ASM Sc. J., 18, 2023

https://doi.org/10.32802/asmscj.2023.1370

Virtual Reality as Experiential Learning to Promote STEM-DRR in Tertiary Education

M. Anggaryani[1*], T. Prastowo[1], N. Suprapto[1], J. Lassa[2], Madlazim[1], F. A. Alifteria[1], A.I. Agusty[3] and N.A. Lestari[1]

[1]*Physics Department, Universitas Negeri Surabaya, Indonesia*

[2]*Charles Darwin University*

[3]*Graduate Institute of Digital Learning and Education, National Taiwan University of Science and Technology, Taiwan*

Efforts and discourses of the need to integrate disaster education into a science curriculum for university students in Indonesia are well documented. However, lecturers need more room to introduce Disaster Risk Reduction (DRR) in a way that involves students as experiential learners. Integrating DRR into Science, Technology, Engineering, and Mathematics (STEM) subjects is a crucial point. The current study used virtual reality (VR) as a pedagogical tool for learning through experience to promote STEM-DRR at tertiary levels of education. This experimental study aimed to determine the effects of VR use on students' experiential learning based on the VR online training developed activities. The methods for data collection included observation and survey. Ten participants were in the final year of their study and were recruited based on their interest in using VR media for their thesis. The results showed that half of the participants understood the training content, and 40% were classified as knowledgeable before training. In addition, significant contributions to the learning process were observed in training, where half participants were satisfied with the new skills attained, and 80% of the participants argued that the training was beneficial to their final projects. Thus, in the present study integrating STEM-DRR into the VR training content to promote students' awareness of disaster risk is considered successful. In conclusion, the results suggest that technology-enhanced learning supports distance learning and is proven economical and efficient.

Keywords: virtual reality; experiential learning; STEM-DRR; tertiary education; disaster risk

I. INTRODUCTION

Disaster preparedness and community resilience towards natural hazards require effective disaster education programs for Indonesian students (Adiyoso & Kanegae, 2012; Amri *et. al.,* 2017; Djalante *et. al.,* 2017; Nurdin, 2019; Anggaryani, 2020). In this framework, a lively, echoed discourse to integrate disaster risk reduction (DRR) in formal education in Indonesia has long been present but with some gaps and limitations in policy and practice (e.g. Rofiah *et. al.,* 2021; Amri *et al.,* 2022). In tertiary levels of education, there has been no room for lecturers to introduce disaster risk reduction (DRR) in class with students' active involvement as experiential learners. Integrating DRR into some courses relevant to Science, Technology, Engineering, and Mathematics (STEM) is essential for promoting STEM-DRR on purpose.

At the global level, the United Nations International Strategy for Disaster Reduction (UNISDR) has promoted DRR efforts across countries around the globe by referring to Hyogo Framework for Action (HFA) 2005-2015 and Sendai Framework for Disaster Risk Reduction (SFDRR) 2015-2030 (Aitsi-Selmi *et al.,* 2015). While HFA is designed to detail the work priorities and practical means to achieve disaster resilience (Zhou *et al.,* 2014), SFDRR focuses on the crucial roles of stakeholders, science and technology in strengthening resilience to a disaster for community at risk (Aitsi-Selmi *et. al.,* 2015; Pearson & Pelling, 2015).

The HFA 2005-20015 explicitly stated that the education sector was one of the five priorities for action necessary for

*Corresponding author's e-mail: mitaanggaryani@unesa.ac.id

the global community to build resilience against disasters (Zhou *et. al.,* 2014; Aitsi-Selmi *et al.,* 2015). In some sense, there is an acceptance that research has driven people to a new paradigm of the next blueprint for DRR development, leading to the SFDRR 2015-2030. The SFDRR has also paid attention to the roles of education in response to the increasing complexity of disaster risks in the future. Disaster risk management (DRM) requires understanding all the dimensions and measures to manage vulnerability, capacity, and exposure in addition to hazard mitigation (Aitsi-Selmi *et. al.,* 2015; Kelman & Glantz, 2015; Pearson & Pelling, 2015).

During the HFA 2005-2015, each relevant priority to DRR education was implemented as best practice from pilot projects, mainly in primary and secondary schools in regions potentially vulnerable to disasters. Whereas, in the SFDRR 2015-2030, tertiary education has received more opportunities to play a role in DRR implementation. Universities have triadic roles, namely teaching, research, and community services. Indonesian universities are mandated to play these roles, also known as the 'Tridharma' of higher education that integrates education, research, and community service into unity (see Figure 1). In principle, Tridharma is vital in supporting the basic elements of all the SFDRR priorities (Mujiburrahman, 2018; Hemachandra *et al.,* 2021).

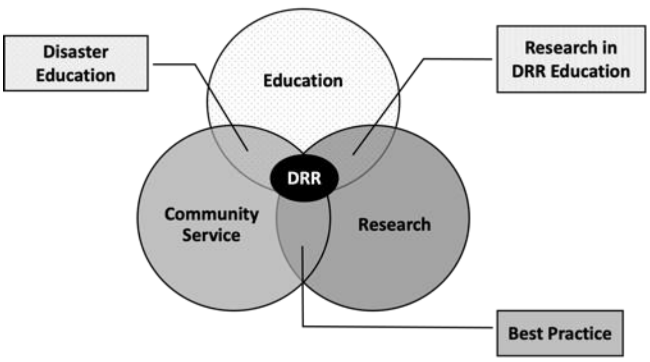

Figure 1. Tridharma in Indonesian universities and the DRR implementation at its centre

Figure 1 indicates that tertiary education can be considered a way of acquiring knowledge, skills, and competencies through a continual process of learning by doing that shapes students' resilience through cognition and behaviours that increase their adaptive capability and capacity. This process leads to educated individuals and hence empowered communities, found to be in an advanced position for preparedness and response to disasters than others without adequate knowledge. This suggests that public investment in favour of human capacity enhancement and vulnerability reduction to disasters through controlled formal education is important (Muttarak & Lutz, 2014; Musacchio *et al.,* 2016).

