Implementation of STEM Book in Earthquake Themes

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***Abstract*—STEM learning in Indonesia has been implemented in several schools. But the fact show that STEM learning is still done once in a semester with the constraints of the unavailability of teaching materials. STEM learning with the activity of making products will make meaningful learning. The purpose of this study is to describe the engineering abilities of students after using the STEM book on the earthquake theme that had been developed using Four Step Teaching Materials Development (4S TMD) method. The results of the application of STEM teaching materials show that the average score of student engineering ability in the competence of understanding the basic principles of technology were in the medium category. On the other hand, 3 groups of students get high average scores in the competence of developing solutions and achieving goals, while 2 groups get medium scores.**

Keywords: STEM book, earthquake, engineering ability

I. INTRODUCTION

Since 2000, Indonesia has participated in the Program for International Student Assessment (PISA), an international level assessment program that measures the level of students' abilities and skills in dealing with problems in the real world. Of the 72 participating countries, in 2006 Indonesia was ranked 50th out of 57 participating countries [1]. In 2009, Indonesia was ranked 60th out of 65 participating countries [2]. Then in 2016, Indonesia was ranked 63 out of 72 countries [3]. The data shows the need for learning innovations to improve students' abilities.

Science, Technology, Engineering, and Mathematics (STEM) is considered as a learning innovation that is not only able to increase student mastery of knowledge but also the ability to think critically and solve everyday problems that cannot be separated from the use of technology and innovation. STEM learning has been applied in a number of developed countries such as the United States, Japan, Finland, Australia and Singapore. The aim of STEM learning in these countries is to increase interest in the STEM career. In 2018, 9 out of 10 rapidly growing jobs require graduates who have significant capacity in the fields of mathematics, science, engineering [4,5]. STEM is an approach that integrates science, technology, engineering and mathematics. Specifically, through the integration of techniques, students can have awareness in roles and presence in the community and can apply the engineering design process to find solutions to real-world problems [5]. Science learning integrated with engineering design will make it easier for students to make product designs. STEM learning with engineering design will train students to use scientific and mathematical knowledge in making products. This will make learning more meaningful in overcoming real problems even by professional engineering workers [6]. Furthermore, STEM learning not only provides student training to be a solution maker in the community, but the success of the teacher in the learning process affects the increase in student interest in STEM careers [7-10]. This is in accordance with the needs of human resources in the world of work. STEM careers are work within the scope of science, technology, engineering, and mathematics [7-9]. In the United States workforce, the STEM field is considered a crisis by many people in the fields of education, government, and industry [8].

STEM learning in Indonesia has been implemented in several schools. Based on preliminary studies, STEM learning is still done once in a semester. However, the implementation is still separate from the delivery of material. The implementation of STEM learning is done at the end of the semester by taking a theme that matches the composition of the material in the semester. STEM learning is done by providing worksheets downloaded from the internet with the theme of creating a simple refrigerator. Based on teacher interviews, special worksheets have not been created by teachers or from schools. The theme of a simple refrigerator if analyzed, its manufacture does not train the exact engineering capabilities. Design is too simple to make a refrigerator from a beam-made stereo foam by adding ice cubes in the stereo foam and one ice cream to test how long the ice will last frozen in the simple refrigerator. So it is necessary to innovate STEM teaching materials that are able to train students' engineering skills.

II. Methods

The method used for developing teaching materials was the four step teaching materials development (4S-TMD) which consists of the stages of selection, structuring, characterization, and didactic reduction. Briefly, the development of the teaching materials was started with the characterization stage. This stage involved six students, of which the test was carried out to find out the difficulty level of the text by writing main idea. After obtaining the second draft, the teaching materials were reviewed by three master graduate teachers and one expert lecturer. Afterwards, a didactic reduction was conducted on the teaching material, resulted in the final draft of the teaching material. This final draft was then tested to18 students in one school in the city of Bandung. The test was to find out the students' understanding of the teaching material. In this recent study, the teaching materials were then implemented to 16 students of grade VII who were divided into five groups. The learning process consist of two meetings. After the learning process, the student engineering ability was tested. The test covered two competencies of which five indicators were derived from.

III. Results and Discussion

Learning process in the earth quakes theme using the developed STEM book went well in accordance with the learning objectives. The learning model used is an inquiry-based learning model in the practice of science and engineering. Students are divided into 5 groups with simple seismograph output and earthquake resistant buildings. With the project, students will learn how to apply define, develop solution, and optimize stages.

