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Using Augmented Reality for Disaster Mitigation Education in a Natural Disaster Response School

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ABSTRACT

Indonesia has a high potential for disasters, especially in coastal areas, so disaster awareness and preparedness need to be instilled early on. One effective way is through Augmented Reality (AR)-based education. This study analyzes the use of AR media as a source of science learning integrated with natural disaster mitigation. The method used is descriptive with qualitative and quantitative approaches. Participants consisted of 58 fifth grade students in South Sumatra. Data were collected through observation, questionnaires, teacher interviews, and analysis of teaching materials. The results of the study indicate that the topics of earth relief, plate movement, and environmental factors can be integrated into disaster mitigation. Students showed interest in AR, teachers supported the use of AR in learning. In conclusion, AR has a positive impact on student understanding, engagement, and disaster preparedness, and has the potential to be an interactive learning medium. Theoretically, this study contributes to science learning by integrating natural disaster mitigation using AR, especially for abstract concepts. Practically, these findings support the development of AR-based learning media to improve natural disaster preparedness. The application of AR integrated with natural disaster mitigation is still rarely explored in previous studies, especially in science learning.

Keyword: Augmented reality, Learning media, Natural disaster mitigation, Science learning.

INTRODUCTION

Indonesia is one of the regions with geographical conditions that have a high risk or level of natural disasters, especially in coastal areas that are directly facing the high seas such as earthquakes, tsunamis, and landslides. The activity of 3 tectonic plates also causes an increasing potential for disasters where Indonesia is located in the subduction zone of the Indo, Australian, and Eurasian plates (Indriyanti, 2020; Murtianto, 2016). The risk of natural disasters makes Indonesia one of the regions that needs to pay attention to the impact caused. The government has done various ways to reduce the impact caused by one of them through natural disaster mitigation education (Havwina et al., 2017). Therefore, disaster mitigation education is an

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urgent need to increase public awareness and preparedness from an early age, especially students.

Formal education such as schools is a major milestone and a very important role in improving natural disaster literacy so as to foster natural disaster preparedness attitudes (Ayub et al., 2020). In this context, schools function not only as a place of learning, but also as a center for education and community response to disasters. The concept of disaster response school encourages schools to play an active role in shaping community resilience through training, simulation, and integration of disaster materials in the curriculum (Chock-Goldman, 2021; Sizelove, 2022). In line with this, the Merdeka Curriculum in Indonesia provides a flexible space for schools to implement project-based learning that is contextual with the surrounding environment, including disaster issues. This approach can support the strengthening of the Pancasila Student Profile, such as mutual cooperation and critical reasoning in dealing with disaster risks.

Based on the results of direct observations conducted by researchers at one of the elementary schools in South Sumatra Province which is in an area prone to natural disasters, it was found that the learning process that took place still did not attract the attention of students. Observations were made on learning activities in the classroom, student interaction with materials, and the use of teaching media. The results showed that teachers still used lecture methods and textbooks without the help of interactive learning media, so that students appeared passive, less involved, and did not show enthusiasm in understanding the concept of disaster. In addition, the material presented has not been contextually related to the environmental conditions around the school, so it does not provide an in-depth learning experience related to natural disasters that have the potential to occur in the area. Research (Patel et al., 2023) revealed that students' awareness and understanding of disaster mitigation is still low, so innovative technology-based solutions are needed that can present material contextually and be able to increase the effectiveness of mitigation education.

In the current technological era, learning media continues to develop, one of which is Augmented Reality (AR) emerging as a learning medium that is superior to conventional media because it is able to present content in a visual-spatial (3D), interactive real time, and provides real-world simulations. The advantage of AR is that it can simplify abstract concepts to be more real in concrete and contextual learning that text-based or 2D media do not have (Eka Ardhianto, 2012; Rais et al., 2024). In line with this, (Haryani, 2020) emphasized that AR can provide an immersive visual experience and make it easier for students to understand complex concepts. According to (Brilliant, 2020) shows that AR can improve student learning outcomes in a more engaging and efficient way. Based on this in the context of natural disaster mitigation education, AR has great potential to simulate disaster situations such as earthquakes and tsunamis, so that students can understand the risks and the steps needed to save themselves, their families and the communities around them (Fitri et al., 2023, 2024). Through this AR media, it is hoped that students can become preparedness agents in schools and the surrounding environment.

However, the use of AR in learning, especially in integrated learning on natural disaster mitigation, is still very few and limited in literature reviews. Research study by (Harahap et al., 2024; Kholifah et al., 2023; Purwinarko, 2021; Rugaiyah et al., 2024) emphasized that the use of AR in elementary education generally still focuses on general science content, not on disaster education specifically and applicatively. This is due to the lack of knowledge about the surrounding environment, learning media and others. So that making AR media in disaster

mitigation education is still very rarely implemented. Furthermore, the AR media developed in this study has a characteristic in the form of integration between science concept content (such as earth structure and environmental change) that is in accordance with the environmental characteristics of students who are prone to natural disasters.