As part of a modern teaching-learning process in controlled formal education at a tertiary level, the practical use of STEM is challenging for lecturers. For example, a set of computer-based devices representing enhanced science and technology were used for various purposes in physics learning (Irwandi *et al.,* 2020). Another specific example was a new strategy of DRR teaching in the university, where STEM-DRR was applied to promote disaster resilience among the students (Agusty *et. al.,* 2021; Chan *et al.,* 2021).

Education sectors in Indonesia and countries worldwide have been severely affected, leading to a multi-dimensional crisis induced by the global COVID-19 pandemic. This hardship forces educators to use online teaching modes for daily learning environments in higher education (e.g. Bao, 2020; Febriz *et al.,* 2021) and adopt various digital platforms to prevent people from possibly being infected via close contact with the spread of the disease. The United Nations International Children's Emergency Fund (UNICEF) Indonesia reported that around 60 million students have to study at home because of the health disaster (UNICEF, 2020). Educational institutions at all levels have struggled to find options for the best solutions to dealing with such circumstances.

Online class on demand is the best alternative way to the teaching-learning process in higher education during the pandemic (Aguilera-Hermida, 2020; Bao, 2020; Mishra *et al.,* 2020). The internet and other advanced digital technology have all driven such a process into student-centred, innovative, and flexible learning experiences in online classroom settings (Lin *et. al.,* 2017; Bali & Liu, 2018; Albelbisi & Yusop, 2019). A recent study defines online learning as students' learning experiences using synchronous and asynchronous techniques. In these online environments, synchronous classrooms require the real-time presence of students involved in the online class. Conversely, asynchronous courses exist when students do not interact with lecturers in real time. Instant feedback and immediate responses are not possible to do in asynchronous learning. However, these two online learning modes are acceptable, particularly during the outbreak (Febriz *et al.,* 2021).

Our study has utilised and reported Virtual Reality (VR) online training by MilleaLab to promote STEM-DRR learning to ten students of pre-service teachers in the Physics Department, The State University of Surabaya, Indonesia, under selection. Numerous studies (Stewart *et. al.,* 2010; Hwang & Hu, 2013; Le *et. al.,* 2015; Martín-Gutiérrez *et. al.,* 2017; Allcoat & von Mühlenen, 2018) define VR as a computer-based digital technology, which provides students (as trainees in the present case) with interactive and engaging learning through direct experience widely called experiential learning. These students were all in the final year and were preparing for final projects by developing modern multimedia for physics learning on purpose. The VR training is designed for easy, meaningful visualisation of materials in Earth Physics and Disaster Mitigation courses. In short, this research is mainly inspired by the remarkably increasing use of VR technology in many disciplines (e.g. Fabris *et al.,* 2019) and the possible best scenario for disaster risk reduction (Strong *et al.,* 2020) in higher education.

The MilleaLab VR training is an all-in-one VR platform that supports students in creating VR-based educational content. The outcome of training activities is expected to be a prototype VR media made by the students. The study focuses on two key issues: how STEM-DRR learning is introduced in the VR training and how the training helps the students understand the importance of STEM-DRR in disaster education. Therefore, the current study aims to determine the effects of VR use on the students' experiential learning in disaster resilience and risk understanding. The VR technology is integrated into online training activities concerning STEM-DRR implementation at the tertiary level. The details of the developed training activities are discussed in the following methods. The effects of the VR used as part of training activities were observed during and evaluated after the training using questionnaires. This study is an initial project executed by the research team for promoting STEM-DRR as an integrated model that can be implemented in relevant courses and training at the university.

II. METHODS

The methods used for data collection in this study included observation and survey. Data were collected using instruments based on each session to address several aspects requiring investigation. The instruments used were: 1) observation sheets of students' activities to indicate all the planned activities have been done completely; 2) observation sheets of Physics concepts developed with VR to track students' interest related to Earth Physics; 3) questions of students' attendance regarding their participation in this training to evaluate their effort and motivation in mastering VR technology; 4) question of students' learning process regarding knowledge levels to evaluate their skills and ability in creating VR media; 5) question of training activities to evaluate the implementation of STEM-DRR in VR online training that has been conducted.

This study used purposive sampling, allowing researchers to select samples from a population that matched the specific criteria required. In research using a purposive sample, the number of samples or people involved has never mattered (Farrokhi & Mahmoudi-Hamidabad, 2012; Almalki, 2016). Hence, the ten students participating in the training were considered adequate for this study. The sampling technique may refer to the criteria used, which involves selecting individuals from experienced, knowledgeable students familiar with the subjects (Creswell & Clark, 2011; Palinkas *et. al.,* 2013; Etikan *et al.,* 2016). Here, these students serving as research participants should meet all the criteria to fulfil the data collection processes in this study.

Ten students interested in developing multimedia-supported learning as their final projects participated in the training. These students should know how to run online applications using multi-devices, such as laptops, desktops, mobile phones, and tablets. The participants were also expected to be able to download sources from the internet and install computer programs into electronic devices.

The VR training developed activities used in this study were designed by the research team collaborated with MilleaLab. The VR online training was conducted in both synchronous and asynchronous. The VR training activities are mainly developed in Physics educational settings where the students can interact within the artificial environment that represents phenomena related to Physics concepts, especially Earth

Physics. The VR training activities facilitate students with experience in using and creating the artificial environment, which may enrich their understanding. Regarding students' experiential learning, Asad *et al.* (2021) claimed that VR as computer-generated virtual interaction is beneficial to both students and lecturers in achieving some specific goals, including as a pedagogical tool for enhanced learning and a teaching-learning model. This study explicitly uses VR technology as part of STEM-DRR model integration that offers fun interaction between the user and the media. This kind of interaction is introduced to the students for the use of cheerful, encouraging active involvement of such an emerging, modern digital technology in tertiary education (Asad *et. al.,* 2021; Etambakonga, 2021) and even applicable to high-school students (Garduño *et al.,* 2021).

