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Development of Earthquake Mitigation Educational Media Using a STEM-Based Approach for Senior High School Students

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Abstract

Knowledge of earthquake disaster mitigation is essential for everyone, leading the government to include this subject in the education curriculum. STEM-based (Science, Technology, Engineering, and Mathematics) earthquake education media is considered effective in enhancing learning by encouraging students to be active, creative, and innovative in completing STEM-based experimental projects, thereby improving their understanding of the subject matter. This study aims to determine the effect of developing educational teaching media in the form of demonstration tools, accompanied by an e-module, for STEM-based earthquake mitigation learning on students' learning outcomes at SMAN 2 Blitar. The research method used in this study was Research and Development (R&D) with the ADDIE development model, which consists of Analysis, Design, Development, Implementation, and Evaluation. Data collection included needs analysis results, module validation, responses, and students' learning outcomes. The T-test results indicate a significant difference, showing an improvement in students' learning outcomes in the class that received instruction using STEM-based educational media.

Keywords: earthquake, educational media, mitigation, STEM

1. INTRODUCTION

Indonesia is one of the countries with many regions at high risk of natural disasters, including floods, extreme weather, earthquakes, and tsunamis. According to the World Risk Index 2019, Indonesia ranked 37th out of 180 countries most vulnerable to disasters. As of May 18, 2020, a total of 1,296 disaster events had been recorded, causing

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damage to various infrastructures, including 331 educational facilities, 396 places of worship, 32 healthcare facilities, 58 offices, and 181 bridges (*Website DJKN*, n.d.). Indonesia is also highly prone to earthquakes as it lies along the convergence zone of three major tectonic plates: the Indo-Australian Plate, the Eurasian Plate, and the Pacific Plate. Learning from the experiences of earthquakes and tsunamis in Aceh, Pangandaran, and other regions that have caused hundreds of thousands of casualties and significant property losses, mitigation efforts at both the government and community levels are highly necessary to reduce the risks caused by earthquakes and tsunamis (BMKG, 2018). This makes disaster knowledge important as a fundamental science for disaster mitigation. The United Nations Educational, Scientific and Cultural Organization (UNESCO), through education, science, and culture, has developed additional learning materials on disaster preparedness for junior high school (SMP) and senior high school (SMA) students. This is done to enhance knowledge and understanding of natural disasters and how to reduce their risks. Moreover, a new learning strategy with good teamwork among students is necessary to establish a connection between natural disasters and scientific knowledge. As a result, this can improve students' skills and knowledge about disasters and their mitigation (Ulfa et al., 2020).

As explained above, Indonesia is constantly exposed to disasters, due to geological, geomorphological, climatological, or anthropogenic factors. This has led the government to implement policies by incorporating disaster mitigation and adaptation materials into the current senior high school curriculum. Considering that the impacts of disasters can endanger children's safety, some of the consequences include: (a) Loss of life, injuries, and physical health issues in children, such as malnutrition and diarrhea. (b) Mental health problems, as children may experience fear and stress when witnessing distressing conditions. (c) Disruptions to children's education due to schools being damaged by disasters. The impacts of disasters can be minimized through preventive measures as part of mitigation efforts (Nabilah Khairunnisa et al., 2024).

School educational institutions are institutions that can make a significant contribution to earthquake disaster mitigation for children. Based on the Hyogo Framework developed by the United Nations (UN), disaster preparedness education is a priority, namely Priority for Action 3: Use knowledge, innovation, and education to build a culture of safety and resilience at all levels. According to Minister of Education and Culture Regulation No. 33 of 2019 on the Implementation of the Safe School Unit Program (SPAB Program) in efforts to prevent and mitigate the impacts of disasters in educational institutions, one of its objectives is to provide educational services that align with the characteristics of disaster risks and the needs of educational institutions (Prayogi & Hendarto, 2024). In relation to this, earthquake disaster mitigation education would be more effective if the learning process were conducted through an educational learning medium that can attract students' interest while also depicting the actual occurrence of an earthquake and its mitigation process. The appropriate teaching media to be used is an earthquake simulation model, accompanied by an e-module on earthquake disaster mitigation.

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With the various advancements that have been achieved, Indonesia is expected to improve the quality of its education and compete globally. One of the efforts that can be made is through the Science, Technology, Engineering, and Mathematics (STEM) learning approach, which is currently implemented by many countries, as it prepares students with multidisciplinary skills that are essential for modern life (Ulfa et al., 2020).

