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ANALYZING HIGHER EDUCATION STUDENTS' UNDERSTANDING OF EARTHQUAKE-RESISTANT BUILDINGS ON STEM LEARNING

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Abstract

Earthquake is one of the natural phenomena that can cause many sudden changes in the environment, which is also one of the topics studied in Earth Science course, especially in Indonesia. This article aims to analyze higher education students' understanding of earthquake-resistant buildings on STEM learning. The researchers designed STEM learning on earthquake units in four main activities, namely problem orientation, inquiry, investigating epicenter location, and designing an earthquake-resistant building. The second-year students of Primary School Prospective Teacher (N=30) participated in this study. The data collection procedure was observation of participants during the learning activity. During the learning process, students analyzed and conceptualized an earthquake in a laboratory activity through an earthquake machine. At the end of the session, students performed better on communicating a map of earthquake epicenter location. This study also showed that students are capable to construct an earthquake-resistant building design with some main considerations, such as angle, foundation, and framing design. The implementation of STEM learning leads to an improved students' understanding on the theory of earthquake, students' mathematical thinking, students' ability to represent earthquake-resistant building model, and real problem-solving ability involving STEM multidiscipline.

Keywords: Earthquake-resistant building, Earth science, STEM learning.

1. Introduction

Earthquakes are vibrations caused by the movement of rocks on the earth's plates [1]. A seismic activity in a region can be used as information to identify earthquakes. Earthquake disasters are capable of causing environmental damage such as tsunamis, broken rocks, landslides, collapsed buildings, soil cracks, and others [2]. Indonesia is a compilation of islands that is tectonically located at the confluence of three world tectonic plates, such as Indo-Australian, Eurasian, and Pacific plates. In addition, many active faults are located in the Indonesian archipelago. As a result, the Indonesian archipelago is an area prone to earthquakes and Tsunamis, such as in Yogyakarta (26 May UTC) and Tsunami Aceh (December, 00:58:53 UTC). Therefore, an earthquake is an important topic to be discussed in education, especially in Earth Science learning.

Some researchers have used various strategies on Earth Science learning, such as web-based learning [3-5], laboratory activities [6-10], inquiry learning [11-13], and digital technology-based learning [14-17]. In addition, Kuester and Hutchiso have used virtual laboratory for earthquake engineering education [18]. Previous empirical studies indicated that the teaching strategy of Earth Science which implemented STEM-based (Science, Technology, Engineering & Mathematics) learning was still limited, especially in earthquake education.

STEM education does not mean strengthening the educational practice in the fields of STEM separately, but it aims to develop an educational approach that integrates science, technology, engineering, and mathematics focusing on educational processes of problem solving in daily life and professional life [19]. Previous studies showed that STEM approach can increase students' performance with low achievements and reduce students' achievement gap [20], produce meaningful learning which affected students' attitude to choose their career in the future [21], improve students' understanding of an integrated STEM learning and students' power of imagination in project-based activity [22], and increase students' science literacy [23]. This article aims to analyze students' understanding of earthquake resistant building on STEM learning in an earth science course.

2. Methods

This study was conducted at Primary School Teacher Education department, Pakuan University in Bogor, Indonesia. Pakuan University was accredited "B" by Indonesian Higher Education National Accreditation Board. It was established on 1 November 1980 under the Foundation of Pakuan Siliwangi. Pakuan University offers 32 programs of study and 8 faculties. Primary School Teacher Education offers an introductory earth and space science course each semester, which includes a required laboratory component. The course is taken by 30 second-year students. Students who participated in the study had received basic courses in biology, physics, chemistry, and mathematics. In the study, those students were formed in a group consisting of 4-5 people.

The earthquake was one of the topics that discussed in Earth and Space Science course. STEM learning in the topic of earthquake was implemented 2 times (or equivalent to 200 minutes). The topic chosen discussed earthquake distribution in Indonesia, determining epicentre location and earthquake mitigation. STEM learning on earthquake topic consisted of four main activities, involving orientation to problems, inquiry using earthquake machine, investigating epicentre location, and designing an earthquake-resistant building. Data in this study were obtained from students' worksheet, photos, and observation of learning process. Meanwhile, the series of activities of the students in the STEM learning can be seen in Table 1 below.

Table 1. Test model Specifications and test conditions.

