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Earthquake scientific literacy profile of Indonesian first year pre-service physics teacher

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ABSTRACT

In higher education, fostering scientific literacy stands essential, especially in understanding and responding to natural disasters. This research investigates the scientific literacy levels among Physics Education students at State University in Surabaya, Indonesia, focusing on earthquake disaster mitigation. This study uses a qualitative descriptive approach that engaged 102 first-year pre-service teachers through a meticulously designed literacy test based on a new programme for international student assessment (PISA) framework 2025. The findings reveal a commendable proficiency in explaining scientific phenomena utilizing scientific knowledge. However, it uncovers a gap in students' abilities to make informed decisions in the context of earthquake disaster mitigation. This drawback is attributed to a lack of comprehensive literacy concerning disaster news, impacts, and mitigative strategies. Despite this, students demonstrated a capacity to argue and articulate their understanding logically based on existing knowledge. The study accentuates the need to enhance students' literacy and decision-making skills regarding natural disasters, advocating for heightened self-awareness and educational interventions to empower students to make informed decisions in disaster-prone scenarios.

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1. INTRODUCTION

Scientific literacy is asking, finding, or deciding on solutions to queries sparked by interest in commonplace experiences. It denotes the capacity to explain, describe, and predict natural processes. To be scientifically literate, one must be able to read articles about science in the popular press clearly and participate in societal discussion regarding the veracity of the findings [1], [2]. Scientific literacy is the ability to recognize the scientific issues that underlie local and national decisions and to articulate scientifically and technologically informed opinions. Students are cognitively required to analyze data, draw decisions, build arguments based on facts, infer word meanings, and create meaning for writing in the context of science [3], [4]. Scientific literacy also denotes the ability to formulate and assess arguments supported by evidence and appropriately apply such arguments' findings [5].

Scientific literacy serves as a gateway to nurturing critical thinking skills. It allows people to think critically, analyze the facts, and distinguish between truth and fiction [6]. By applying this point of view, people develop their understanding of complex information and a mindset that values evidence-based reasoning and skepticism. Understanding scientific concepts helps people evaluate information critically and make decisions supported by logic and facts, whether related to social issues, environmental concerns, or personal health [7]. Innovation and advancement are stimulated by a society that is literate in science. It stimulates creativity, inspires curiosity, and improves problem-solving [8]. Scientifically literate people frequently act as catalysts for technical breakthroughs, fostering societal advancement, industry innovation, and economic expansion. In a rich data world, scientific literacy is a barrier against lies. Scientifically knowledgeable people can better distinguish reliable sources and assess assertions critically, making them more resistant to pseudoscience and false information and contributing to the development of a society based on accurate knowledge [9]. Fundamentally, scientific literacy allows people to make wise decisions in various life situations, including disaster mitigation.

Indonesia is encircled by volcanoes, placing it at a high risk for earthquakes and tsunamis [10]. These natural disasters are not standalone events but the episodic outcomes of longstanding natural processes, which may be exacerbated by modern human activities [11]. The occurrence of natural calamities should not be entirely unexpected. Although humanity cannot prevent natural disasters governed by Earth's systems, the event can be mitigated. With research and preparedness, it is possible to identify critical risks to specific locales, predict impact zones, and recognize precursory signs of an impending disaster [12], [13]. An earthquake is a terrestrial shock resulting from plate tectonics, volcanic eruptions, and the collapse of hillside debris that forcibly joins rocks together [13], [14]. Earthquakes, caused by faults and instability within the Earth's crust, send vibrations to the surface.

Mitigating disasters is crucial to protecting lives, infrastructure, and the environment from the devastating impact of natural or human-induced calamities [15]. Disaster mitigation involves a comprehensive approach aimed at reducing the vulnerabilities of communities and enhancing their ability to withstand potential hazards. Early warning systems, strategic planning, and mitigation efforts strive to minimize the adverse effects of disasters, ultimately saving lives and minimizing economic losses [16]. Disaster mitigation seeks to reduce the risks posed by natural hazards such as earthquakes, floods, hurricanes, and wildfires while addressing the human factors that exacerbate vulnerability [17]. Mitigation strategies encompass a range of actions, from structural improvements, such as building resilient infrastructure and retrofitting buildings, to non-structural approaches, including land-use planning, education, and community engagement. Society must be literate in disaster mitigation to support this system.