The advantages of the STEM learning model (Widana & Septiari, 2021) include motivating students to learn, enabling them to analyze conceptual problems, and developing their creative thinking skills, thought patterns, logic, and reasoning. Therefore, supporting learning materials are needed to enhance the learning process. In mathematics learning using the STEM model, teaching materials such as pocketbooks, modules, LKPD (student worksheets), or technology-based learning media, including Android-based applications and software technology like E-Modules (Fauziyah & Wijayanti, 2024). E-Modules have several advantages, including accessibility via computers or Android devices, both online and offline.

Based on the explanation above, the researcher is motivated to develop educational media in the form of demonstration tools and an e-module that can facilitate students in understanding the material, align with the Merdeka Curriculum, and be used beyond formal learning hours. The educational media developed in this study is STEM-based, aiming to enable students to learn independently and enhance their understanding of earthquake disaster mitigation.

2. LITERATURE REVIEW

Learning Media: Demonstration Tools and E-Modules

Learning media refers to any form of tools or materials used in the learning process to help students understand and master subject matter. This media can take the form of physical objects, technology, or a combination of both, designed to communicate information more effectively and facilitate comprehension and retention of learning concepts. The purpose of using media in learning is to enhance student engagement, improve conceptual understanding, increase memory retention, and promote collaborative learning (*Media Pembelajaran Dan Jenis-Jenisnya – Fakultas Keguruan Dan Ilmu Pendidikan*, n.d.).

E-module is an application in the learning process that includes methods, materials, and assessments that are systematically designed to guide students toward achieving the expected competency levels based on their complexity. Unlike a traditional module, an e-module is a technology-based module (ICT-based), which can be accessed efficiently through laptops or mobile phones, both online and offline. For schools located in remote areas with limited internet access, the e-module is highly beneficial as it can be accessed offline. The e-module has an essential role in learning. Learning can take place effectively when using e-modules, as they can assist students who experience difficulties in learning. E-modules enable students to learn independently and assess their own level of understanding. Within an e-module, there is a final objective for the learning activities to

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be carried out, allowing students to identify what they need to master or understand to achieve the predetermined learning goals. As a teaching material that supports independent learning, the e-module uses communicative and interactive language, making it easier for students to understand the lesson material (Lastri, 2023).

Meanwhile, demonstration tools serve as one of the key components in determining learning effectiveness, as they are used to facilitate the understanding of concepts in learning. According to Sudjana (2004: 99), demonstration tools play an essential role in the learning process as teaching aids that help create an effective learning environment. In any learning process, various elements are involved, including objectives, learning resources, methods, tools, and assessments. These elements cannot be overlooked, as they serve as essential means to achieve learning goals (Qosyim, n.d.). The use of demonstration tools as learning media is chosen due to their practicality and multitasking potential, which can be utilized for educational activities. Demonstration tools offer several advantages in the learning process, including fostering students' interest in learning by making lessons more engaging, clarifying the meaning of learning materials to enhance students' understanding, creating a more varied teaching process to prevent students from becoming easily bored and encouraging more active participation in learning activities such as observing, performing, and demonstrating (Mursyid et al., 2019)

STEM (Science, Technology, Engineering, and Mathematics) Learning Model

According to the *Kamus Besar Bahasa Indonesia* (KBBI; English: Great Dictionary of the Indonesian Language), these four fields of study have different meanings: (1) Science refers to systematic knowledge obtained through observation, research, and experimentation, leading to principles related to the subject being investigated and studied; (2) Technology encompasses all tools and systems designed to provide goods necessary for human survival and comfort; (3) Engineering refers to an approach or system used to carry out a particular task; and (4) Mathematics is the study of numbers, relationships between numbers, and operational procedures used to solve numerical problems (Suwardi, 2021). The concept of the STEM approach is one of the most popular learning approaches today, aimed at supporting and preparing students to be skilled and competitive in the workforce. Through STEM education, students are trained to become individuals who can handle problems and learn new things, generate creative solutions, be self-reliant, think logically, and be technologically literate (technologically literate) (Muttaqiin, 2023).

The purpose of the STEM learning model is to enhance problem-solving skills (Fauziyah & Wijayanti, 2024). STEM learning can improve students' critical thinking abilities and foster their creativity. It also enables teachers to design more engaging and challenging lessons. Additionally, STEM learning can be integrated with various learning models, such as Project-Based Learning, Problem-Based Learning, and cooperative learning models.