Activity	Description
Problem Orientation	A Lecturer showed a phenomenon of an earthquake in Indonesia through earthquake distribution map.
Inquiry Laboratory	Students were divided into groups, then they conduct an inquiry in accordance with students' worksheets of the earthquake machine. Students in groups do an experimental activity about the elastic rebound theory
Investigating the epicentre of earthquake	Each group was asked to locate the epicenter of earthquake. Students investigated the epicenter location of an earthquake.
Design of earthquake resistant building	Students were asked to make solutions to earthquake prone areas by creating a technology, which is earthquake resistant building design.

3. Results and Discussion

The purposes of studying earthquake were that students were able to analyze the causes of earthquakes, investigate the tectonic earthquake, communicate the epicentre location of an earthquake based on the seismogram data, understand the mitigation of earthquake disaster with the appropriate technology. All of these purposes can be achieved through STEM learning.

Indonesia is an earthquake-prone country. The earthquake cases that occurred in Indonesia are not only theoretically studied, but also the learning source for students to solve their problems. STEM learning requires students to explore problems about earthquakes, learn the concepts, and design a technology as an effort to solve earthquake problems. The design expected in this study is earthquake-resistant buildings. Students not only learn about the concept of the earthquake, but they also have to solve the problem by making technological designs. The expected technology design in the study is earthquake-resistant buildings.

At the beginning of the lesson, the lecturer presented a map of earthquake distribution in Indonesia (See Fig. 1). Students analyzed the distribution of earthquake, such as the magnitude, the depth and the area which earthquake took place. In addition, this activity also trained students' inquiry and critical thinking skills [24].

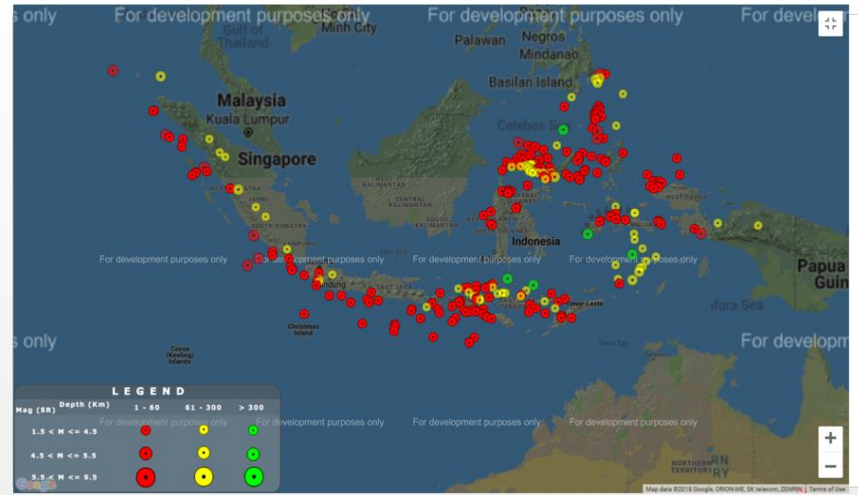

Fig. 1. A map of earthquake distribution in Indonesia (Data obtained from BMKG).

In the second stage, students investigated the elastic rebound theory by using an earthquake machine. The design of earthquake machine used by students in the experimental activity is shown in Fig. 2. Students are also able to identify the factors of earthquakes, such as tectonic plate shifts and changes in energy occurring in the earth. The lecturer played a role in directing students to think scientifically and assist students in constructing the concept of earthquakes. This was in line with Clark et al. [25] who state that the lecturer acts as a facilitator in laboratory activities conducted by the students. Therefore, a laboratory section enriches students' understanding of the concept of the elastic rebound theory. Forcino [26] also confirms that a laboratory activity supports students' learning in earth science.