Two competencies in engineering ability, namely competence in understanding the basic principles of technology (competency 1) and competence in developing solutions and achieving goals (competency 2), are the focus of the assessment. The engineering abilities of students were measured by using a multiple choice test consisting of 6 test items on the competence of understanding the basic principles of technology that have previously been tested using Anatest. While students' abilities in the competency 2 were measured by the work on Student Worksheets contained in teaching materials.

The results showed that the average scores of students' understanding in the basic principles of technology were in the medium level (Table 1). Overall, students in groups are able to explain the features of a system or process, identify examples, explain the characteristics of material differences that are suitable for use as products, analyze needs and group elements of the system to be made. In the competence of developing solutions and achieving goals, overall indicators, 3 groups showed the achievement of scores with a high category and 2 groups were in the medium category. In this competency, students' abilities are measured by the work on Student Worksheets contained in teaching materials. Interestingly, the group that gets a moderate category score in competency 1, allows getting a high category score in the competency 2 (Table 1).

TABLE I. Average Value of Two Competencies in Engineering Ability of Student Groups

Competencies	Group				
	1	*2*	*3*	*4*	*5*
Understanding basic principles of technology	82.5 (Medium)	83.3 (Medium)	66.7 (Medium)	77.8 (Medium)	72.2 (Medium)
Develop solutions and achieve goals	85.0 (High)	80.0 (Medium)	90.0 (High)	75.0 (Medium)	90.0 (High)

Table 2 shows the average score of the students based on the indicators developed for competence 2. It can be seen that students in the groups are able to make maximum product designs using appropriate materials and processes. Students are also able to develop techniques that are possible. In the optimize phase, students are able to test and to improve the product endurance by redesigning it.

TABLE II. Average Score of Indicators of the Competence in Developing Solutions and Achieving Goals of Student Groups

No	Indicators	Group				
		1	*2*	*3*	*4*	*5*
6	Design products using appropriate materials and processes	4	4	4	4	4
7	Developing possible techniques	3	3	3	3	3
8	Test models and prototypes	3	2	3	2	4
9	Solve damage problems	4	4	4	3	4
10	Plan product durability	3	3	4	3	3

Based on the learning process, group 1 was able to evaluate the prototype of a simple seismograph when tested. Group 1 gets the maximum value on indicator 6 (Table 2). Group 1 has been able to develop techniques that make it possible to make prototypes. The members of group 1 work together and all of them know in designing, assembling bracing, and making a simple prototype size balanced seismograph. After making a prototype and testing the product, students observe the deviations formed during an earthquake, in this case the prototype is placed on the shake table (earthquake table). Students in group 1 shared roles, including holding a stopwatch to observe time, moving the shake table, taking notes, and observering what happens on the prototype while simultaneously pulling a roll of paper on which the seismogram is formed. Students able to distinguish large deviations when a weak earthquake and a strong earthquake. In indicator of solve damage problems, the score of group 1 reaches the maximum by being able to mention the weaknesses of the seismograph testing process accompanied by a prototype endurance plan through prototype redesign The learning process at this optimize stage will make students in group 1 learn from failure. Weakness of the product being tested will make students able to evaluate and plan the next activity that is at the redesigning indicator. The process of solving these problems is very valuable for student creativity, by identifying the best solutions by looking at solutions that have existed before even from failure [11-15]. So that students' knowledge is intact in understanding a concept. The group seemed enthusiastic about carrying out STEM learning. With the wholeness of knowledge and the existence of learning that builds engineering capabilities in science education, it can help prepare students to engage directly in society when meeting current and future challenges in modern and technological challenges [16-17].

