilization	Extensive use of media

2. Subject

The media that had been developed was tested on 33 eleventh-grade students at SMAN Pesanggaran. The subjects were selected because disaster mitigation material in the geography curriculum is covered in the eleventh grade. The trial was conducted to obtain students' responses regarding the feasibility of the developed media. The types of data obtained included quantitative and qualitative data. Quantitative data was obtained from the percentage score of the feasibility test, while qualitative data was gathered from students' responses in the form of critiques and suggestions. However, before the trial was conducted on students, the developed media was first validated by media experts and subject matter experts to ensure the product was valid and ready for testing

3. Instrument and Data Collection

Data collection for the development of learning content utilized both primary and secondary data. Primary data was obtained through direct field observations in disaster-prone areas in Banyuwangi, while secondary data was gathered from articles, journals, and publications. The instruments for data collection included both closed and open questionnaires to determine the feasibility of the developed media product (Kusdiyanti et al., 2022). The questionnaire was designed in a checklist model containing researcher-generated questions. The questions were based on the feasibility of the content and the appearance of the developed product. A Likert scale was used for the questionnaire items due to its detailed nature and stronger reliability (Daryanes et al., 2023). The scale was structured in the form of questions followed by four values indicating levels, as shown in Table 2.

Table 2. Likert Scale Assessment

Score	Qualification
4	Very good / very appropriate / very feasible
3	Good / appropriate / feasible
2	Less good / less appropriate / not feasible
1	Very poor / very inappropriate / very not feasible

Source: (Sugiyono, 2010)

4. Data Analysis

The data from the product trial was then subjected to data analysis. The analysis technique used was quantitative descriptive analysis. This technique was conducted by converting quantitative data into percentage form. The percentage data was then transformed into descriptive sentences. To convert the data from the validators and research subjects into percentages, the following formula was used:

$$P = \frac{\sum R}{N} \quad (1)$$

Where P is the percentage, $\sum R$ is the total score of responses given by each respondent, and N is the total ideal score for one item.

The percentage results obtained from expert validation and student responses were then classified according to predetermined categories. The media feasibility classification is presented in Table 3.

Table 3. Media Feasibility Classification

Value	Qualification
76 – 100	Very Feasible / Very Valid / Very Good
51 – 75	Feasible / Valid / Good
26 – 50	Not Feasible / Not Valid / Less Good
< 25	Very Not Feasible / Very Not Valid / Very Poor

C. RESULT AND DISCUSSION

1. Define

The define stage was the initial stage to analyze the needs in the process of developing the metaverse-based virtual disaster gallery. Observations during the analysis of student characteristics conducted on eleventh-grade students at SMAN Pesanggaran revealed that students often felt bored during geography lessons, especially on disaster mitigation material. This was due to the lack of interactive and contextual learning models and media for delivering the material. Additionally, the learning process appeared to be teacher-centered. The level of student participation in the learning process was still low, with most students having an audio-visual learning style.

In the material analysis, disaster mitigation material was chosen as the content for the development of the metaverse-based virtual disaster gallery. This was because disaster knowledge was one of the most important subjects to be maximally imparted to students, considering that Indonesia is a disaster-prone country. However, there were still limitations in the implementation process. Disaster mitigation material had comprehensive and practical characteristics, requiring a holistic approach that combined theory and practice to provide a clear understanding of disasters. Due to the limitations of the media used, the disaster mitigation material had not been optimally delivered.

The media was designed in the concept of a virtual disaster gallery, utilizing metaverse technology to build an immersive environment. This media addressed the limitations in the implementation process of disaster material to provide a real field depiction. As a result, students' disaster knowledge could increase in line with their disaster preparedness capabilities. The developed learning media needed to establish its limitations, especially concerning the learning objectives to be achieved. The scope of the content in the metaverse-based virtual disaster gallery is presented in Table 4.