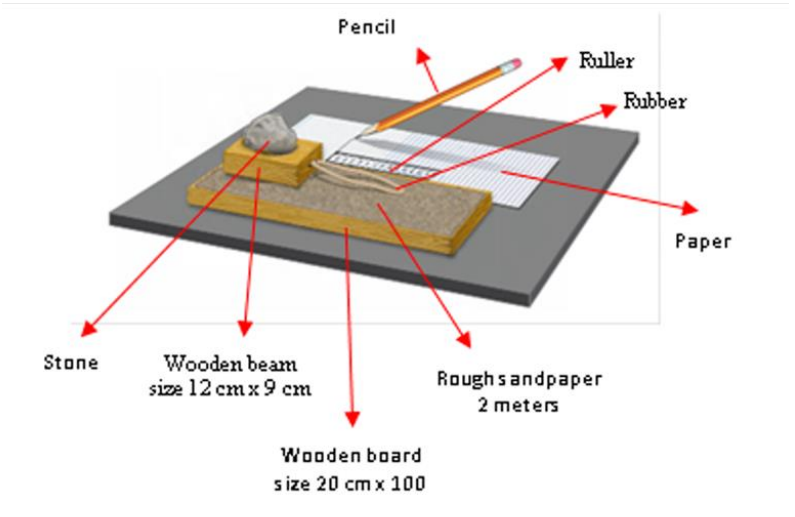

Fig. 2. The design of earthquake machine.

In the next activity, students investigate an epicentre of an earthquake based on seismogram data in three seismograph stations. Students determined the location of the epicentre of the earthquake by converting the station distance to the epicentre from kilometer to centimeter. For example, in the seismogram shown in Fig. 3, students determined the S&P time lag on seismogram scale of 18 mm which equals 18 seconds. Student used the scientific data to determine of the S&P time lag. This activity shows that STEM learning is able to facilitate students' ability to communicate scientific data. In line with Wagner et al. [27], STEM learning can improve students' communication skills.

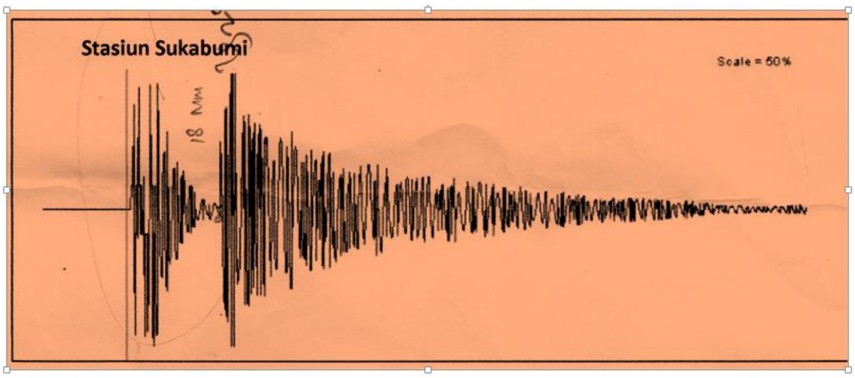

Fig. 3. Example of students' work "determining the scale of the seismogram".

Students are also able to make representations of earthquakes epicentre by using scientific data (See Fig. 4), where students represented the location of the earthquake epicentre by making circle on the map (See Fig. 5). Figure 5 shows that students are able to use mathematical concepts in finding epicentre locations based on seismogram data. The series of activity shows that students used visual representation to find the epicentre location. This finding suggests that STEM learning supported by visual representation directly assists students' conception of the epicentre location. The finding is in accordance with Adullah et al. which state that construction of representation in learning can support students' ability to communicate their understanding of that problem [28].

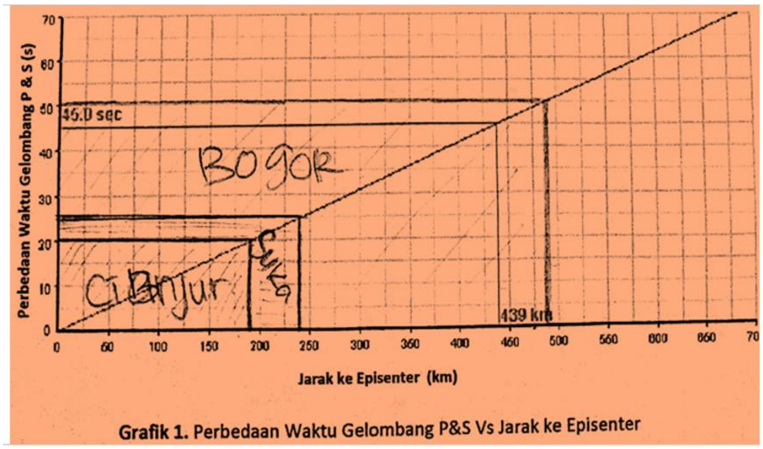

Fig. 4. Examples of student work "determining the distance of the station".