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Earthquake Disaster Mitigation

A disaster is an event or series of events that threaten and disrupt the lives and livelihoods of communities, caused by natural, non-natural, or human factors, resulting in loss of life, environmental damage, property loss, and psychological impacts. Lack of preparedness in facing disasters, especially in areas with high economic value, can lead to significant losses (Nursyabani et al., 2020).

Disaster mitigation, according to Government Regulation of the Republic of Indonesia Number 21 of 2008 on the Implementation of Disaster Management, is one of the methods or actions taken to reduce disaster risks, either through physical development or by raising awareness and enhancing the capacity to face disaster threats (BPK, 2020). Disaster mitigation is divided into two types: structural and non-structural mitigation. Structural mitigation refers to efforts to minimize disasters by constructing various physical infrastructures using technology. For example, constructing reservoirs to prevent flooding, developing devices to detect volcanic activity, creating early warning systems to predict tsunami waves, and designing disaster-resistant buildings or structures that are specifically planned to withstand disasters and ensure the safety of their occupants in case of unexpected events. Meanwhile, non-structural mitigation refers to efforts to reduce the impact of disasters through policies and regulations. Examples include the Disaster Management Law (UU PB; *Undang-Undang Penanggulangan Bencana*), urban spatial planning, or other activities aimed at strengthening community capacity (Atap, 2021).

Structurally, efforts to reduce vulnerability to disasters involve engineering disaster-resistant buildings. Meanwhile, culturally, efforts to reduce vulnerability to disasters focus on shifting paradigms, increasing knowledge, and fostering attitudes that contribute to building a resilient community. Cultural mitigation includes raising public awareness about environmental responsibility to minimize the occurrence of disasters. Common activities in this stage include creating maps or layouts of high-risk disaster areas, developing disaster alarms, constructing buildings resistant to specific disasters, and providing extensive outreach and education to communities living in disaster-prone areas (BPBD, 2022).

3. METHODS

This study was conducted at SMA Negeri 2 Kota Blitar using the Research and Development (R&D) method. The population in this study consisted of all 11th-grade students in the odd semester of the 2023/2024 academic year. The sampling technique used was purposive sampling, with the sample consisting of four 11th-grade classes from all study programs. The instruments used in this study included questionnaires and objective tests. The questionnaire sheets served as instruments for module validation and collecting students' responses, while the multiple-choice written test was used to assess students' learning outcomes.

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Development Procedure

The development procedure in this study followed the Analysis, Design, Development, Implementation, and Evaluation (ADDIE) model, as shown in Figure 1, which consisted of five development stages (Hidayat & Nizar, 2021) The first stage was the initial phase, where an initial needs analysis and an assessment of earthquake mitigation materials for students at SMA Negeri 2 Kota Blitar were conducted. The second stage was design, which built upon the analysis phase by developing demonstration tools along with an e-module on earthquake mitigation. Several aspects were considered when designing the module, such as format selection, language, and expected outcomes. The third stage was development, where the module's format and content were validated by media experts, language experts, and educators. The results of the validation, along with expert feedback, served as a reference for revisions if necessary. The fourth stage was implementation. After validation was completed, the educational media, including the demonstration tools and e-module, were ready for implementation. The final stage was evaluation, which took place during the module's implementation in schools, and the collected data were analyzed.

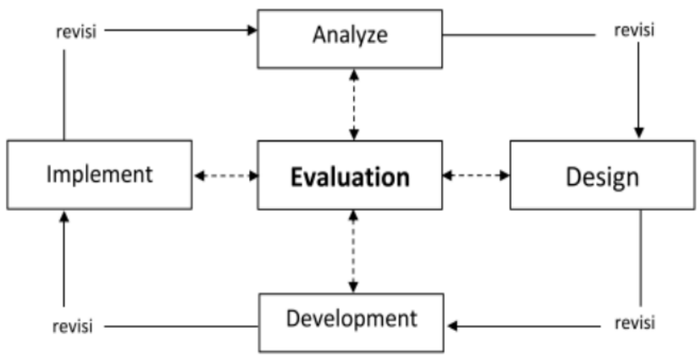

Figure 1. ADDIE Model Diagram
(Hidayat & Nizar, 2021)

Implementation of Educational Media in Schools

The implementation of demonstration tools and e-modules in schools was a crucial aspect of this study, as the design and development of the module had to align with the school's schedule and policies. The implementation of the module during the learning process was carried out in each class selected as the research sample and was conducted separately. For the research design during the module implementation, an experimental approach was used in the form of a pre-test and post-test control group, involving two class groups. These two groups consisted of a control class and an experimental class (Lukma et al., 2020). The learning process in the experimental class was conducted by implementing the STEM-based module. In contrast, the control class followed the learning process without applying the module. The research design can be seen in Table 1.