Table 4. Scope of metaverse-based virtual disaster gallery content

Variable	Material	Indicator
Natural disaster mitigation	Types and characteristics of natural disasters	Identify the meaning, types, and characteristics of disasters
	Distribution of disaster-prone areas	Identify disaster-prone areas in Indonesia
	Disaster management cycle	Identify disaster management measures

2. Design

The second design stage, was the initial planning phase of the product to be developed according to the needs analysis in the define stage. Activities conducted

during the design stage included the preparation of materials, product prototypes, and the instruments to be used. The materials used as content for the metaverse-based virtual disaster gallery were disaster mitigation materials, including the types and characteristics of disasters, the distribution of disaster-prone areas, and the disaster management. During the product prototype design process, sketches and storyboards were created to depict the structure of the virtual gallery, including the placement of objects, navigation, and user interactions. The design stage also included the preparation of instruments used to assess the feasibility of the media

3. Develop

The product design that had been prepared was then realized in the develop stage. The main focus of this stage was the product development process, validation testing, and trials with students. The metaverse-based virtual disaster gallery was developed in a virtual form using Spatial.io. Spatial.io is a web-based platform that allows users to create, share, and explore immersive and interactive virtual spaces (Rasyida et al., 2023). The choice of the Spatial.io platform was due to its ease of use for beginners and its free access anytime and anywhere (Rasyida et al., 2023).

The development process began with building an initial prototype of the virtual disaster gallery, which involved developing visual and interactive elements such as 360-degree panoramas, videos, and images. The results of the development of the metaverse-based virtual disaster gallery are presented in Figure 1.

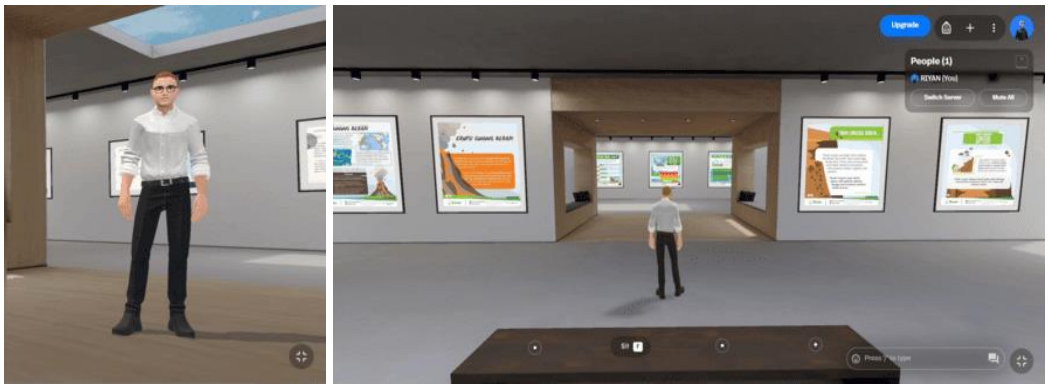

Figure 1. Avatar Selection

At the beginning of the metaverse-based virtual disaster gallery, students had to create an avatar that represented themselves to be used in the virtual world (Figure 1). Through this avatar, students could explore the virtual space, communicate with teachers or other students through voice and even body gestures. This supported collaborative learning, where students could interact within an immersive environment. The metaverse-based virtual disaster gallery also accommodated diverse learning styles by presenting various media such as images, videos, infographics, and maps that could be used in the learning process of disaster mitigation material.

Figure 2. Content Presentation

Disaster mitigation material was packaged in a virtual gallery concept that presented images accompanied by explanations of disaster material through text with attractive displays to prevent students from getting bored. Students could freely learn disaster mitigation material through the presentation of images, videos, and infographics in the virtual disaster gallery (Figure 2). The media presented materials related to the understanding of disasters, disaster distribution, and disaster management, along with discussions about the disaster conditions in the Banyuwangi area. This aimed to make learning more contextual, allowing students to better understand the disasters around them.