Scientific literacy plays a pivotal role in decision-making processes related to disaster mitigation, influencing how individuals, communities, and policymakers comprehend, assess, and respond to potential hazards [18]. Due to its importance, many researchers studied scientific literacy in disaster mitigation or disaster mitigation literacy, such as Genc *et al*. [19] studied the level of disaster literacy in Türkiye; Logayah *et al*. [20] discussed the importance of disaster mitigation literacy in social studies learning; Kanbara *et al.* [21] investigated the disaster risk-reduction literacy in Japan related to decision making in a disaster; and Li and Li [22] explored present situation of disaster education in China. Furthermore, in 2022, the Organisation for Economic Co-operation and Development (OECD) issued the new programme for international student assessment (PISA) 2025 framework by adding decision-making skills in the science literacy competency aspect [23], [24].

Several studies have examined scientific literacy in disaster mitigation. However, little research examines earthquake mitigation literacy, primarily based on the new PISA 2025 framework, which includes decision-making skills in disasters. In this paper, we study scientific literacy about earthquake mitigation based on the new PISA 2025 framework in first-year Physics Education students. The research aims to determine the level of scientific literacy on earthquake mitigation of first-year Physics Education students from the state universities in Surabaya, Indonesia.

2. METHOD

The study uses a qualitative descriptive method, which involves collecting and analyzing non-numerical data such as interviews, observations, focus groups, or written documents. This approach provides a detailed summary of a particular phenomenon or topic, focusing on individuals' or groups' experiences, perspectives, or behaviors. The study utilized thematic and content analysis techniques, as seen in Figure 1, to preserve the authenticity of participant experiences and explore complex phenomena in various fields.

A total of 102 students who were enrolled in the first year of Physics Education at a public institution in Surabaya participated in the study. These students utilized an innovative approach to investigate and assess their capacity to comprehend scientific concepts, with a particular emphasis on mitigating earthquake disasters' effects. Undergraduate students enrolled in the Physics Education Study Program were the primary subjects of the research carried out in December of 2022.

Figure 1. Qualitative descriptive method

Data was collected through a questionnaire that contained a news article on a recent earthquake disaster in Indonesia, followed by seven associated research questions. Both quantitative and qualitative analyses were performed on this data. While the results from the questionnaire were analyzed qualitatively, data on students' science literacy accomplishment scores were analyzed using descriptive statistics and discussed comprehensively.

3. RESULTS AND DISCUSSION

This study assesses the earthquake science literacy of first-year pre-service physics teachers in Surabaya. The research starts with a literature review of previous and related studies. Following this, data will be collected using a seven-question test, which will then be analyzed based on the students' scientific literacy abilities. The number of correct student answers to the test is shown in Figure 2.

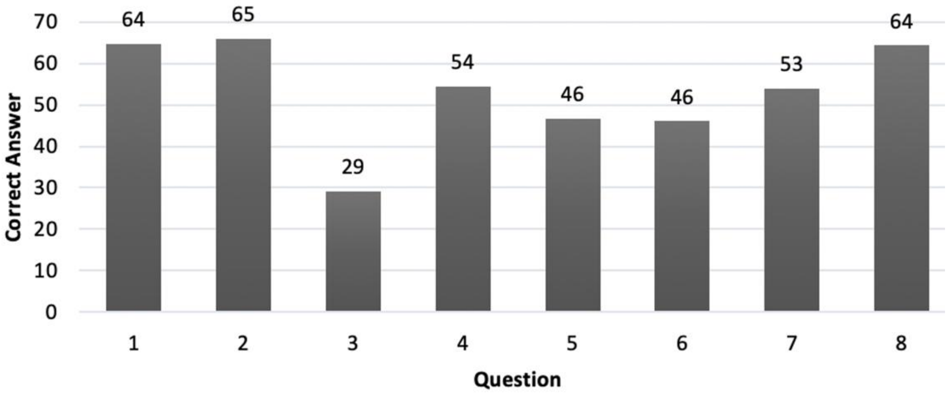


Figure 2. The result of the questionnaire

Figure 2 shows that students' literacy skills in formulating problems and making decisions still need to improve, with an average of 29.21. This finding aligns with the results of the 2022 PISA test for Indonesia, with a score of 383, lower by 13 points than the 2018 PISA results despite the increasing Indonesia country rank to 66th [25]. Overall, students need comprehensive guidance to make a decision regarding earthquake mitigation. Understanding information from news or articles about earthquakes needs to be improved. This weakness causes students difficulty in making correct decisions. Another flaw in the students's answers is the irrelevant answer between problem formulation and the proposed solution or experimental design. Students still cannot provide appropriate solutions for earthquake disaster mitigation.