Therefore, this study aims to analyze the use of AR media as an integrated science teaching resource for natural disaster mitigation to support disaster response schools. In particular, this study examines how AR media can improve understanding of science concepts related to disasters, build student preparedness through contextual learning experiences, and foster awareness of disaster risk in the surrounding environment. The ultimate goal of this study is to support the realization of disaster response schools with innovative learning approaches that are adaptive to the needs of students in disaster-prone areas. This research contribution not only provides an interesting learning experience, but also offers an AR-based media design model that is applicable, and can be replicated in other disaster-prone areas in Indonesia. It is hoped that this research can be the first step to support the development of disaster response schools in Indonesia.

METHOD

Research Design

This study uses a mixed-method approach with a convergent parallel design model, which is a quantitative and qualitative approach carried out simultaneously and equally, then the results are compared to obtain a comprehensive understanding of the use of AR media in integrated science learning for disaster mitigation. This research does not focus on media development, but analyzes the use of AR media as a teaching resource in order to support disaster response schools. This research was carried out in July-December 2024 at SDN South Sumatra.

Stages of AR Media Development

The AR learning media used in this study was developed independently by the research team with reference to the 4D model (Define, Design, Develoment, and Dessimination). The platform used in development is Unity 3D, which allows for the integration of 3D objects and camera-based marker recognition. 3D visual models related to catastrophic phenomena (earthquakes, tsunamis, floods, etc.) are adapted to science topics in elementary schools. AR applications are implemented in the form of Android applications that can be run through mobile phones or tablets. This media was developed over 11 months, and validated by three experts, namely one learning media expert, one disaster mitigation material expert, and one elementary school science teacher. Validation is based on 3 aspects, namely content, language, and graphic aspects. The trial was conducted outside the research subject.

Stages of AR Media Implementation

The use of AR media is carried out in four stages of learning activities, namely: (1) Introduction: students are introduced to the basic concepts of disaster and how to use AR applications. At this stage, observations are made on how students respond to the introduction to disaster materials and AR technology. Observation sheets are used to record students' initial participation, interest in media, and readiness to use AR applications; (2) Science Concept Exploration: students learn about science concepts related to natural disasters, such as the

structure of the earth, plate movement, and environmental changes. At this stage, the analysis of the teaching materials was carried out to assess how the science material delivered by the teacher integrated the concept of disaster mitigation. Document analysis sheets are used to assess the extent to which teaching materials can be integrated in the understanding of scientific concepts such as the structure of the earth, plate movements, and their impact on disasters; (3) Simulation Using AR: students use AR media to conduct interactive visual simulations that depict disaster situations and mitigation measures. At this stage, observation is again used to record students' responses to the simulations provided by the AR media, including engagement, interaction, and the ability to relate the simulation to real situations; and (4) Reflection and Evaluation: students discuss learning outcomes and fill out questionnaires to gauge their level of understanding and preparedness. In this final stage, a disaster preparedness questionnaire is used to measure the impact of AR-based learning on students' understanding of disaster types, early warning signs, evacuation strategies, and safety measures. The results of this questionnaire reflect the extent to which the previous stages have succeeded in providing comprehensive disaster preparedness for students. In addition, interviews with teachers were conducted to obtain teachers' opinions regarding the application at this simulation stage in improving student understanding and involvement.

Participants

This study involved 58 grade V students in South Sumatra as research subjects. The sampling technique used is purposive sampling, by selecting students based on their involvement in science learning that is integrated with disaster mitigation. All students were subjected to observation techniques carried out by researchers directly during the learning process, focusing on student involvement, their interaction with AR media, and response to disaster materials. In addition, the 58 students were also respondents in filling out a disaster preparedness questionnaire to measure their level of understanding of disaster types, causes, and mitigation measures after using AR media. In addition, 3 science teachers who taught in the class were also involved as informants in a semi-structured interview technique to gain an in-depth perspective on the use of AR media in learning and the challenges faced during its implementation in the classroom.

Data Collection Instruments and Techniques

The data collection instruments used include: (1) Observations are used to assess student engagement and interaction during the learning process. Observations were conducted in a non-participatory manner using open-ended observation sheets and field notes; (2) A disaster preparedness questionnaire designed to measure students' perceptions, motivation, and understanding of disaster preparedness after using AR media, this questionnaire was compiled based on disaster preparedness indicators from LIPI-UNESCO (2006), which are used to assess students' preparedness levels before and after using AR media; (3) The teacher interview guide was conducted in a semi-structured manner to explore teachers' perceptions of the effectiveness, advantages, and challenges of using AR in learning; and (4) Analysis of Teaching Materials was carried out on science learning materials using document analysis sheets prepared based on natural disaster mitigation integration indicators. This analysis aims to examine the extent to which teaching materials can be integrated into natural disaster mitigation in learning activities.