Figure 3. Virtual Field Trip Feature

The metaverse-based virtual disaster gallery was equipped with a Virtual Field Trip (VFT) feature (Figure 3). Students could explore disaster-prone areas in Banyuwangi. Through the VFT feature, students could observe the conditions of these areas using virtual reality with a 360-degree view (Figure 4) (Putra et al., 2022). The VFT feature encouraged students to be directly involved in the disaster mitigation learning process. VFT addressed the limitations of conducting field activities in disaster-prone areas, allowing students to make observations in a safe environment.

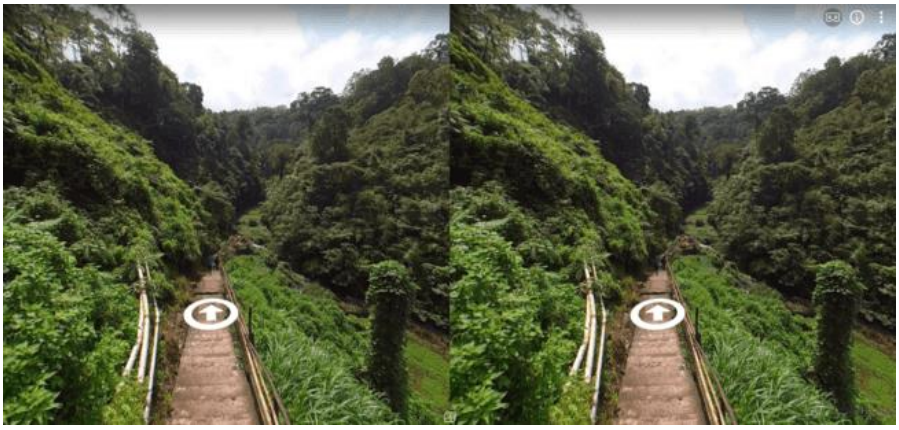

Figure 4. 360-Degree Panorama View

After development, the metaverse-based virtual disaster gallery underwent validation testing, which included material expert validation and media expert validation. The material validation was conducted to determine the suitability of the material in the virtual disaster gallery. The material validation consisted of three assessment aspects: instruction, content, and monitor display quality. The results of the material validation are presented in Table 5.

Table 5. Results of Material Validation Testing

Aspects	Percentage (%)	Qualificatiom
Instruction	87	Very Valid
Content	86	Very Valid
Monitor display quality	90	Very Valid

Media validation was conducted to determine the feasibility of the virtual disaster gallery. The media validation consisted of four assessment aspects: relevance, convenience, attractiveness, and usefulness. The results of the media validation are presented in Table 6.

Table 6. Results of Media Validation Testing

Aspects	Percentage (%)	Qualificatiom
Relevance	92	Very Valid
Convenience	87	Very Valid
Attractiveness	90	Very Valid
Usefullness	90	Very Valid

The developed product was then revised based on feedback from the validators. Subsequently, trials were conducted to determine the students' responses to the metaverse-based virtual disaster gallery. The trials involved 33 students from SMAN Pesanggaran (Figure 5). The trial process utilized the metaverse-based virtual disaster gallery in the disaster mitigation learning process. The learning process was conducted collaboratively, where students were divided into three large groups. Each group observed the material presented in the virtual disaster gallery and engaged in VFT activities to analyze disaster potentials and mitigation measures that could be implemented at the presented locations.

In the final activity, each group presented the results of their analysis on

disaster potentials and possible mitigation steps (Figure 6). The observation and exploration activities through VFT helped reinforce the concepts by organizing perceptions and understanding that had been acquired and integrating them into disaster mitigation issues.

During the trial process, students appeared very enthusiastic about participating in each learning activity. They responded positively to the development of the metaverse-based virtual disaster gallery. Students gained new learning experiences by utilizing metaverse technology, creating an immersive environment that was safe for studying disaster mitigation material. The results of the trials are presented in Table 7.