Question number 2 presented news about an earthquake in Cianjur in 2022. Students were asked to analyze the effects of earthquakes on houses and buildings in Indonesia. The results showed that students could justify and support their arguments based on observed phenomena. The answer with the highest score demonstrated a robust and comprehensive understanding of the underlying scientific principles related to the evaluated phenomena. Based on Figure 2, question number 2 had the highest score. It reflects their knowledge of scientific content and the ability to analyze information critically, apply scientific reasoning, and communicate effectively. Individuals who are good at explaining phenomena scientifically can connect different scientific ideas, interpret data, and offer well-supported explanations using scientific evidence [26]. A high score in this indicator shows good scientific literacy, including sound conceptual understanding, critical thinking skills, and adeptly communicating scientific knowledge. Furthermore, the example of a student's answer can be seen in Figure 3.

> 2. Indonesia often experiences earthquakes because it is located between three major tectonic plates, namely the Eurasian plate, the Pacific plate, and the Indo-Australian plate. When shifts occur between these plates, energy is released and causes earthquakes. In addition, many areas in Indonesia consist of soft soils and sedimentary deposits that are not vibration-resistant and are more susceptible to the effects of earthquakes in Indonesia. Many buildings are not built by earthquake-resistant building standards, so they easily collapse when an earthquake occurs. Not only that, the level of awareness from the community still needs to improve towards disaster preparedness. As a result, earthquakes in Indonesia often have a significant impact on buildings and casualties.

Figure 3. Student's answer for question number 2

Figure 3 shows one of the student's answers to question number 2, with the indicator explaining phenomena scientifically. It can be seen that the student can answer the question comprehensively. It shows the student's understanding in earthquake phenomenon. Earthquakes are complex natural phenomena that involve geological, seismological, and physical principles. Prospective teachers in teaching earthquake science need to comprehend these phenomena thoroughly. The ability to explain earthquakes using scientific knowledge ensures they can effectively teach and communicate these concepts to their students [27]. The ability to explain phenomena scientifically ensures they can communicate complex ideas clearly and quickly, aiding students' learning and understanding of earthquake science [28]. Future teachers develop the skills to assess seismic events critically and propose effective mitigation measures [29]. These competencies are crucial for understanding the causes, effects, and potential earthquake mitigation strategies.

Earthquake literacy among teachers is critical for promoting community preparedness and mitigation strategies. Teachers are crucial influencers and educators, imparting knowledge about earthquake risks, safety measures, and mitigation strategies to students and, indirectly, the broader community that contributes to disaster resilience [30]. Teachers who can explain scientific phenomena related to earthquakes contribute significantly to fostering a resilient community equipped with knowledge and preparedness measures to minimize the impact of such events [31]. An informed and scientifically literate society is more resilient in natural disasters like earthquakes.

The lowest score in the earthquake mitigation literacy test is question number 3. Students are asked to design an experiment to assess the strength or quality of the building of a resident's house. Students have difficulty constructing and evaluating designs for scientific inquiry. This problem signifies potential difficulties in formulating hypotheses, designing controlled experiments, selecting appropriate variables, and preparing data collection methods. Students have problems engaging in systematic scientific inquiry, restricting their ability to rigorously explore and comprehend seismic phenomena. This finding aligns with Eddif *et al.* [32] and Cabello [33]. Eddif *et al.* [32] found that students in Morocco do not have sufficient knowledge about earthquakes while Cabello's [33] study has similar results in Chile. In addition, the typical students' answers in problem formulation can be seen in Figure 4.

> 3a) Experimental problem formulation:
> 1. How to assess the strength or building quality of houses in earthquake-prone areas?