ISSN: 2502-8521 (Print) / 2503-1155 (Online)
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Table 1. Research Design

Group	Pre-test	Treatment	Post-test
Experimental	Y_1	X	Y_2
Control	Y_3	-	Y_4

Description:
Y_1 : Pre-test for the experimental group
Y_2 : Post-test for the experimental group
Y_3 : Pre-test for the control group
Y_4 : Post-test for the control group
X : Experimental class receiving treatment with educational media
(Rahayu et al., 2021)

Analysis of Learning Outcomes and Student Responses

The analysis of students' learning outcomes was conducted using a quantitative data analysis technique, with test score calculations based on N-Gain. This study included four types of tests: normality test, homogeneity test, hypothesis test, and N-Gain test. These tests were performed using IBM SPSS 26. The normality test and homogeneity test were used as prerequisite tests before conducting the hypothesis test using the independent sample t-test. The hypothesis test was applied to determine whether the implementation of educational media had an effect on high school students' learning. In interpreting the hypothesis test results, if the significance value of the t-test was greater than 0.05, then Ho was accepted and Ha was rejected. This means that there is no effect of the independent variable on the dependent variable. Furthermore, if the significance value of the t-test is less than 0.05, then Ho is rejected, and Ha is accepted, indicating that there is an effect of the independent variable on the dependent variable. In addition to hypothesis testing, N-Gain analysis was also used to analyze students' learning test results. The N-Gain test was applied to determine the criteria for the average improvement in students' learning outcomes (Putri & Sudibyo, 2018). Gain refers to the difference between the pre-test and post-test scores. According to Meltzer as cited in (Oktavia et al., 2019) the N-Gain formula is as follows:

$$NGain = \frac{S_{post} - S_{pre}}{S_{maks} - S_{pre}}$$

Description:
N-Gain represents the normalized gain test value.
Spost represents the post-test score.
Spre represents the pre-test score.
Smaks represents the maximum score.
(Oktavia et al., 2019)

The interpretation criteria for N-Gain can be classified into three categories, as shown in the table below:

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Table 2. Interpretation of N-Gain Values

g	**Category**
$g < 0.3$	Low
$0.3 \leq g \leq 0.7$	Medium
$g \geq 0.7$	High

(Ramdhani et al., 2020)

4. RESULTS AND DISCUSSION

The results of this study include the development of STEM-based educational media, consisting of demonstration tools and an e-module on natural disaster mitigation within the wave lesson for 11th-grade high school students. The data presented in this study cover STEM-based module validation analysis, learning outcomes, and student responses. The development stages, which include Analysis, Design, Development, Implementation, and Evaluation, will be described sequentially.

Analysis

The initial stage, analysis, was conducted as a step to examine the problem and determine possible solutions. The aspects analyzed in this study included observations of students and teaching materials. It was found that, on average, students had difficulty answering the questions given by the teacher. This was due to a lack of concentration among students. For some students, there was a tendency to perceive learning as monotonous. Monotonous teaching in the context of education refers to the repeated use of the same teaching methods or approaches without significant variation. This often relies on the lecture method, where communication flows in a one-way direction from teacher to students. As a result, students may experience fatigue, boredom, and a lack of motivation to learn due to the absence of engaging interactions and the cognitive stimulation needed to maintain their interest in learning (Pendidikan, 2024). Material analysis was conducted to identify the difficulties students face when learning about earthquake mitigation. This concept is actually both simple and essential, as it is closely related to everyday life.

Design

The second stage of the ADDIE development model was designed, which served as the initial step in developing this educational media, consisting of demonstration tools complemented by an e-module. The demonstration tool provided a simple simulation of an earthquake event. Meanwhile, the initial draft of the e-module was written in Indonesian, following EYD (*Ejaan Yang Disempurnakan*), the Enhanced Spelling

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DOI: https://doi.org/10.35457/josar.v10i1.4362

System, to ensure clarity and ease of understanding for students. The design of the demonstration tool and e-module is shown in Figure 2.