Each activity was completed in a separate meeting, running for about two hours daily with no time to maintain continual work. While the meetings used Zoom as a simple, common digital platform for synchronicity, the instructors (either lecturers or MilleaLab's trainers involved) managed communication between the participants (ten students) and the instructors using WhatsApp Group.

The participants were allowed to raise questions on the topics using this mode of communication, but the replies may have time delays between questions and responses. Thus, this communication type is considered asynchronous as the participants may not likely interact with the instructors in real time. All of the activities are presented in Figure 2.

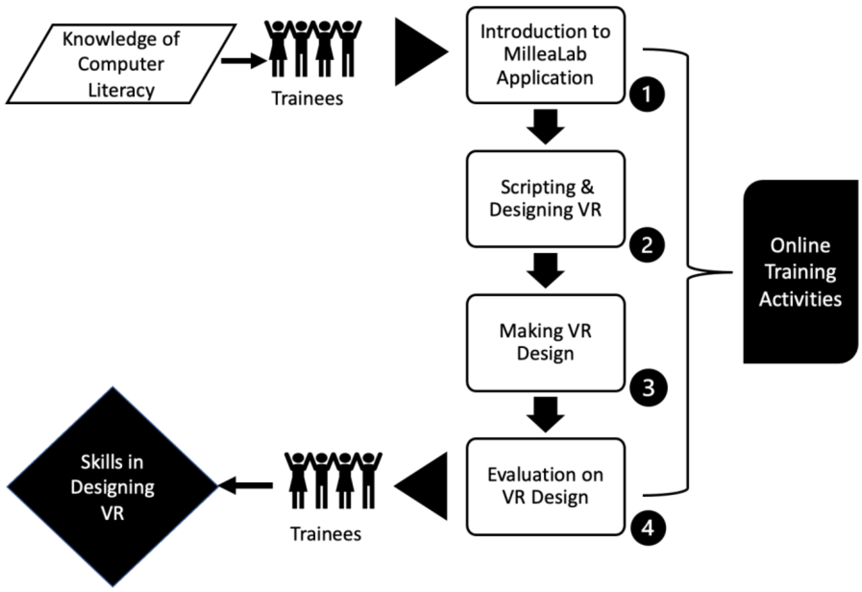

Figure 2. Flowchart of the four activities in the VR training

The followings are detailed descriptions of each activity shown in Figure 2.

Activity 1: Introduction to MilleaLab Application

In this opening stage, one of the instructors from a MilleaLab team gave a short talk, briefly explaining the MilleaLab to the participants. The introduction session then began with the MilleaLab initial formation, followed by its development and use of the MilleaLab to facilitate pre-service teachers' initial understanding of the MilleaLab application.

Activity 2: Scripting and Designing VR

Participants who had already made their lesson plans were given a chance to get involved in the training by putting the plans into a learning flow script. The script was used as a reference in creating an explanatory flow in the MilleaLab application. The content of the chosen material must be relevant to Physics concepts related to disaster risk caused by natural processes and phenomena, as the training is linked closely to earth physics and disaster mitigation as topic courses for STEM-DRR. The MilleaLab trainers and lecturers guided the participants in setting the plans into the flowing script. Later, each student behaving as a pre-service teacher had their learning script as educational content in VR-based learning media.

Activity 3: Making VR Design

Having trained in producing the flowing script, the participants were introduced to MilleaLab features. The MilleaLab trainer explained the knowledge necessary by order and demonstrated when entering various components in the features, such as places, the environment, and humans. In addition, there was also an interactive feature used to enter quizzes or questions associated with learning materials used as learning content. The components selected and included in the content were those that followed the script. The participants could easily use them by simply selecting or dropping the objects.

Activity 4: Evaluation on VR Design

In the final stage of training, the participants were expected to be able to create a VR learning tool based on the script made on their own. By bringing earth physics learning materials, each participant was expected to create content according to their personal creativity and perspectives on the materials. The obtained outcomes in the form of learning media were finally collected and assessed by the trainers and the lecturers responsible for managing the activities. The media from each participant was evaluated by providing comments on it. The students were required to revise the media according to the suggestions for fixing the problems, if any, after which the revised media was ready for use.

III. RESULTS AND DISCUSSIONS

The effects of VR online training as a model for STEM-DRR integration can be observed during the training by using observation sheets of students' activities. In the first activity, Introduction to MilleaLab Application, the students joined online VR training. These participants were excited to listen to the explanation about MilleaLab features available in the MilleaLab application by asking some questions in Table 1 below.

Table 1. Questions from participants in the VR training

No	Questions
1.	What about if I want to add a virtual object but it is unavailable?
2.	What about if I, too, focus on making media and forget to save it?
3.	How about the license of background music available in MilleaLab? Is it free for use?
4.	Is there any tip for beginners to place the object in the right position?
5.	Does MilleaLab support a look-like real world in the virtual simulation?

The questions indicate that the participants were already entangled with training materials. During the discussion, all the participants agreed to consider important issues when conducting online learning and developing learning media using VR software.

Here are some participants' responses to the VR training. Firstly, they agree that during the COVID-19 outbreak, digital learning through online classes is a good choice to support and make a computer-enhanced learning process more engaging, interactive, and meaningful. Previous studies reported a similar statement to this idea prior to the global pandemic era to the recent publications (Lin *et. al.,* 2017; Bali & Liu, 2018; Albelbisi & Yusop, 2019; Aguilera-Hermida, 2020; Bao, 2020; Mishra *et. al.,* 2020; Febriz *et al.,* 2021). Secondly, they also believe that VR equipment and a corresponding learning media program are challenging to run. Thirdly, they find it difficult to start with and need technical assistance from the trainers or the lecturers. To this end, some steps to do by the trainers or the lecturers are to install the MilleaLab application from a relevant website and Google Playstore into two devices, namely 1) MilleaLab Creator on their own PCs or laptops with a unique specification required for use; and 2) MilleaLab Viewer on their Android-based smartphones to review and run the program.