Data Analysis Techniques

The data analysis techniques used in this study consist of qualitative and quantitative descriptive analysis to interpret the results obtained. Qualitative data, which includes data from observations, interviews, and document analysis, are analyzed using thematic analysis through several stages: (1) data familiarization by re-reading observation and interview transcripts in depth; (2) initial coding by creating open codes from meaningful raw data; (3) theme search by grouping codes into thematic categories or patterns; (4) theme review to evaluate the alignment of themes with the data; (5) naming and defining themes by providing conceptual meanings; and (6) reporting results in a context-rich narrative form. To ensure the validity of the qualitative data, the source triangulation technique is applied by comparing data from observations, interviews, and teaching documents. All data recording and analysis processes are conducted systematically and documented for traceability.

Quantitative data, data from the natural disaster preparedness questionnaire were analyzed using descriptive statistics to determine the level of students' preparedness for their understanding after using AR media in integrated science learning on natural disaster mitigation. The parameters of the disaster preparedness questionnaire consist of 5 parameters, namely: (1) knowledge and attitudes; (2) policies and guidelines; (3) emergency response plans; (4) disaster warning systems; (5) resource mobilization. Natural disaster preparedness parameters can be seen in the Appendix. The questionnaire data is analyzed by a calculation that refers to the number of scores divided by the maximum score and multiplied by 100. Assessment criteria were determined based on five categories comprising strongly agree ($81 \leq N \leq 100$), agree ($61 \leq N \leq 80$), neutral ($41 \leq N \leq 60$), disagree ($21 \leq N \leq 40$), and strongly disagree ($0 \leq N \leq 20$) (Maiyena, et al, 2020).

RESULTS AND DISCUSSION

Results

The use of Augmented Reality (AR) media integrated with natural disaster mitigation is carried out through four stages of activities, namely introduction, exploration of science concepts, simulation using AR, as well as reflection and evaluation. In the first stage, students are introduced to AR media, including an overview of AR, steps to use it, the devices used, and the implementation of AR in natural disaster mitigation learning. In addition, students were also introduced to geographical conditions in Indonesia that are prone to natural disasters, including their impact and how to overcome them through education. At this stage, it is adapted to the conceptual framework at this stage, as shown in Figure 1. The conceptual framework in this study focuses on the relationship between the concept of science, natural disasters, and mitigation efforts through Augmented Reality (AR)-based learning media. Indonesia is vulnerable to natural disasters caused by natural factors, such as earthquakes, volcanic eruptions, tsunamis, hurricanes, floods, and landslides, as well as human factors that include environmental changes due to the development of settlements, industries, and infrastructure. The impact of these disasters includes both physical and social aspects, which drives the need for mitigation efforts through structural and non-structural approaches. In the context of education, both formal and informal, understanding of disaster mitigation can be strengthened by teaching scientific concepts such as the structure of the earth, the movement of tectonic plates, natural changes due to environmental and human factors, and the impact of the environment on social, economic, and community life. AR-based learning media is an

innovative solution to present more interactive and in-depth learning, allowing students to visually understand how disasters occur and how preparedness strategies can be implemented. The implementation of AR technology in disaster mitigation education is expected to form disaster response schools that are better prepared to face future disaster threats. Based on the results of observations carried out at this stage, it shows that students have an initial interest in the use of AR with high enthusiasm when introduced to its features. Teachers explain the geographical context of disaster-prone Indonesia and relate it to students' local experiences, which directly strengthens emotional engagement in learning.