Figure (a) Figure (b)

Figure 2. (a) Earthquake Demonstration Tool (b) E-Module Interface

Development

The third stage in this study was development, which focused on refining the design of the educational media that had been previously structured. After the module was developed, validation was conducted to assess the feasibility of the teaching media. This process involved one subject matter validator and two expert validators. The average module validation score, which ranged between 0.56 and 0.89, indicated that the module met the requirements as a valid instrument and could be used in field research. The results of the teaching media validation are shown in Figure 3.

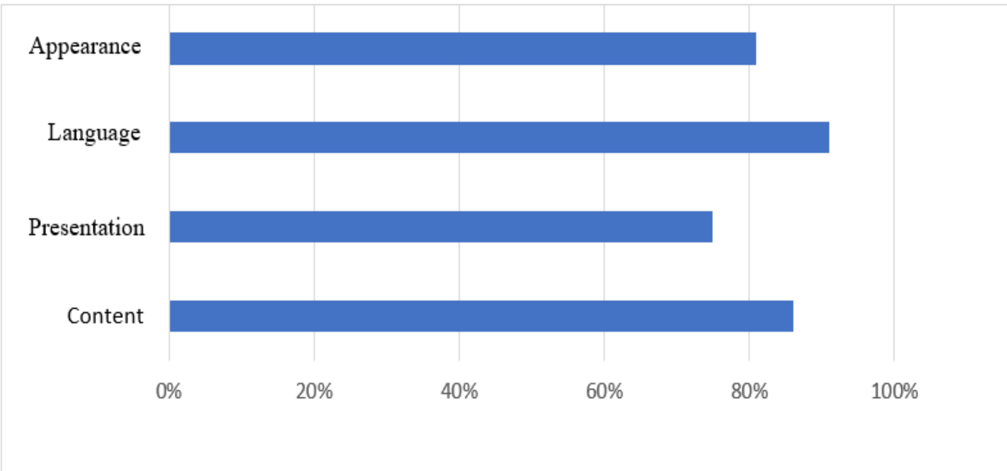

Figure 3. Validation Results of Teaching Media

Based on the validation results from experts, several revisions were made according to their feedback and suggestions. The cover was redesigned to be clearer and more relevant to the earthquake mitigation material. The module was enhanced with a

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detailed table of contents and included learning objectives, Core Competencies (KI), and Basic Competencies (KD), which were compiled into a single page and made more visually appealing to facilitate student reading. Additionally, the demonstration tool was equipped with a buzzer to produce an alarm sound when vibrations occur. The revised STEM-based demonstration tool and e-module can be seen in Figure 4 below.

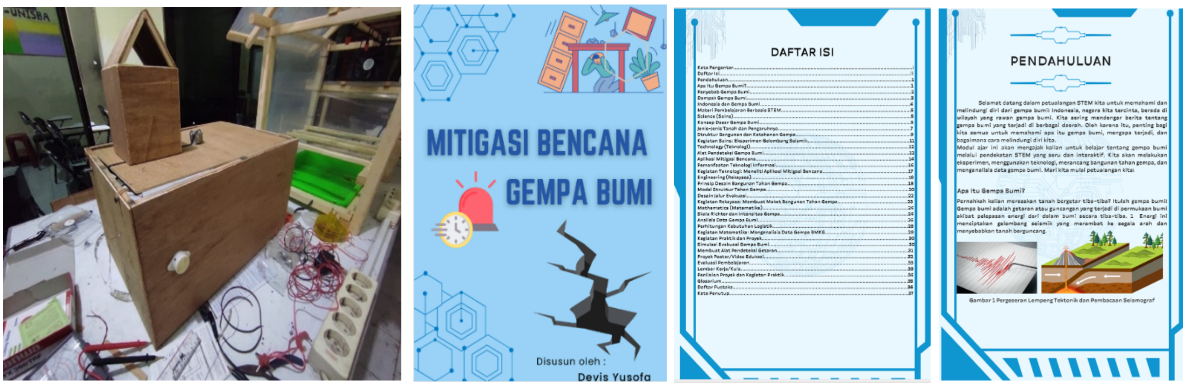

Figure (a) Figure (b)

Figure 4. (a) Demonstration Tool Equipped with a Buzzer (b) Revised E-Module Focused on Earthquake Disaster Material

Implementation

Implementation was the trial phase, in which the STEM-based natural disaster mitigation educational media was applied at SMAN 2 Blitar. The purpose of this implementation was to observe the learning process, student responses, and student abilities.