Table 7. Trial Results

Aspects	Percentage (%)	Qualificatiom
Media display	90	Very Valid
Content	88	Very Valid
Usage	92	Very Valid
Total	90	Very Valid

4. Disseminate

The disseminate stage was the final stage in the 4D development model. This stage focused on the widespread distribution of the developed product. At this stage, the virtual disaster gallery, which had undergone validation, feasibility testing by students, and revisions, was disseminated to geography teachers in schools in Banyuwangi. The aim of the disseminate stage was to ensure that the developed product could be widely utilized as a learning medium to support disaster education in geography subjects.

Findings from the development of the metaverse-based virtual disaster gallery indicated that this technology successfully created a more interactive and immersive learning experience for students. This virtual gallery allowed students to explore disaster environments with 360-degree visualization, videos, animations, and interactive simulations, making disaster mitigation material more engaging and easier to understand (Cheng, 2022; Petersen et al., 2020; Wen & Gheisari, 2020). Trials conducted with eleventh-grade students at SMAN Pesanggaran revealed that students felt more involved and motivated in the learning process, reducing the boredom they often experienced when studying disaster material through conventional methods.

Additionally, the use of avatars and the Virtual Field Trip (VFT) feature in the virtual gallery provided students with opportunities to communicate and collaborate with classmates and teachers in a safe and controlled virtual environment (Jiawei & Mokmin, 2023). This not only increased student participation but also helped them develop social and collaborative skills (Bos et al., 2022; Klippel et al., 2019). Validation by subject matter and media experts showed that the virtual gallery met high standards of quality and effectiveness, with aspects of relevance, convenience, attractiveness, and usefulness rated very well.

Overall, these findings indicated that the metaverse-based virtual disaster gallery could be an effective learning tool for disaster mitigation education, offering a richer learning experience and enhancing students' preparedness for natural disasters. The implementation of this gallery also demonstrated that metaverse technology has great potential for application in other educational fields, opening up opportunities for further innovation in teaching and learning methods.

D. CONCLUSION

Metaverse-Based Virtual Disaster Gallery is an educational medium that uses metaverse technology to present materials on disaster mitigation. The development of the metaverse-based virtual disaster gallery aims to serve as a disaster education support system to enhance disaster preparedness, particularly for students in disaster-prone areas. The features of the virtual disaster gallery support the geography learning process. With material presentation packaged in a virtual gallery concept and integrated with virtual field trip (VFT) features, students can observe and explore disaster-prone areas without having to visit the locations physically. The immersive environment created by the metaverse-based virtual disaster gallery provides students with a new and contextual learning experience, enabling them to understand the hazards around them. Research findings indicate that the metaverse-based virtual disaster gallery is highly valid for use as a disaster education support system in geography learning. These findings can serve as a reference for developing innovative media, especially those integrating VR technology in disaster education

ACKNOWLEDGEMENT

The authors are grateful to Universitas Negeri Malang for supporting this research through the Faculty Decentralization grant. The author is also grateful to the teachers and students of SMA Pesanggaran who have helped with this research activity. Thanks are also extended to all agencies and parties as well as the research team who have helped until this research can be completed.

DAFTAR RUJUKAN

Bachri, S., Rahman Hakiki, A. R., Wibowo, N. A., Sumarmi, Amini, R., Yosritzal, & Nursaribilah, E. (2024). Developing an education support system for disaster management through an ethnoscience-based digital disaster learning module. *International Journal of Disaster Risk Reduction*, *100*. https://doi.org/10.1016/j.ijdrr.2023.104214

Bos, D., Miller, S., & Bull, E. (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

Cheng, K. H. (2022). Teachers' perceptions of exploiting immersive virtual field trips for learning in primary education. *Journal of Research on Technology in Education*, *54*(3), 438–455. https://doi.org/10.1080/15391523.2021.1876576

Daryanes, F., Darmadi, D., Fikri, K., Sayuti, I., Rusandi, M. A., & Situmorang, D. D. B. (2023). The development of articulate storyline interactive learning media based on case methods to train student's problem-solving ability. *Heliyon*, *9*(4), e15082.