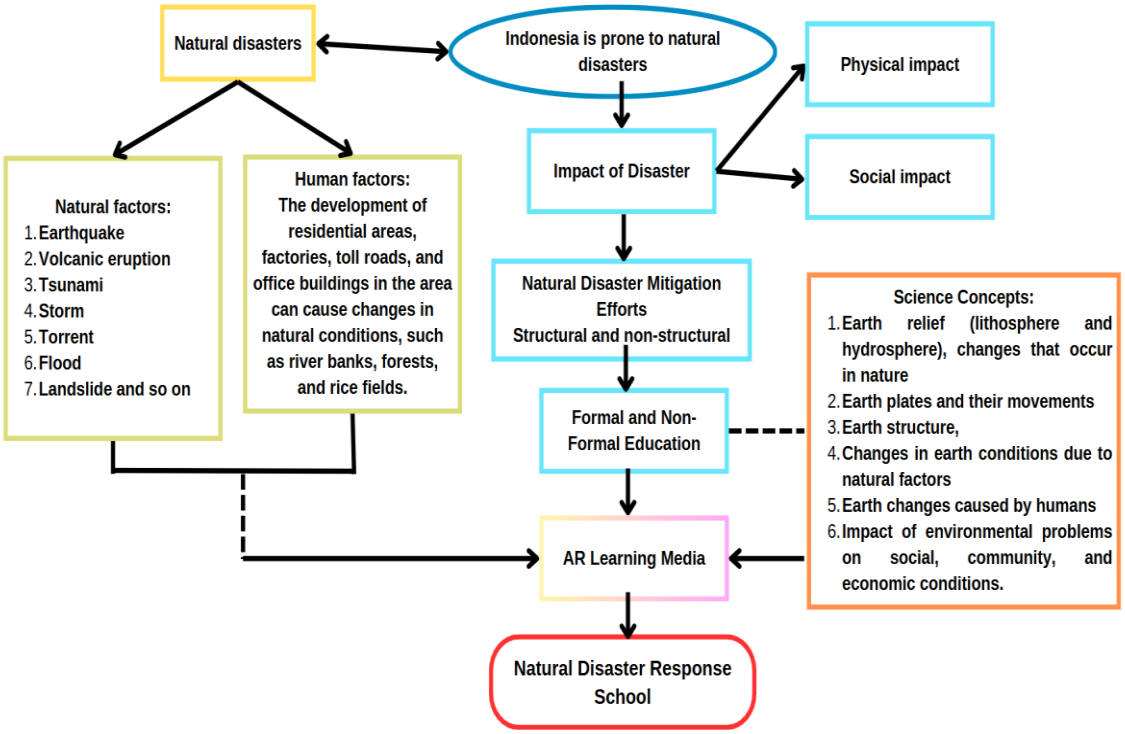


Figure 1. Conceptual Framework

In the second stage, the exploration of the concept of integrated science for natural disaster mitigation. At this stage, it focuses on the integration of science concepts and natural disaster mitigation. The teacher first makes a mapping by analyzing the teaching materials using content analysis as shown in Table 1. After the teacher analyzes the content of the teaching materials that integrate the concepts of science and natural disaster mitigation, students are involved in discussions to examine the relationship between the concepts of earth change, both caused by natural and human factors, and various types of disasters that can occur. Based on the results of this discussion, students showed that they were able to relate scientific concepts such as the structure of the earth, the movement of tectonic plates, and the impact of human activities on the environment with the type of disaster that occurred. In addition, students were also able to explain how earthquakes occur due to plate collisions and the importance of earthquake-resistant buildings as a mitigation effort.

Table 1. Analysis of Science Concepts in the Context of Natural Disaster Mitigation

Material Analysis - Science Concepts	Material Analysis-Disaster Mitigation Concepts
Relief of the earth (lithosphere and hydrosphere), changes that occur in nature;	1. The earth's surface is divided into lithosphere (land), hydrosphere (water), and atmosphere (air). 2. Changes that occur in nature can be due to changes in natural factors, including earthquakes, volcanic eruptions, tsunamis, rainstorms, tornadoes, and so on. For example, a tsunami can cause the environment to become damaged. 3. Changes in human factors. Examples of the construction of residential areas, factories, toll roads, and office buildings in the area can cause natural conditions, such as riverbanks, forests, and rice paddy areas to change.
The earth's plates and their movements; Earth Structure	1. The earth's surface consists of several plates that are constantly moving. 2. The earth's crust (the outermost layer of the earth's surface) is solid, while the outer mantle and core of the earth are liquid. 3. The movement of the earth's plates occurs due to convection currents in the outer core and mantle of the earth. 4. The movement of the earth's plates causes several disasters, namely earthquakes, tsunamis, landslides and others.
Changes in the condition of the earth due to natural factors.	Changes in the condition of the earth are caused by natural factors such as earthquakes, tsunamis, volcanic eruptions, floods, droughts, tornadoes, and landslides
Changes in the earth caused by humans	Changes in the earth due to human factors such as dumping samaph, cutting down forests indiscriminately, damaging the environment and others
The impact of environmental problems on social, community, and economic conditions.	Impacts caused by environmental damage due to natural and non-natural disasters on social, community, and economic conditions

The science concepts taught include the relief of the earth (lithosphere, hydrosphere, and atmosphere) as well as the movement of tectonic plates that affect the occurrence of earthquakes and tsunamis. In addition, changes in the condition of the earth due to natural factors, changes in the earth caused by humans, the impact of environmental problems on social, social, and economic conditions. In addition to the science concept, the content aspect covers different types of natural disasters and mitigation measures, such as self-rescue measures before, during, and after, tsunami early detection and evacuation, as well as flood, landslide, and forest fire prevention strategies. In the context of technology-based learning, AR

media is used to strengthen students' understanding through interactive simulations, allowing them to experience evacuation simulations and practice self-rescue measures in real life.