Further discussion between the trainer and participants led to technical issues in developing VR media. The discussion indicates the participants can follow the explanation very well. Some issues discussed by the participants include aspects of reality needed to create a look-like real world in the VR media. MilleaLab VR has some features to deal with by providing 3D asset objects: the environment and the base plain, structures; static objects; and animated objects. Other features are also available for inserting music backgrounds and video clips that support the creation of a particular situation in the virtual world. For example, we can choose a dynamic music vibe as the background of adventurous scenarios in the VR design. MilleaLab uses a portal, pop-up info, standpoint, and image to provide an interactive learning experience for the user. The user who uses VR-Gyro (VR 3D device) can move from the portal to pop-up info or image by moving their sights from one standpoint to another.

Regarding the video clips for supporting interactive learning experience, we can add clips from YouTube video, YouTube 360, Uploaded Video, and Uploaded Video 360. During the discussion, the participants realised, then, that MilleaLab still has limited objects related to physics materials. Regarding a data storage system available, the MilleaLab cloud-integrated saving system is accessible for the creator or students to develop media content on different devices.

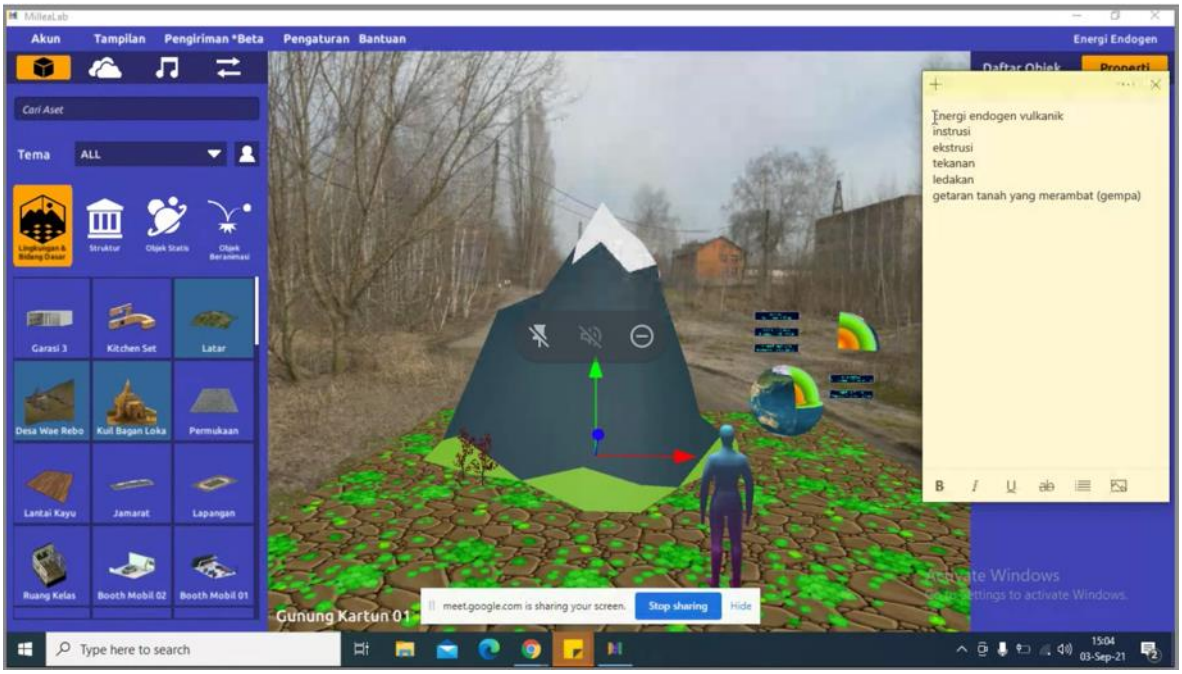

Figure 3. Screenshot of the MilleaLab VR training, showing initial product development made by a participant who created the VR environment by selecting a particular theme from the MilleaLab features on the left panel

VR technology embedded in the MilleaLab application requires various devices for multiple purposes, such as creating, storing, and assessing or playing. Thus, VR media could be very segmented because it could not be accessible to everyone since the technology remains expensive. The issues discussed by the participants also indicate that they already have basic knowledge regarding VR technology. Therefore, the discussion can run smoothly.

In the second activity, scripting and designing VR, the effects of VR used in training were observed using observation sheets of Physics concepts developed with VR to track students' interest in Earth Physics. In this activity, students have individually created a script and initial VR product (see Figure 3) in the online training to be discussed.

This activity improved students' creativity skills in creating VR learning media based on the controlled VR training. At this stage, if necessary, the participants were advised by the trainers to make the VR media (made by the students on their own) more interactive. The trainers also needed some time to fix objects up and interact with positions to guarantee that every single step was in the right way.

Table 2 presents the concepts of learning media developed by the participants in their scripts. At first, the participants were allowed to create VR media based on any concept related to physics or a particular disaster.

Table 2. Physics and VR concepts applied in the VR media

No	Physics Concept	VR Concept
1	Linear Motion	A student is given a task to walk around a city to travel from one building to another and calculate the distance and travel time. To make it more interactive, students can develop tasks to create the best road to go to a safe place in the city. The student may study evacuation plan when a disaster occurs in the city.
2	Tsunami and Earthquake	A student is tasked to visit and learn from a tsunami museum, especially the 2004 Aceh Tsunami Museum, to understand the phenomenon and its impact. The student may study the possible causes of earthquakes and tsunamis and work on the quiz.
3	Volcanic Eruption	A student is tasked to climb the Semeru volcano to observe the crater directly. The student may study the possible causes for and through which explosive volcanic eruption occurs and work on the quiz.
4	Static and Dynamic Fluids	Student is given a task to walk following the flow of water. The student may study the possible causes of floods and relevant physics concepts to the fluid flow of floods and work on the quiz.