https://doi.org/10.1016/j.heliyon.2023.e15082

Di, X., & Zheng, X. (2022). A meta-analysis of the impact of virtual technologies on students' spatial ability. *Educational Technology Research and Development*, *70*(1), 73–98. https://doi.org/10.1007/s11423-022-10082-3

Endah Sudarmilah, Iis Hamsir Ayub Wahab, Devi Afriyantari Puspa Putri, Wiwien Dinar Pratisti, & Irma Yuliana. (2019). Game Education of Disaster Mitigation: A Systematic Literature Review. *International Journal of Advanced Trends in Computer Science and Engineering*, *8*(February 2020), 231–237.

Hajar, I., Milfayetty, S., & Damanik, U. A. (2023). The Development of a Locally-Based Virtual Gallery Grounded in Folklore Wisdom for Enhancing Creative Thinking Skills at Sekolah Alam. *AL-ISHLAH: Jurnal Pendidikan*, *15*(4), 5776–5787. https://doi.org/10.35445/alishlah.v15i4.4310

Haryati, S. (2012). Research and Development (R&D) sebagai salah satu model penelitian dalam bidang pendidikan. *Majalah Ilmiah Dinamika*, *37*(1), 15.

Hoffmann, R., & Muttarak, R. (2017). Learn from the Past, Prepare for the Future: Impacts of Education and Experience on Disaster Preparedness in the Philippines and Thailand. *World Development*, *96*, 32–51. https://doi.org/10.1016/j.worlddev.2017.02.016

Jiawei, W., & Mokmin, N. A. M. (2023). Virtual reality technology in art education with visual communication design in higher education: a systematic literature review. *Education and Information Technologies*, *28*(11), 15125–15143. https://doi.org/10.1007/s10639-023-11845-y

Johnson, V. A., Ronan, K. R., Johnston, D. M., & Peace, R. (2016). Improving the Impact and Implementation of Disaster Education: Programs for Children Through Theory-Based Evaluation. *Risk Analysis*, *36*(11), 2120–2135. https://doi.org/10.1111/risa.12545

Karapakdee, J., & Wannapiroon, P. (2023). Immersive Digital Storytelling Learning Experience with a Metaverse Gamification Game Platform to Enhance Game Developer Competency. *International Journal of Information and Education Technology*, *13*(6). https://doi.org/10.18178/ijiet.2023.13.6.1884

Kersten, T., Tschirschwitz, F., & Deggim, S. (2017). Development of a virtual museum including a 4D presentation of building history in virtual reality. In *TC II & CIPA 3D Virtual Reconstruction and Visualization of Complex Architectures, 1–3 March 2017, Nafplio, Greece* (pp. 361–367). https://repos.hcu-hamburg.de/handle/hcu/731

Khorram-Manesh, A., Lupesco, O., Friedl, T., Arnim, G., Kaptan, K., Djalali, A. R., Foletti, M., Ingrasia, P. L., Ashkenazi, M., Arculeo, C., Fischer, P., Hreckovski, B., Komadina, R., Voigt, S., Carlström, E., & James, J. (2016). Education in disaster management: What do we offer and what do we need? Proposing a new global program. *Disaster Medicine and Public Health Preparedness*, *10*(6), 854–873. https://doi.org/10.1017/dmp.2016.88

Khusnani, A., Husein, R., Jufriansah, A., Welly Jenni Thalo, O., Dewi Rahmawati, K., Fitri, M., & Aurora Adina, C. (2023). Identification of Understanding of Disaster Preparedness in the School Environment. *Indonesian Journal on Learning and Advanced Education*, *5*(3), 233–248. https://doi.org/10.23917/ijolae.v5i3.22974