The third stage is that students start using AR devices to learn about types of natural disasters such as earthquakes, tsunamis, floods, forest fires, and so on. With interactive visualizations of AR, students can learn the causes, impacts, and mitigation measures needed for each type of disaster. In addition, simulations were also carried out where students were invited to practice disaster mitigation measures that had been learned through interactive simulations using AR. For example, students will learn how to react to the sound of disaster warning sirens and take rescue measures for themselves and those around them. The following is the documentation in the third stage in Figure 2.

Figure 2. Students Using AR

The results of observations show that AR media provides a more concrete and interesting learning experience for students. Students seemed enthusiastic and actively involved when observing the simulation of tectonic plate movements and their impact on earthquakes. They can see how the Earth's structure is made up of layers, how plates collide or shift, and how these phenomena cause earthquakes and tsunamis. In addition, students can also simulate disaster scenarios such as landslides due to heavy rains on slopes that have experienced vegetation damage, as well as understand the relationship between human activities and increased disaster risk.

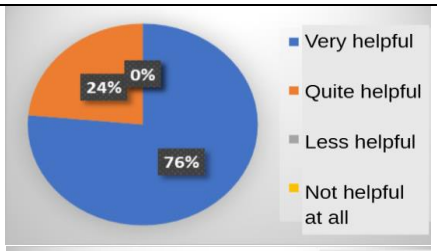
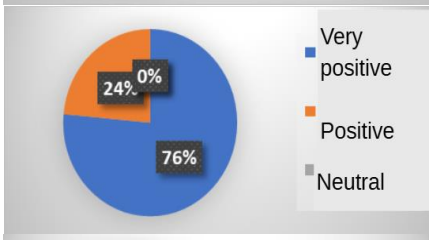
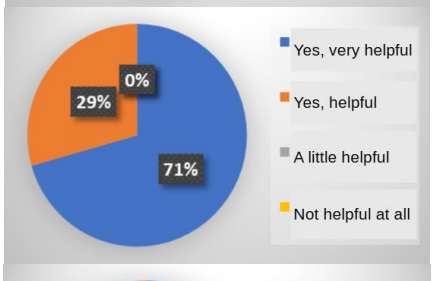
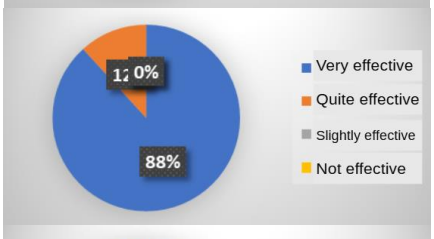
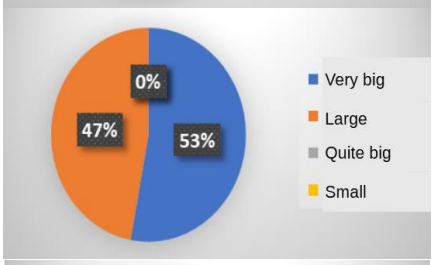
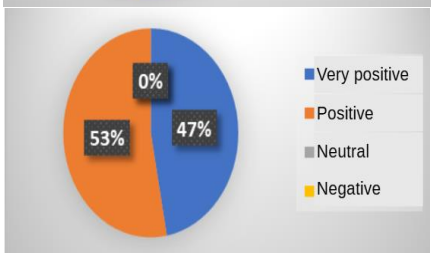
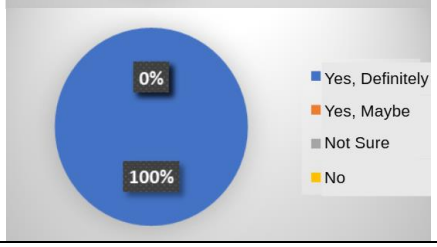
The last stage is reflection and evaluation, where at the reflection stage students discuss with the teacher what they have learned through AR media. Furthermore, at the evaluation stage, students were given the opportunity to provide feedback regarding their experience using AR. To see the perception of students after using integrated AR media for natural disaster mitigation, a questionnaire was used that referred to the natural disaster preparedness indicator from (LIPI-UNESCO/ISDR, 2006). The results of the questionnaire analysis can be seen in the Table 2. Table 2 shows that most students experience an increase in comprehension. As many as 69% of students understood the types of disasters after learning with AR, 65% of students were able to explain how to deal with disasters, and 97% of students understood the importance of action when they heard disaster warning sirens. However, the understanding of emergency bag preparation still needs more attention, with only 68% of students stating that they understand the importance of this preparation.