Evaluation

The evaluation was conducted after the implementation of the teaching media, including an assessment of student learning outcomes and responses to the teaching media. The student's learning outcomes can be seen in Figure 4. Students' learning outcomes were obtained from scores recorded after completing a pre-test before learning with the STEM-based module and a post-test after the learning process. The average pre-test score for the experimental class was 65.73, while for the control class, it was 64.12. The average post-test score was 82.35 for the experimental class and 71.45 for the control class. These results indicate that the average pre-test scores between the experimental class and the control class were not significantly different. However, the post-test scores showed a difference due to the improvement observed after using the module. The complete results can be seen in the following Table 3.

ISSN: 2502-8521 (Print) / 2503-1155 (Online)
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Table 3. Pre-Test and Post-Test Data Statistics

Class	**N**	**Pre-Test**			**Post-Test**		
		Xmin	**Xmax**	**Mean**	**Xmin**	**Xmax**	**Mean**
Experimental	37	65	85	65.73	75	95	82.35
Control	37	65	80	64.12	65	85	71.45

The results of the normality test, homogeneity test, and T-test for both the pre-test and post-test in the control and experimental classes can be seen in the Table 4.

Table 4. Results of Pre-Test and Post-Test Data Analysis

Class	**Sig. Value for Pre-Test Data**			**Sig. Value for Post-Test Data**		
	Normality	**Homogeneity**	**T-Test**	**Normality**	**Homogeneity**	**T-Test**
Experimental	0.689	0.923	0.615	0.110	0.081	0.004
Control	0.897			0.092		

For the normality test results, both the experimental class and the control class, for both the pre-test and post-test, showed that all data were normally distributed. This can be seen from the significance value (sig.) being greater than 0.05. Meanwhile, for the homogeneity test results, all data were also homogeneous, as indicated by the significance value (sig.) being greater than 0.05. As for the T-test results, there was a difference. In the pre-test data, the significance value (sig.) was greater than 0.05, meaning that there was no significant difference in the average pre-test scores between the control class and the experimental class. However, in the post-test data, the significance value (sig.) was less than 0.05, indicating that there was a significant difference in the average post-test scores between the control class and the experimental class.

Table 5. N-Gain Test Results

Class	N	Mean	Criteria	Sig. Value for N-Gain Data		
				Normality	Homogenity	T-Test N-Gain
Experimental	37	0.53	Medium	0.212	0.405	0.001
Control	37	0.27	Low	0.298		

From the table above, it can be seen that the implementation of the teaching media in the experimental class resulted in a moderate outcome, whereas in the control class, it resulted in a low outcome. For the statistical output from the normality test, it was found that all data were normally distributed (sig. > 0.05). For the homogeneity test, the data were found to be homogeneous (sig. > 0.05). Meanwhile, for the independent t-test, the significance value (sig.) was 0.001. Since the sig. value is less than 0.05, Ho is rejected, and Ha is accepted. Thus, it can be concluded that the implementation of the earthquake demonstration tool accompanied by an e-module affected students' understanding.

With the use of demonstration tools, abstract concepts can be presented in a concrete form that can be seen, touched, and tested, allowing the learning material delivered by the teacher to be more easily understood by students (Nurfadhillah et al., 2021). The e-module also has a significant effect on students' learning outcomes. Within

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the e-module, there is a combination of learning and real digitalization, which enhances students' interest in learning, leading to an improvement in their learning outcomes after the implementation of the e-module as a learning media (Nuryana & Jurusan, 2006). The presence of educational media makes the learning process more engaging and less monotonous, encouraging students to be more active and focused in understanding the material. Moreover, teachers are no longer limited to using only textbooks and lectures (Christiani & Airlanda, 2024).

Learning media is one of the important factors in education because learning media has a significant effect on students' motivation and interest in understanding lessons (Mahmudah et al., 2022). The use of media in the learning process must align with the material being taught and consider the complex and unique nature of the learning process. Therefore, the appropriate selection of media is very influential in the learning achievement of students (Mupida et al., 2019). Additionally, educational demonstration tools accompanied by a STEM-based module are highly feasible for earthquake disaster mitigation learning.

6. CONCLUSION

The results of this study indicate that the STEM-based earthquake mitigation educational media was successfully implemented, as evidenced by the improvement in students' learning outcomes at SMA Negeri 2 Kota Blitar. The STEM-based disaster mitigation module, developed using the ADDIE development model, is feasible for use as a learning medium in general secondary education while also enhancing students' understanding of earthquake disaster mitigation

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