Klippel, A., Zhao, J., Oprean, D., Wallgrun, J. O., & Chang, J. S. K. (2019). Research framework for immersive virtual field trips. *26th IEEE Conference on Virtual Reality and 3D User Interfaces, VR 2019 - Proceedings*, 1612–1617. https://doi.org/10.1109/VR.2019.8798153

Kusdiyanti, H., Sopingi, K., Febrianto, I., Wijaya, R., & Agustina, N. I. (2022). Development of Edu-Kit Media for Entrepreneurship Learning based on Gamification Model Toward Disruptive Education. *International Journal of Interactive Mobile Technologies*, *16*(4), 17–29. https://doi.org/10.3991/ijim.v16i04.28985

Kusumandari, R. B., Wibawa, B., & Muchtar, H. (2019). Game Learning to Optimize Learning in Disaster Area. *KnE Social Sciences*, *2019*, 530–543. https://doi.org/10.18502/kss.v3i18.4744

Ma, L. (2021). An Immersive Context Teaching Method for College English Based on Artificial Intelligence and Machine Learning in Virtual Reality Technology. *Mobile*

Information Systems, *2021*. https://doi.org/10.1155/2021/2637439

Marliyani, G. I., Helmi, H., Arrowsmith, J. R., & Clarke, A. (2020). Volcano morphology as an indicator of stress orientation in the Java Volcanic Arc, Indonesia. *Journal of Volcanology and Geothermal Research*, *400*, 106912.

Mirza-Babaei, P., Robinson, R., Mandryk, R., Pirker, J., Kang, C., & Fletcher, A. (2022). Games and the Metaverse. *CHI PLAY 2022 - Extended Abstracts of the 2022 Annual Symposium on Computer-Human Interaction in Play*. https://doi.org/10.1145/3505270.3558355

Partuti, T., & Umyati, A. (2019). Pengenalan Upaya Mitigasi Bencana Gempa Bumi Untuk Siswa. *Jurnal Pengabdian Dinamika, Edisi 6 Volume1_November 2019*, *1*.

Paul, J. D., Bee, E., & Budimir, M. (2021). Mobile phone technologies for disaster risk reduction. *Climate Risk Management*, *32*. https://doi.org/10.1016/j.crm.2021.100296

Petersen, G. B., Klingenberg, S., Mayer, R. E., & Makransky, G. (2020). The virtual field trip: Investigating how to optimize immersive virtual learning in climate change education. *British Journal of Educational Technology*, *51*(6), 2098–2114. https://doi.org/10.1111/bjet.12991

Putra, A. K., Purwanto, 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

Rafiq, A. A., Triyono, M. B., & Djatmiko, I. W. (2022). Enhancing student engagement in vocational education by using virtual reality. *Waikato Journal of Education*, *27*(3), 175–188. https://doi.org/10.15663/wje.v27i3.964

Rajabi, M. S., Taghaddos, H., & Zahrai, S. M. (2022). Improving Emergency Training for Earthquakes through Immersive Virtual Environments and Anxiety Tests: A Case Study. *Buildings*, *12*(11). https://doi.org/10.3390/buildings12111850

Rasyida, R., Nurdin, E. A., & Rasim, R. (2023). Pembelajaran Berbasis Metaverse – Virtual Reality Menggunakan Spatial.io dengan Model Discovery Learning untuk Meningkatkan Minat dan Pemahaman Siswa. *Jurnal Pendidikan Tambusai*, *7*(2), 15875–15882. https://jptam.org/index.php/jptam/article/view/8880

Sari, A., & Setiawan, A. (2018). The development of internet-based economic learning media using moodle approach. *International Journal of Active Learning*, *3*(2), 100–109.