Fig. 5. Map of the epicenter point location of the earthquake.

The final activity requires students to design an earthquake-resistant building. This activity confirms the engineering activities in this learning. Earthquake-resistant building designs theoretically need to pay much considerations of the building plan. The plan for earthquake-resistant buildings needs to be symmetrical and not too long, and there should be a separation path (See Fig. 6). Non-symmetrical building design (See Fig. 7) will cause torsion when an earthquake causes a large amount of damage to the building [29]. In addition, the shape of a tall building needs to be a separator made of material that may be easily repaired. This aims to reduce torque when an earthquake occurs.

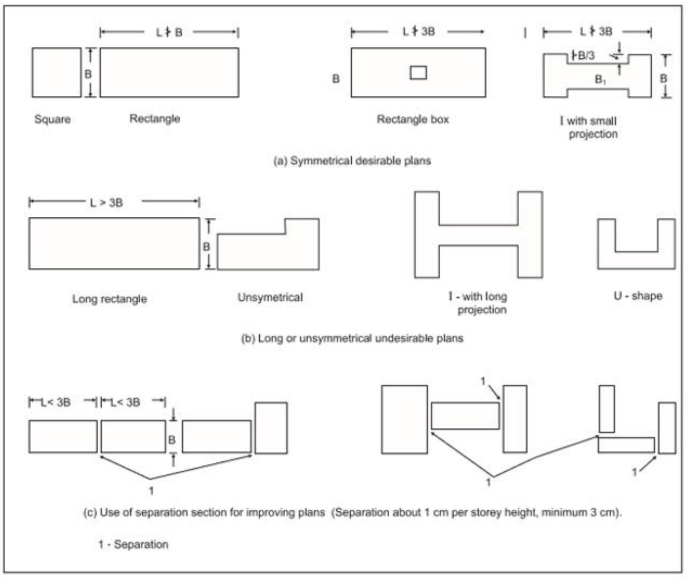

Fig. 6. Plan of block building (design obtained from national information center of earthquake engineering).

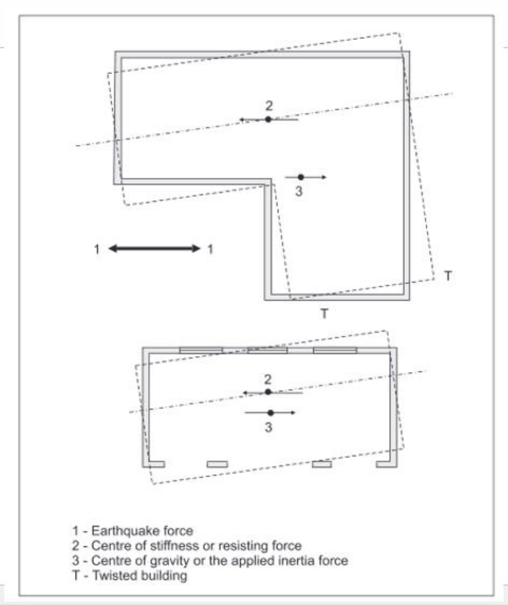

Fig. 6. Asymmetrical plan (design obtained from national information center of earthquake engineering).

Based on the observation in the class, students were able to create earthquake-resistant building design in accordance with the creativity and knowledge in their respective groups (see Fig. 8). Group 1 used cross bracing in the top, middle and bottom of the building. Group 1 also decided to use a square pyramid in the top of the building. Group 1 claimed that "the square pyramid structure aims to reduce the wind pressure above the building." Therefore, they also considered base isolation in the bottom of the building. They stated that the presence of base isolation on the foundation would make the building safe when an earthquake occurred. This reason is in line with Holt et al., which stated that the base isolators can absorb energy during an earthquake. Those will keep seismic waves from moving through the building [30].

Groups 2 and 4 decided to make a rectangular building structure. Group 2 used a cross bracing on the front side, while group 4 used cross bracing on all sides. However, the two groups did not consider the building foundation. In fact, the National Institute of Building Sciences (NIBS) indicates an importance of a stable foundation for considering earthquake-resistant buildings [30]. Group 3 designed a hexagonal building, where each side of the square was a frame that formed a triangle on each side. Group 3 claimed that hexagonal-shaped buildings will be much more stable than the square structure. They also stated that the presence of many sides will make the building stronger. Group 3 implemented a cross brace in their building. Group 3 considered a symmetrical, complicated structure. Buildings with many projections will increase torsion when an earthquake happens. NIBS also suggests that symmetrical, simple buildings are better than the building with many projections [30].