Table 2. Analysis of student questionnaires on AR media

Question Items	Presentation	Category
I understand the types of natural disasters after learning with AR.	69%	Strongly Agree
I can explain to a friend how to deal with natural disasters	65%	Strongly Agree
AR helped me understand why it's important to be prepared for disasters.	76%	Strongly Agree
I feel more concerned about the safety of myself and my family after learning with AR.	68%	Strongly Agree
I know what to do in the event of an earthquake after using AR	54%	Strongly Agree
I can make a plan to save myself in case of a natural disaster at school.	89%	Strongly Agree
AR helped me understand the importance of having an emergency plan at home.	78%	Strongly Agree
I understand what to do when I hear a disaster warning siren.	97%	Strongly Agree
AR helps me recognize the early warning signs of natural disasters.	65%	Strongly Agree
I know who to contact if there are signs of a disaster.	62%	Strongly Agree
I was more aware of disaster warning information after learning with AR.	36%	Strongly Agree and disagree
I know what things need to be prepared in case of a natural disaster.	62%	Disagree
AR helped me understand the importance of having an emergency bag at home.	68%	Strongly Agree
I can help my family gather important items when disaster strikes.	54%	Strongly Agree
I understand that it is important to work with others when disasters occur.	70%	Strongly Agree
I know the rules to follow in school when a disaster occurs.	62%	Strongly Agree
AR helped me understand why there are safety rules in schools.	54%	Strongly Agree
I can explain to others the importance of following the rules during disasters.	81%	Strongly Agree
I feel safer because I know there are rules that protect us during disasters.	65%	Strongly Agree

Teachers' responses regarding the integration of AR media as part of science teaching materials are one of the main focuses where the results of the interview guide to teachers regarding AR media can be seen in Table 3.

Table 3. Results of Interview Guide to Teachers on AR Media

Question	Data Results
What is the impact of using AR media in learning	
How is the assistance provided to students and teachers in implementing AR media integrated for natural disaster mitigation	
Can the application of AR media help in science learning	
Is AR media effective in delivering natural disaster mitigation materials	
How to increase student involvement in science learning after the use of AR media integrated with natural disaster mitigation is applied	
How to prepare for disasters in schools after the use of AR media integrated with natural disaster mitigation	
Are you planning to develop natural disaster mitigation teaching materials on other materials	

Based on teachers' responses after the use of AR media in learning, it can be seen from the positive response to the impact of the use of AR media in science learning, especially for the topic of natural disaster mitigation.

Discussion

The results of the study show that the implementation of AR media in learning natural disaster mitigation at the exploration stage is very important to build students' curiosity and interest before they start using media. As also stated by (Bower et al., 2014) that an early understanding of technology can increase the effectiveness of its use in learning. This is in line with the opinion (Buliali, 2022), which states that AR allows the creation of an interactive learning environment, where students can practice and learn independently through technology-based simulations.

The integration of science concepts in learning through AR media makes it easier for students to understand abstract concepts to be more concrete. As explained by (Alfi et al., 2024), AR media is able to improve students' visualization abilities of abstract concepts, thereby supporting more contextual learning. The concept of earth relief was chosen because this concept is directly related to the earth's surface where there is nature consisting of the lithosphere (darata), hydrosphere (water), and atmosphere (air). Earth reliefs, such as mountains, valleys, and plains, affect the impact of natural disasters such as floods, landslides, and earthquakes (Rahman, 2015). For example, mountainous areas tend to have a higher risk of landslides due to slope slopes and soil types that are prone to erosion. In disaster mitigation learning, an understanding of the earth's relief can help students identify areas prone to disasters and develop mitigation strategies.

The movement of the earth's plates is one of the main causes of earthquakes and tsunamis. This concept can be integrated into disaster mitigation learning to help students understand the causes of disasters such as tectonic earthquakes and their impacts. (Sunardi, 2018) noted that variations in seismic activity are often related to the fault of the Earth's plates. With this understanding, students can learn the importance of earthquake-prone zones and how to prepare for those risks. The structure of the earth, such as the crust, mantle, and core of the earth, is a basic concept in understanding how natural disasters occur. Crustal layers that are prone to cracking due to tectonic plate pressure are often the cause of earthquakes. (Sunardi, 2018) also highlights that certain geological structures can affect the distribution of energy during earthquakes. This concept is important for building students' scientific literacy and preparing them to understand science-based natural disaster mitigation.