In addition to learning materials related to earth physics, which directly considered a good basis for DRR education, for example, earthquake, tsunami, and volcanic eruption, the participants also tried to create other materials associated with physics in general, such as linear motion, Newton's law of motion, and fluid flow.

In the third activity, making VR Design, the training accommodated synchronous and asynchronous ways of learning regarding the complexity of making VR design. The synchronous session was performed for a progress report on the participants' VR design. The participants could ask the trainers how to create an appropriate environment that fits their scenario. Since the process of VR design took a long time to complete, this activity continued running in the asynchronous session by which WhatsApp Group was then used to facilitate further discussions. Using this social media, the participants were allowed to ask for help from the trainers whenever they faced difficulties and needed technical assistance.

In the last activity, the evaluation of the VR design was finished after the participants presented their designs and explained the related concepts and scenarios. In this final stage, the participants discussed all the difficulties and challenges in creating the learning media based on VR technology. Since the features in MilleaLab can use video clips from YouTube, there was also a discussion about the ethics of using materials made by others. During the discussion, the participants presented the reasoning behind each decision to select a particular image or video in their own design. The trainers commented on the decision and provided suggestions for a better creation of VR-based learning media.

After the VR training, the participants provided feedback by completing questionnaires on the Google form available based on their learning experience when joining the training and using the VR equipment. In general, the students got inspired by all the activities performed during the training and found it exciting and challenging. The topics were simple to understand and to engage. Technical problems, such as internet connections, were present during the training but were finally handled. Overall, the VR training received positive responses from the students.

Plotted in Figures 4, 5, and 6 are detailed results for feedback from the participants on the MilleaLab VR training, given as three distinct evaluations: level of attendance, contribution to learning process, and in-depth training activity.

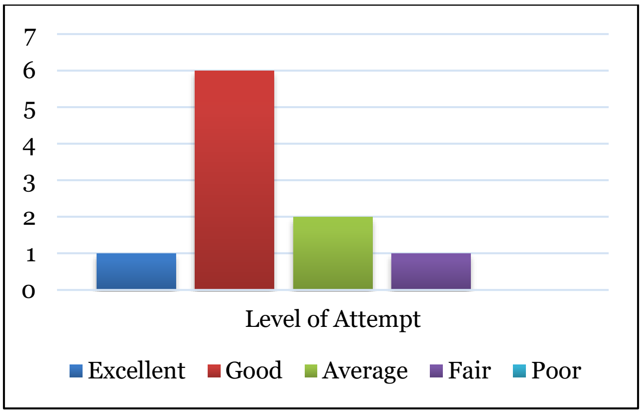

Figure 4. Feedback on question of students' attendance regarding their participation in this training to evaluate their effort and motivation in mastering VR technology

Figure 4 presents the participants' efforts to attend the VR training. Most of the participants are happy to join the training from the beginning to the end. All participants can fairly maintain consistency in attending the meetings by actively involving in all activities scheduled. This suggests that the training proved interesting as it encourages students to be active and involved in using emerging technology, similar to previous findings (Asad *et. al.,* 2021; Etambakonga, 2021). Further, they are engaged as it offers the same subject as their interest in disaster education and STEM-DRR to promote resilience among students in the university using the scenarios possible to do during limited access to face-to-face learning (Strong *et. al.,* 2020; Agusty *et. al.,* 2021; Chan *et al.,* 2021).

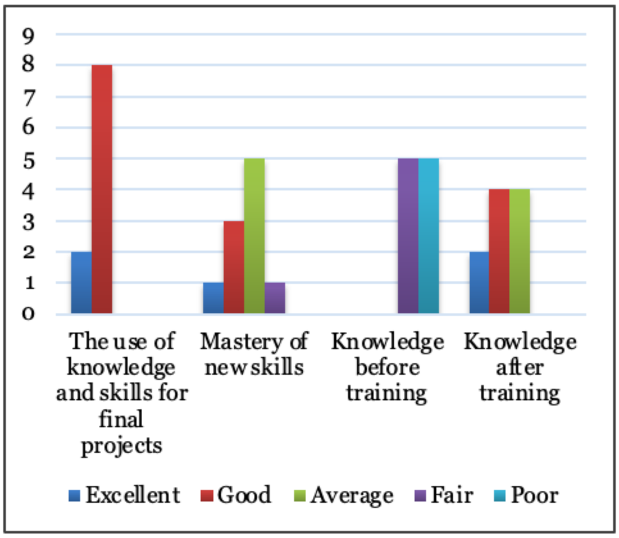

Figure 5. Feedback on question of students' learning process regarding knowledge levels to evaluate their skills and ability in creating VR media

Figure 5 shows the direct contribution of online training to the learning processes. Notice that half of the participants knew about VR technology used in the online training, while the other half admitted that they had poor knowledge about the technology. However, during the training, their capacity is improved while experiencing something new associated with the VR equipment, implying that experiential learning plays an important role in a computer-based learning environment (Le *et. al.,* 2015; Martín-Gutiérrez *et. al.,* 2017; Allcoat & von Mühlenen, 2018). After the training, 40% of the participants are observed to be in average knowledge, the other 40% are classified as good, and the rest 20% are in excellent knowledge. In mastery of newly trained skills during the online training, the participants show their satisfaction with varying levels, namely fair (10%), average (50%), good (30%), and excellent (10%). It is found that the training designed for pre-service teachers benefits the participants working on the final project or thesis (80%) with the same subject.