Figure 4. Student's answer for question number 3a

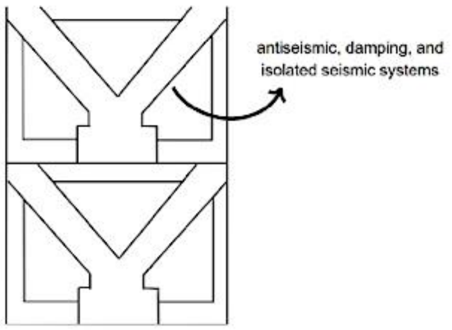
Figure 4 illustrates the typical students' answers to problem formulation or research questions. This finding reflects students' low science process skills, especially in formulating problems. Students must be accustomed to participating in science learning based on scientific inquiry. They also need a thorough understanding of earthquake-specific disaster preparedness to create suitable problem formulations. Formulating problems is very important so that students can design experiments well according to the problem to be solved [34]. Understanding how to construct and evaluate scientific inquiry designs is also a fundamental skill for future teachers. They need practical skills to plan, execute, and assess scientific earthquake-related experiments or investigations to design excellent inquiry-based learning that fosters students' more profound understanding of seismic phenomena.

Proficiency in constructing scientific inquiry designs enables future teachers to devise inquiry-based learning strategies. They can design engaging experiments or activities that elucidate earthquake concepts, thus sparking students' curiosity and interest [35]. Educators are crucial in heightening awareness about earthquake risks and mitigation measures. Constructing scientific inquiries and critically interpreting data empowers teachers to disseminate accurate information on seismic hazards, preparedness strategies, and mitigation techniques [36]. This knowledge is essential in fostering a culture of preparedness and resilience in earthquakes among students and the wider community. By engaging in scientific inquiry and critically analyzing data, future teachers acquire the proficiency to propose effective mitigation strategies, thereby enhancing community disaster resilience [37]. Figure 5 shows an example of a student's answers about creating research hypotheses, variables, designs, and stages.

3b) Experimental hypothesis:
- The working principle of buildings with isolated antiseismic, damping, and seismic systems can resist earthquake damage.
- The working principle of buildings with isolated antiseismic, damping, and seismic systems cannot resist earthquake damage.

3c) Experimental variables:
- Control variable: materials used to develop the antiseismic, damping, and isolated seismic systems.
- Manipulation variables: systems run on antiseismic, damping, and isolated seismic.
- Response variables: the robustness of the antiseismic, damping, and seismic remote systems.

3d)



3e) Experimental steps:
- Prepare tools and materials such as earthquake insulators in wood, steel, reinforced concrete, and steel-reinforced concrete.
- Design steel concrete like the letter Y in a multi-story building.
- Install steel concrete as designed in the experiment.
- Install a multi-story building.

Figure 5. Student’s answer for question number 3b-3e

Figure 5 shows students' answers to questions 3b-3e about creating research hypotheses, variables, designs, and stages. The response suggests a working hypothesis that structures outfitted with anti-seismic, dampening, and seismic systems can endure and resist damage caused by earthquakes. In contrast, structures lacking these measures are prone to sustaining harm. The specified experimental phases provide a comprehensive strategy, commencing with fabricating materials such as earthquake insulators composed of wood, steel, reinforced concrete, and self-reinforced concrete. In the design phase, a steel-concrete frame is created with the letter 'Y,' representing the common anti-seismic feature in multi-story buildings. In addition, Figure 6 illustrates how a damper is installed in a building.