Environmental damage, such as deforestation, soil erosion, and ecosystem degradation, can exacerbate the impact of natural disasters. For example, mangroves lost due to human activities can increase the risk of abrasion and tsunami in coastal areas (Suratman, 2021). Thus, disaster mitigation learning can include education on the importance of maintaining ecosystems as a disaster mitigation effort. Climate change, which causes an increase in the intensity of disasters such as floods, droughts, and storms, needs to be made part of disaster mitigation learning. According to (Thomas et al., 2019) shows that vulnerability to disasters due to climate change often varies based on social factors such as poverty, access to education, and gender gaps. The integration of these topics can help students understand the importance of a cross-disciplinary approach to disaster mitigation. A similar study by (Jiang, 2022) shows that students who use AR in the learning process on geology topics show an increase in understanding earthquake processes. Another research by (Safitri, 2023) by developing AR

media in environmental education shows that AR is not only interesting but also increases contextual understanding and awareness of mitigation actions directly against the environment.

The disaster preparedness aspect is also a concern in this study. Based on the results of the disaster preparedness questionnaire, it is known that most students show that AR media has succeeded in improving students' understanding of the types of natural disasters, as shown by 69% of students stating that they understand the types of disasters after using AR media. In addition, 65% of students recognize the early warning signs of natural disasters. This question item refers to the natural disaster preparedness indicator, which explains the types, sources, causes and magnitude/scale of disasters. Based on this, interactive and realistic visualization through AR allows students to understand various disaster phenomena, types of disasters, their causes and others as a more concrete one. However, the understanding of the causes and magnitude of disasters has not been fully explored in the questionnaire, so this aspect needs to be strengthened in the development of the material. According to (Amri et al., 2017) it is suggested that disaster mitigation education needs to integrate important elements such as a deep understanding of the causes of disasters and the factors that exacerbate their impacts, in order to improve students' preparedness for disaster risks.

Referring to the second natural disaster preparedness indicator, namely the availability of plans for natural disaster evacuation places, maps, and evacuation routes, it is known that 89% of students stated that they were able to make a self-rescue plan in the event of a disaster at school, which reflects their awareness of the importance of having clear maps and evacuation routes. AR media also provides 78% of students with an understanding of the importance of having an emergency plan at home. However, to increase effectiveness, AR materials can be further developed by including interactive simulations of the use of maps and specific evacuation routes. This is in line with research from (Ma et al., 2021), which shows that students' involvement in community-based disaster simulations can significantly improve their preparedness.

The results of the questionnaire showed that 54% of students felt able to help their families collect essential items during a disaster, and another 54% understood safety rules at school. This refers to the natural disaster preparedness indicator where students are trained/trained to simulate natural disasters so that they have real and direct experience when natural disasters occur so that they are expected to minimize the impact caused. However, based on this low percentage, it shows that disaster simulations carried out through AR are still not fully optimal. There needs to be more in-depth simulation exercises that involve students in various disaster scenarios to improve their skills.

The use of AR media as part of disaster mitigation learning shows that this material is relevant to be integrated into science lessons. This can support the natural disaster preparedness indicator, namely the availability of a plan to integrate disaster preparedness materials into the relevant curriculum. Based on the results of the student questionnaire analysis, 81% of students felt able to explain to the people around them the importance of following safety rules. However, integration into formal curriculum or local content still requires clearer policies. In addition to being integrated into learning in the classroom, AR media also has the potential to be used in disaster-based extracurricular activities, such as disaster response clubs (Fitri et al., 2023b).

AR media has been shown to increase students' awareness of the importance of safety policies, with 65% of students feeling safer knowing there are rules in place to protect them in

times of disaster. This is in accordance with the natural disaster preparedness indicator, namely there are education policies and guidelines for natural disaster preparedness. However, on the other hand, only 36% of students stated that they were more aware of disaster warning information. This shows that there needs to be a more structured guide to support learning based on disaster preparedness policies, both in the form of modules, teacher guidelines, and other supporting activities.

The teacher's response to learning using AR media is considered to help convey material in a more interesting and contextual way, where students more easily understand abstract concepts that were previously difficult to explain through conventional methods. In addition, AR media also provides an interactive learning experience, so that students become more active in the learning process (Talan et al., 2022). In the use of AR, it does not take a long time and is difficult to use because it has been designed to make it easier to use so that it can be used for all people, especially elementary school students who are new to technology. Teachers feel that the technical use of AR devices and applications is very helpful in overcoming the initial obstacles, especially in schools that are new to this technology. According to (Brilliant, 2020), which shows that AR media provides a more inclusive learning experience, allowing students with different levels of technological ability to participate.

AR media is considered very effective in delivering natural disaster mitigation materials. The teacher assessed that AR not only attracted students' attention, but also provided real simulations that helped students understand the impact of disasters and the importance of mitigation. This is in line with the increase in student involvement in learning, which according to teachers becomes more active and enthusiastic when using AR media. The teacher also stated that there was an increase in students' ability to explain disaster mitigation measures to their friends. So that the use of AR media is considered successful in increasing disaster preparedness in schools and there is a change in the attitude of students who become more vigilant and concerned about personal safety and the school environment. The teacher stated that after using AR, students better understand the importance of having an evacuation plan, recognizing early warning signs, and working together in dealing with emergency situations.