Figure 6 depicts the participant's responses to the activities performed during the training. They confirmed that training materials and corresponding instructions are easy to follow. Almost 70% of the students agree that the Q & A session helps them understand either the VR media content or problems imposed during the creation of learning media. Nearly 80% also agree that VR potentially applies to learn media development in physics. As reported by previous work (Creswell & Clark, 2011; Palinkas *et. al.,* 2013; Etikan *et al.,* 2016), a purposive sampling technique used in this study is significant as it guarantees the participants in the training are familiar with this computer-enhanced digital learning. In other words, the small number of participants involved is acceptable (Farrokhi & Mahmoudi-Hamidabad, 2012; Almalki, 2016). This may minimise the possible complicated technical problems that potentially affect running activities. However, some problems remain present, mainly related to internet access, but these are manageable.

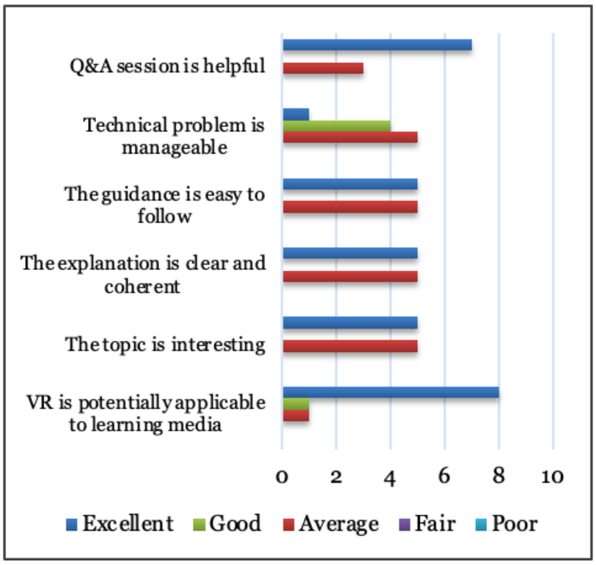

Figure 6. Feedback on question of training activities to evaluate the implementation of STEM-DRR in VR online training that has been conducted

In general, promoting STEM-DRR education using VR training as experiential learning in the university is considered successful. Each component of STEM learning is attributable to all training sessions, and the integration of DRR into STEM learning goes smoothly with the training. The training results indicate that increasing awareness of disaster management and risk among university students, and to some extent, among secondary school students is consistent (Anggaryani, 2020; Agusty *et. al.,* 2021; Chan & Nagatomo, 2021; Amri *et al.,* 2022). Furthermore, the training has completed the participants with specific skills necessary for accessing industrial revolution 4.0, both hard and soft skills from enhanced learning by the use of modern, digital technology, similar to educational efforts previously reported (Lin *et. al.,* 2017; Martín-Gutiérrez *et. al.,* 2017; Bali & Liu, 2018; Albelbisi & Yusop, 2019; Bao, 2020; Febriz *et al.,* 2021).

Thus, this study highlights the flexibility of STEM learning integrated into disaster-related materials within the university's disaster education context. It brings the mission into the implementation of STEM-DRR at tertiary education that is possible for practical and fundamental reasons of solving the challenges addressed in previous studies (Amri *et. al.,* 2017; Djalante *et. al.,* 2017; Hemachandra *et al.,* 2021). Down to secondary school environments, various problems in implementing disaster education into school curricula and disaster preparedness programs in Indonesia have long been present but with limited action (Adiyoso & Kanegae, 2012; Nurdin, 2019; Anggaryani, 2020; Rofiah *et. al.,* 2021; Amri *et al.,* 2022). The VR training discussed in this study provides a new way of improving hard skills associated with the best practice of disaster preparedness and increases empathy for the fatalities induced by disasters. These two are important to build community resilience concerning possible future hazards. To give an example of students' creation of learning media using VR technology, we provide in Figure 7 tsunami awareness and alert created in some features.

Figure 7. Example of student's creation of VR media content on tsunami awareness at the end of the training

This study also considers other online training issues based on the participants' feedback: schedules, activities, guidance, and supporting devices. These issues align with Bao's recommendation for online learning (2020). She claimed that the five high-impact teaching practices influence large-scale online education: relevancy, effective delivery, sufficient support, high-quality participation, and contingency plan.

The schedules and activities should be well organised for training effectiveness. The schedules could be adjusted to align with students' agenda in the running semester so that more students can join the activities. Moreover, sufficient support and technical assistance for trainees, including preparation and checking for proper equipment, are crucial for successful online training runs.

In short, the topic of STEM-DRR education integrated into the VR training targeting pre-service teachers is relevant to the need for mastering computer-based digital learning, such as skills in designing VR learning media. In addition, specific topics offered in training give a better environment for both educators and students to create VR media and content, consistent with previous results (Febriz *et al.,* 2021).

IV. CONCLUSIONS

This study has used the sophisticated equipment of MilleaLab VR as a pedagogical tool for research participants utilising experiential learning to promote STEM-DRR, integrating disaster resilience education into online STEM courses at tertiary education in Indonesia. The method has considered online training as distance learning that could be performed in general if the COVID-19 pandemic ends. It was found that VR provides insight into using emerging, modern digital technology for a teaching-learning process in higher education in a broader range of applications, including disaster preparedness among university students. The VR use is then found to widen the students' ideas and creativity into interactive, engaging and meaningful learning despite some challenges. The resulting feedback shows positive responses from the participants to the training content, as they are excited about all training activities.

During the COVID-19 outbreak, with many obstacles in traditional learning methods, VR training successfully facilitated trainers and trainees with an internet-based digital platform. In this study, STEM-DRR integrated into the VR training content to promote increased students' awareness of disaster risks is also considered successful. This awareness can be justified by determining qualitatively how good the Museum of Tsunamis and Volcanoes as part of the student's final project is. In short, the results suggest that technology-enhanced learning supports distance learning, which is proven economical and efficient.