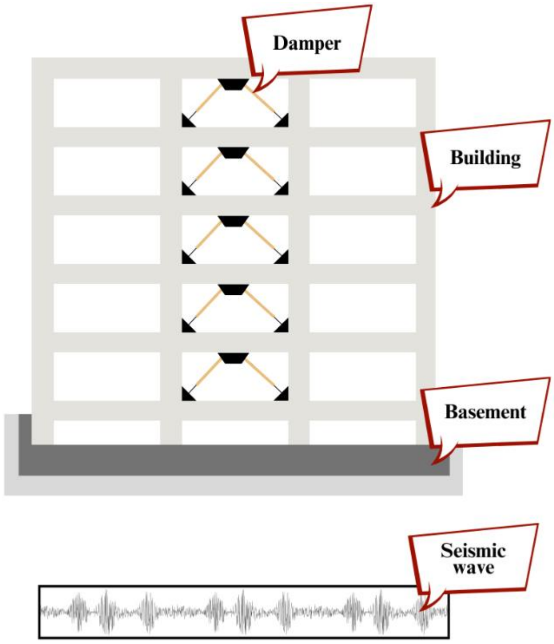


Figure 6. Illustration of model installation on a building

Figure 6 indicates that installations that limit the space in the structure pose a challenge for architects. Hence, the issue needs to be carefully considered while designing earthquake-resistant structures. Using passive systems, particularly metal dampers, as an additional device to dissipate energy was one of the earliest approaches adopted in earthquake-resistant design [38], [39]. From an architectural perspective, the main proposed structural controls, including active and semi-active systems, are designed to be installed in specific structural locations, with many of them taking the form of X, V, or Z shapes [38], [40]. Apart from the foundation, the frame of a house or building can significantly impact its robustness and strength. While the frame of an ordinary house is not explicitly designed to withstand earthquakes, earthquake-resistant houses employ specialized frames such as RISHA and RIKA models. In the 2022 Cianjur earthquake, most collapsed houses were due to the failure of the roof frames, which were made of bamboo or wood and covered with roof tiles or asbestos [41]. Therefore, it is crucial to pay close attention to earthquake-resistant houses' structural and foundation design to prevent such occurrences.

The student's answer highlights the importance of decision-making abilities among first-year pre-service physics teachers. Their skills are crucial in connecting theoretical knowledge to practical scenarios, enabling them to effectively guide students in comprehending scientific concepts. This concept is particularly significant when addressing scientific literacy queries related to constructing and evaluating designs for scientific inquiry [42]. Furthermore, honing decision-making skills among first-year pre-service physics teachers significantly enhances their capacity to instill scientific literacy in students. By facilitating meaningful connections between theoretical content and real-world problem-solving, they can inspire students to critically analyze, problem-solve, and innovate, fostering a deeper understanding of scientific processes [43]. Improving the decision-making skills of pre-service physics teachers is essential for their professional development. It is an effective way to empower students to become scientifically literate individuals capable of solving real-world problems.

From the low results of students' answers regarding problem formulation or decision-making, students' literacy towards natural disasters, especially earthquakes, needs to be improved. It can occur because many students are less interested in news, impacts, and mitigation of natural disasters, especially earthquakes. It takes self-awareness from students to increase literacy towards earthquake disasters. The need for student awareness of earthquake disaster mitigation is in line with Prihatini and Rochman [44] research, which found that students' low science literacy skills in the attitude area were caused by a lack of awareness or practice of earthquake disaster mitigation knowledge. The community needs more awareness about disaster mitigation, which aligns with the low level of disaster literacy among students, starting from understanding disasters, disaster management, infrastructure and facilities for disaster mitigation, and natural disaster mitigation regulations [45]. Enhancing this understanding among students is crucial for fostering a culture of preparedness and resilience in natural disaster mitigation.

This study explored a comprehensive description of the scientific literacy profile of pre-service physics teachers on earthquakes based on the new PISA Science Framework 2025. However, further and in-depth studies may be needed to confirm the findings about pre-service Physics teachers' low literacy in earthquake disaster mitigation, especially regarding the ability to design scientific inquiry in earthquakes and decision-making ability regarding earthquake disaster mitigation. Future studies may explore educational strategies to overcome these issues since Indonesia has a potential risk of earthquake disasters. Future research may be conducted to develop a learning model to enhance the students' scientific literacy skills based on the new framework of PISA Science 2025, which is based on the various Indonesian local wisdom.

4. CONCLUSION

The study reveals that students possess commendable scientific literacy in explaining phenomena through scientific knowledge but display a notable gap in applying this skill to the decision-making process in earthquake disaster mitigation due to insufficient attention to the complexities of disasters. Despite this, their ability to argue and reason based on observed phenomena suggests a strong foundation for further development. To bridge this gap, educational strategies should deepen students' understanding of natural disasters and integrate theoretical knowledge with practical decision-making strategies. Future research is encouraged to explore pedagogical approaches that enhance students' scientific literacy to empower them to make informed decisions in the face of natural hazards, thus fostering a comprehensive scientific literacy that is both knowledgeable and actionable using the various Indonesian local wisdom.

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