Group 5 used a triangular prism in the concept of earthquake-resistant buildings. Group 5 considered the use of cross bracing to support the building structure. They also divided the building into three floors. Unlike Group 5, Group 6 made the top of the building with a pyramid shape. They claimed that the structure reduces the gravity on the building. However, the two groups did not consider the shape of a symmetrical building.

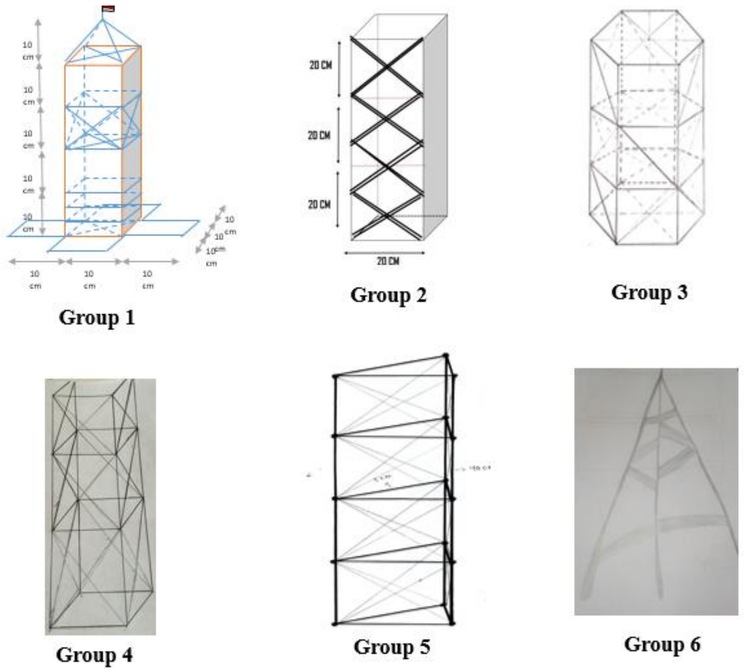

Fig. 8. Students' earthquake resistant building design.

In regards to the students' design, they believed that symmetrical and regular simple rectangular behave better during an earthquake than other shapes with many projections. NIBS & NICEE state that the plan of earthquake-resistant building should consider the symmetry of the building and its regularity (such as simple rectangular shapes) [29, 30]. This finding suggests that students are able to design earthquake-resistant buildings based on a proper engineering techniques, even though their scientific discipline is not from engineering techniques. They also could apply the theory of earthquake to solve the real life problem (particularly at the earthquake hazard). These findings indicated that students employ science and mathematical knowledge in the engineering design.

In addition, engineering activities stimulate students in critical thinking, logical thinking, and analytical skills. They also involve multidisciplinary basic knowledge such as mathematics in making a design. This engineering activity also trains students' skills in solving real problems and improves their understanding and communication skills related to the science and engineering aspects of earthquake-resistant building models. In line with Wagner, et al. STEM-based learning can improve students' problem solving skills and engineering skills [27]. Tseng et al. also state that a series of engineering activities in the learning process are able to develop meaningful knowledge [31]. The findings also support Marulcu's finding in that that a series of engineering activities in the learning process can improve students' learning outcomes in the science and can help students acquire accurate conceptions and develop student problem-solving skills [32].

4. Conclusions

Earthquakes can be learned through the STEM learning approach. The orientation of problems facilitates students' critical and analytical thinking about earthquake in Indonesia. The inquiry activity supports students in discovering the elastic rebound theory through laboratory works and collaboration between students. The students applied their mathematics and inquiry skills on designing earthquake machine to prove the elastic rebound theory, but they needed more effort to confirm the theory. Investigating a location of an earthquake epicentre requires students to use the concept of scale and data literacy, mathematical thinking skills, and applied engineering practice. The final goal of this learning was to have students made the earthquake-resistant building. This activity prepares students to have creative thinking skills, logical thinking skills, analytical skills, collaboration, engineering skills and proper mitigation skills on natural disaster.

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