V. ACKNOWLEDGEMENTS

The authors would like to thank The Faculty of Mathematics and Natural Sciences, Universitas Negeri Surabaya for funds available under a grant scheme of International Research Collaboration for ASIIN based on the Decree of Rector of UNESA Number 638/UN38/HK/PP/2021. The authors also thank a team of Shinta MilleaLab VR for technical assistance. The VR training is part of mutual collaborative work between the Physics Department, Universitas Negeri Surabaya and Shinta MilleaLab VR.

VI. AUTHORS' STATEMENT

The authors declare that there is no conflict of interest regarding this work.

VII. REFERENCES

Adiyoso, W & Kanegae, H 2012, 'The effect of different disaster education programs on tsunami preparedness among schoolchildren in Aceh, Indonesia', Disaster Mitigation of Culture Heritage and Historic Cities, vol. 6, pp. 165-172.

Aguilera-Hermida, AP 2020, 'College students' use and acceptance of emergency online learning due to COVID-19', International Journal of Educational Research Open, vol. 1, 100011. doi: 10.1016/j.ijedro.2020.100011.

Agusty, AI, Alifteria, FA & Anggaryani, M 2021, 'STEM in disaster learning media: A literature review', Journal of Physics: Conference Series, vol. 2110, no. 1: 012016. doi:

10.1088/1742-6596/2110/1/012016.

Aitsi-Selmi, A, Egawa, S, Sasaki, H, Wannous, C & Murray, V 2015, 'The Sendai Framework for Disaster Risk Reduction: Renewing the global commitment to people's resilience, health, and well-being', International Journal of Disaster Risk Science, vol. 6, pp. 164-176, doi: 10.1007/s13753-015-0050-9.

Albelbisi, N & Yusop, F 2019, 'Factors influencing learners' self–regulated learning skills in a massive open online course (MOOC) environment', Turkish Online Journal of Distance Education, vol. 20, pp. 1-16. doi: 10.17718/tojde.598191.

Allcoat, D & von Mühlenen, A 2018, 'Learning in virtual reality: Effects on performance, emotion and engagement', Research in Learning Technology, vol. 26, p. 2140. doi: 10.25304/rlt.v26.2140.

Almalki, S 2016, 'Integrating quantitative and qualitative data in mixed methods research-challenges and benefits', Journal of Education and Learning, vol. 5, no. 3, pp. 288-296. doi: 10.5539/jel.v5n3p288.

Amri, A, Bird, DK, Ronan, K, Haynes, K & Towers, B 2017, 'Disaster Risk Reduction education in Indonesia: challenges and recommendations for scaling up', Natural Hazards and Earth System Sciences Discussions, vol. 17, no. 4, pp. 595-612. doi: 10.5194/nhess-17-595-2017, 2017

Amri, A, Lassa, JA, Tebe, Y, Hanifa, NR, Kumar, J & Sagala, S 2022, 'Pathways to Disaster Risk Reduction education integration in schools: Insights from SPAB evaluation in Indonesia', International Journal of Disaster Risk Reduction, vol. 73. doi: 10.1016/j.ijdrr.2022.102860.

Anggaryani, M, 2020, 'School-Based DRR Programs in Disaster-Prone Areas: The Case of Yogyakarta', PhD Thesis, The Australian National University.

Asad, MM, Naz, A, Churi, P & Tahanzadeh, MM 2021, 'Virtual reality as pedagogical tool to enhance experiential learning: A systematic literature review', Education Research International, vol. 2021. doi: 10.1155/2021/7061623.

Bali, S & Liu, MC 2018, 'Students' perceptions toward online learning and face-to-face learning courses', Journal of Physics: Conference Series, vol. 1108, 012094. doi: 10.1088/1742-6596/1108/1/012094.

Bao, W 2020, 'COVID-19 and online teaching in higher education: A case study of Peking University', Human Behaving and Emerging Technologies, vol. 2, pp. 113-115, doi: 10.1002/hbe2.191.

Chan, MN & Nagatomo, D 2021, 'Study of STEM for sustainability in design education: Framework for student learning and outcomes with design for a disaster project', Sustainability, vol. 14, no. 1: 312. doi: 10.3390/su14010312.

Creswell, JW & Plano Clark, VL, 2011, Designing and conducting mixed methods research Second edition. Los Angeles and London: Sage Publications. Retrieved from https://www.proquest.com/books/designing-conducting-mixed-methods-research/docview/859280606/se-2?accountid=8330

Djalante, R, Garschagen, M, Thomalla, F & Shaw, R 2017, 'Chapter 1 Introduction: Disaster Risk Reduction in Indonesia: progress, challenges, and issues', in Djalante, R, Garschagen, M, Thomalla, F & Shaw, R (eds) Disaster Risk Reduction in Indonesia, Disaster Risk Reduction, Springer, Cham, pp. 1-17. doi: 10.1007/978-3-319-54466-3_1.

Etambakonga, CL 2021, The rise of virtual reality in online courses: Ethical issues and policy recommendations, in A. G. Hessami, P. Shaw (eds), Factoring Ethics in Technology, Policy Making, Regulation and AI, IntechOpen, London. doi: 10.5772/intechopen.97516.

Etikan, I, Musa, SA & Alkassim, RS 2016, 'Comparison of convenience sampling and purposive sampling', American Journal of Theoretical and Applied Statistics, vol .5, no. 1, pp.1-4. doi: 10.11648/j.ajtas.20160501.11

Fabris, CP, Rathner, JS, Fong, AY & Sevigny, CP 2019, 'Virtual reality in higher education', International Journal of Innovation in Science and Mathematics Education, vol. 27, no. 8, pp. 69-80. doi: 10.30722/IJISME.27.08.006.

Farrokhi, F & Mahmoudi-Hamidabad, A 2012, 'Rethinking convenience sampling: Defining quality criteria', Theory and Practice in Language Studies, vol. 2, no. 4. doi: 10.4304/tpls.2.4.784-792.