In addition, this use also provides an opportunity for teachers to understand the potential of AR media in integrating disaster mitigation materials with science learning effectively. Most of the teachers expressed interest in developing natural disaster mitigation teaching materials using AR media for other relevant topics. They see AR media as an innovation that can be adapted to various learning themes, both in science and other fields. With further development, AR media has the potential to become an important part of technology-based learning strategies in the future. This is in line with the opinion (Tuwoso, 2021), which highlights the potential of AR to be applied in various learning themes as part of technology-based learning innovations in the digital era.

CONCLUSION

Based on the results of research that has been conducted on the use of AR media in integrated learning of natural disaster mitigation, it can be concluded that there are several topics that can be integrated into the context of natural disasters such as earth relief, movement of earth plates, earth structure, problems that are expected due to environmental and human factors. In addition, the results of the questionnaire also show that students are interested in using AR in the learning process and can also add science concepts so as to improve natural disaster preparedness. Based on the results of the interviews, the teachers

strongly support the use of AR media in learning, especially for the topic of natural disaster mitigation. AR media has a positive impact on student understanding, involvement in learning, and disaster preparedness in schools. Therefore, it is recommended to teachers and schools to further develop and utilize AR media as learning innovations based on local issues, especially in disaster-prone areas in other materials. This research has theoretical implications in contributing to science learning by integrating natural disaster mitigation using AR, especially for abstract concepts. Practically, these findings support the development of AR-based learning media to improve natural disaster preparedness. The application of integrated AR for natural disaster mitigation has rarely been explored in previous research, especially in science learning.

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APPENDIX

Natural Disaster Preparedness Parameter

Parameters	Variable	Indicator
Knowledge and Attitudes	Knowledge: 1. Natural events and disasters (type, source, magnitude, location) 2. Consequential/derivative disasters 3. Physical vulnerability (location, condition of critical facilities, building standards).	1. Explain the history of disasters and their impacts 2. Explain the types, sources, causes and magnitude/scale of disasters 3. Mention the types of disasters that occur 4. Knowing the signs of disaster
	Attitude: Attitude towards disaster risk	School community motivation for preparedness in anticipation of natural disasters

Parameters	Variable	Indicator
Policies and Guidelines	Policy	1. Existence of education policies and guidelines for disaster preparedness 2. Availability of facts/data on the implementation of disaster preparedness education policies
	Regulation	1. Adaeducation regulations related to disaster preparedness 2. The availability of facts/data on the implementation of education regulations related to disaster preparedness
Emergency Response Plan	Plans to Respond to Emergencies	1. Availability of school plans for emergencies 2. The availability of permanent procedures (protap) for disasters
	Evacuation Plan	Availability of place plans, maps and evacuation routes
	First Aid, Rescue, Safety and Security	1. Availability of a first aid plan 2. Availability of school rescue, safety and security plans
	Fulfillment of Basic Needs	3. Availability of back-up of important school documents 4. Availability of data on the allocation of basic school needs
	Equipment and Equipment	Availability of documents, essential school equipment and secure storage
	Essential Facilities (Hospital, Fire Department, Police, PAM, PLN, Telkom)	1. Availability of addresses and telephone numbers of essential facilities 2. Access to essential facilities
	Rehearsals and simulations/rehearsals	3. Access to disaster preparedness education 4. Frequency of rehearsals and simulations/rehearsals (public and school)
Disaster Warning System	Traditional that is hereditary Local agreement	Access to traditional and/or local disaster warning information sources
	TWS/Tsunami Detection System (Technology - signs, signals, standards)	Access to TWS information sources

Parameters	Variable	Indicator
	Installation (engineering, equipment, signs and signals)	The existence of equipment that can capture disaster warning information
	Dissemination of alerts and mechanisms	Availability of disaster warning information distribution procedures
	Exercises and simulations	1. Number of teachers and students who have been trained/trained 2. Frequency of training and simulation
Resource Mobilization	Institutional Structuring	Availability of teams in charge of emergencies
	Command system	Availability of procedures for disaster emergencies
	Communication and Coordination between relevant Stakeholders	The involvement of schools in disaster preparedness networks
	Sumber Daya Manusia	Teachers and students who are trained/trained for disaster emergency response preparedness and management
	Technical Guidance and Provision of Materials	Availability of disaster preparedness materials and materials
	Funding	There is a mobilization of funds for preparedness
	Monitoring and Evaluation (Monev)	Availability of plans to integrate disaster preparedness materials into the curriculum of relevant subjects, local or extracurricular content

Source: (LIPI-UNESCO/ISDR, 2006)