Setiawan, T. H., Salim, G. H., Wimala, M., Van Roy, A. F., & Adianto, Y. L. D. (2020). Development of Knowledge and Attitude Measurement Tools in Disaster Preparedness Schools. *International Journal of Disaster Management*, *3*(1). https://doi.org/10.24815/ijdm.v3i1.17298

Shah, A. A., Gong, Z., Pal, I., Sun, R., Ullah, W., & Wani, G. F. (2020). Disaster risk management insight on school emergency preparedness – A case study of Khyber Pakhtunkhwa, Pakistan. *International Journal of Disaster Risk Reduction*, *51*(July), 101805. https://doi.org/10.1016/j.ijdrr.2020.101805

Shoji, M., Takafuji, Y., & Harada, T. (2020). Behavioral impact of disaster education: Evidence from a dance-based program in Indonesia. *International Journal of Disaster Risk Reduction*, *45*, 101489. https://doi.org/https://doi.org/10.1016/j.ijdrr.2020.101489

Sugiyono, D. (2010). Metode penelitian kuantitatif kualitatif dan R&D. In *Penerbit Alfabeta*.

Thouret, J. C., Wavelet, E., Taillandier, M., Tjahjono, B., Jenkins, S. F., Azzaoui, N., & Santoni, O. (2022). Defining population socio-economic characteristics, hazard knowledge and risk perception: The adaptive capacity to persistent volcanic threats from Semeru, Indonesia. *International Journal of Disaster Risk Reduction*, *77*. https://doi.org/10.1016/j.ijdrr.2022.103064

Vivien Pitriani, N. R., Desy Wahyuni, I. G. A., & Bali Sastrawan, I. K. (2023). Pengembangan Media Poster Berbasis Pictorial Riddle Model 4D Sebagai Bahan Ajar Mata Kuliah Pendidikan Agama Program Studi Pendidikan Agama Hindu. *Cetta: Jurnal Ilmu Pendidikan*, *6*(1), 135–150. https://doi.org/10.37329/cetta.v6i1.2027

Wang, X., Peng, L., Huang, K., & Deng, W. (2022). Identifying the influence of disaster education on the risk perception of rural residents in geohazard-prone areas: A

propensity score-matched study. *International Journal of Disaster Risk Reduction*, *71*, 102795. https://doi.org/https://doi.org/10.1016/j.ijdrr.2022.102795

Wardani, D. L., Degeng, I. N. S., & Cholid, A. (2019). Developing interactive multimedia model 4D for teaching natural science subject. *International Journal of Educational Research*, *7*(1), 63–72. www.ijern.com

Wen, J., & Gheisari, M. (2020). A review of virtual field trip applications in construction education. *Construction Research Congress 2020: Safety, Workforce, and Education - Selected Papers from the Construction Research Congress 2020*, 782–790. https://doi.org/10.1061/9780784482872.085

Wilopo, W., Putra, D. P. E., Fathani, T. F., Pramaditya, A., Tandirerung, R., & Erzagian, E. (2023). Comparison of two landslide hazard zonation methods in the volcanic terrain of Temanggung Regency, Central Java, Indonesia. *Journal of Degraded and Mining Lands Management*, *10*(3), 4537–4546. https://doi.org/10.15243/jdmlm.2023.103.4537

Yusuf, R., Razali, Sanusi, Maimun, Fajri, I., & Gani, S. A. (2022). Disaster education in disaster-prone schools: A systematic review. In *IOP Conference Series: Earth and Environmental Science* (Vol. 1041, Issue 1). https://doi.org/10.1088/1755-1315/1041/1/012034

Zainudin, Z., & Widjayanti, R. (2019). Development of Science Module Based on Disaster Mitigation Based on Disaster Mitigation Using Eruption Software. *Kasuari: Physics Education Journal (KPEJ)*, *2*(1). https://doi.org/10.37891/kpej.v2i1.97

Zulhelmi, Z., Fauza, N., Syaflita, D., Pratiwi, J., Wijaya, T. T., & Hermita, N. (2023). Development of Learning Media to Improve Students' Higher Order Thinking Skills in Circular Motion Material. *Jurnal Penelitian Pendidikan IPA*, *9*(4), 1734–1740. https://doi.org/10.29303/jppipa.v9i4.3536