Febriz, S, Mendzheritskaya, J & Stehle, S 2021, 'Impact of synchronous and asynchronous settings of online teaching and learning in higher education on students' learning experience during COVID-19', Frontiers in Psychology, vol. 12, no. 733554. doi: 10.3389/fpsyg.2021.733554.

Garduño, HAS, Martínez, MIE & Castro, MP 2021, 'Impact of virtual reality on student motivation in a high school science course', Applied Sciences, vol. 11, no 20: 9516. doi: 10.3390/app11209516.

Hemachandra, K, Haigh, R & Amaratunga, D 2021, Chapter 4 - Role of higher education institutions toward effective multi-hazard early warnings in Asia, Editor(s): José Manuel Mendes, Gretchen Kalonji, Rohit Jigyasu, Alice Chang-Richards, Strengthening Disaster Risk Governance to Manage Disaster Risk, Elsevier, pp. 27-46, ISBN

9780128187500. doi: 10.1016/B978-0-12-818750-0.00004-0.

Hwang, W-Y & Hu, S-S 2013, 'Analysis of peer learning behaviors using multiple representations in virtual reality and their impacts on geometry problem solving', Computers and Education, vol. 62, pp. 308-319, doi: 10.1016/j.compedu.2012.10.005.

Irwandi, I, Sari, IM, Oktavia, R & Syukri, M 2020, 'MEMS and IoT application in ISLE-based STEM physics learning media for mechanics' topic with LabVIEW integration', Journal of Physics: Conference Series, vol. 1462, no. 1: 012066. doi: 10.1088/1742-6596/1462/1/012066.

Kelman, I & Glantz, MH 2015, 'Analyzing the Sendai Framework for Disaster Risk Reduction', International Journal of Disaster Risk Science, vol. 6, no. 2, pp. 105-106. doi: 10.1007/s13753-015-0056-3.

Le, QT, Pedro, A & Park, CS 2015, 'A social virtual reality based construction safety education system for experiential learning', Journal of Intelligent and Robotic Systems, vol. 79, pp. 487-506. doi: 10.1007/s10846-014-0112-z.

Lin, M-H, Chen, H-C & Liu, K-S 2017, 'A study of the effects of digital learning on learning motivation and learning outcome', EURASIA Journal of Mathematics Science and Technology Education, vol. 13, no. 7, pp. 3553-3564. doi: 10.12973/eurasia.2017.00744a.

Martín-Gutiérrez, J, Mora, CE, Añorbe-Díaz, B & González-Marrero, A 2017, 'Virtual technologies trends in education', EURASIA Journal of Mathematics Science and Technology Education, vol. 13, no. 2, pp. 469-486. doi: 10.12973/eurasia.2017.00626a

Mishra, L, Gupta, T & Shree, A 2020, 'Online teaching-learning in higher education during lockdown period of COVID-19 pandemic', International Journal of Educational Research Open, vol. 1, 100012. doi: 10.1016/j.ijedro.2020.100012.

Mujiburrahman 2018, 'The role of universities in Indonesia multi-hazard early warning system', in MATEC Web of Conferences, vol. 229, pp. 1-8, EDP Sciences. doi: 10.1051/matecconf/201822902018.

Musacchio, G, Falsaperla, S, Bernhardsdottir, AE, Ferreira, MA, Sousa, ML, Carvalho, A & Zonno, G 2016, 'Education: Can a bottom-up strategy help for earthquake disaster prevention?', Bulletin of Earthquake Engineering, vol. 14, pp. 2069-2086. doi: 10.1007/s10518-015-9779-1.

Muttarak, R & Lutz, W 2014, 'Is education a key to reducing vulnerability to natural disasters and hence unavoidable climate change?', Ecology and Society, vol. 19, no. 1: 42. doi: 10.5751/ES-06476-190142.

Nurdin, N 2019, 'Disaster Risk Reduction in education and the secondary high school science curriculum in Indonesia', PhD thesis, University College London.

Palinkas, LA, Horwitz, SM, Green, CA, Wisdom, JP, Duan, N & Hoagwood, K 2015, 'Purposeful sampling for qualitative data collection and analysis in mixed method implementation research', Administration and Policy in Mental Health and Mental Health Services Research, vol. 42, no. 5, pp. 533-544. doi: 10.1007/s10488-013-0528-y.

Pearson, L, & Pelling, M 2015, 'The UN Sendai Framework for Disaster Risk Reduction 2015–2030: Negotiation process and prospects for science and practice', Journal of Extreme Events, vol. 2, no. 1, 1571001. doi: 10.1142/S2345737615710013.

Rofiah, NH, Kawai, N & Hayati, EN 2021, 'Key elements of disaster mitigation education in inclusive school setting in the Indonesian context', Jàmbá: Journal of Disaster Risk Studies, vol. 13, no. 1. doi: 10.4102/jamba.v13i1.1159.

Stewart, B, Hutchins, HM, Ezell, S, De Martino, D & Bobba, A 2010, 'Mitigating challenges of using virtual reality in online courses: A case study', Innovations in Education and Teaching International, vol. 47, no. 1, pp. 103-113. doi: 10.1080/14703290903525937.

Strong, L, Carpenter, O & Ralph, D 2020, Scenario best practices: developing scenarios for disaster risk reduction, Cambridge Centre for Risk Studies at the University of Cambridge Judge Business School and Lighthill Risk Network.

UNICEF 2020, COVID-19 and children in Indonesia: an agenda for action to address socio-economic challenges, UNICEF, Jakarta, Indonesia.

Zhou, L, Perera, S, Jayawickrama, J & Adeniyi, O 2014, 'The implication of Hyogo framework for action for disaster resilience education', Procedia Economics and Finance, vol. 18, pp. 576-583. doi: 10.1016/S2212-5671(14)00978-2.