Referring to Table 2, group 2 reaches indicator 6 with a maximum value. Students are able to design products using appropriate materials and processes. In practice, students make a prototype with a ruler and neat with a size according to what is designed. In indicator 7, students are sufficient to develop techniques that are possible in making products. There is already a good division of roles between members and mutual assistance if there is difficulty in installing needles on a simple seismograph prototype. The simple seismograph prototype is quite complex and requires compact collaboration. In the process of working on the product on the student worksheet, group 2 gets the lowest points on indicator 8, which is to test the model and prototype. As in Figure 8, group 2 has been able to design well accompanied by size in each section. However, when testing the needle on a simple prototype seismograph it did not work well so the needle was unable to show a well-read seismogram. In indicator 9, group 2 reaches the maximum value. When group 2 discovers the phenomenon of needles that are not upright so seismograms are not formed, group members directly look for weaknesses in the prototype and fix it properly. So that the indicator 10 shows the value which means that group 2 is capable enough in planning product endurance. In indicator 9, group 2 reaches the maximum value. When group 2 discovers the phenomenon of needles that are not upright so seismograms are not formed, group members directly look for weaknesses in the prototype and fix it properly. So that the indicator 10 shows the value which means that group 2 is capable enough in planning product endurance.

Based on the results of the two competition scores on engineering ability as in Table 1, group 3 gets the lowest average score in competency 1. Interestingly, they got the highest scorein competency 2. This shows the difference between understanding and skills in making products. Based on the results of the analysis during learning, group 3 has not been able to reach indicator 4 (analyze needs). The indicator 4 with the aim of students being able to analyze the needs, shows the medium category. The indicator 7 will train students to determine the tools and materials according to their needs, as an engineer who needs to consider the tools and materials used in order to effectively and efficiently solve the problem [18]. However, students in group 3 have not been able to carry out this competency with the analysis that students have not really been working on the activity "It's time to become an analyst engineer". Students are given 3 forms of earthquake resistant building innovations in several cities in Indonesia. Then, students are invited to work on the material analysis and construction activity sheet of the building. So, students will be able to work on indicator 1 well. In competency 2, group 3 is able to complete the activities on the student worksheet at the fastest with a very good average score of 90. Group 3 gets the maximum value on indicators 6, 9, and 10. So that group 3 is very capable in designing products with the right ingredients and processes. Students are able to write tools and materials as well as details with size. Group 3 has been able to test the model or prototype so that this is next able to plan product durability.

Group 4 got almost the same average score of competencies 1 and 2. Based on the working on the Student Worksheet, group 4 requires the most time in making prototypes. When compared to groups 1, 2, 3 and 5, group 4 gets the lowest score on the competence of developing solutions and achieving goals. Group 4 has not reached indicator 8 properly. The process of testing a prototype in learning activities build student knowledge in finding concepts as well as learning from failure. Figure 1 shows the earthquake resistant building product made by group 4 (A) and group 5 (B). Both images are buildings that have been tested on a shake table. From these simulations, students know that building construction and installation of bracing affect the strength of earthquake resistant buildings. This stage is called the optimize stage. After that, students can improve the building so that it has better building durability. The process of solving these problems is very valuable for student creativity, by identifying the best solutions by looking at solutions that have existed before even from failure. Students who initially make prototypes according to the first design will learn to identify prototype weaknesses and improve them. The engineering design process is a decision making process (often repetitive), in which the basic sciences, mathematics, and engineering are applied to optimally convert resources to meet stated goals. The design process is a series of events and a set of guidelines that help determine a clear starting point that makes the designer visualize a product in his imagination to manifest it in real life systematically without hampering their creative processes [19]. STEM education gives educators the opportunity to show students how the concepts, principles and techniques of STEM are used in an integrated way in the development of products, processes, and systems used in their daily lives. Therefore, the definition of STEM education was adopted as an interdisciplinary approach to learning.

Group 5 gets an average score of engineering ability on competency 1 of a medium category. In contrast they get the highest score on each indicator in competency 2 (Table 2). Referring to the results of work and experiments, group 5 is very good at making earthquake resistant building prototypes. In indicator 6, group 5 gets the maximum value. Group 5 has been able to make designs with good sizes, materials and processes. Furthermore at indicator 7, the group members have been awakened division of roles with each other. For indicator 8 group 5 gets the maximum value. This is evident from the results of testing, a strong prototype with bracing (stakeholder ribs) that makes an earthquake resistant building does not change its position when it is on the earthquake table and is given a load. However, group 5 still provides additional bracing to strengthen the building at the redesign stage which is an achievement of indicators 9 and 10 where students are able to show the weaknesses of the prototype that was made and how to fix it. This shows the optimize activity with the trial process, students are able to know the weakness of the prototype and plan the durability of the prototype by making a redesign. STEM learning by practicing engineering skills, will train students in using scientific and mathematical knowledge in making products and even give an idea of how professional engineering workers work [18-19].

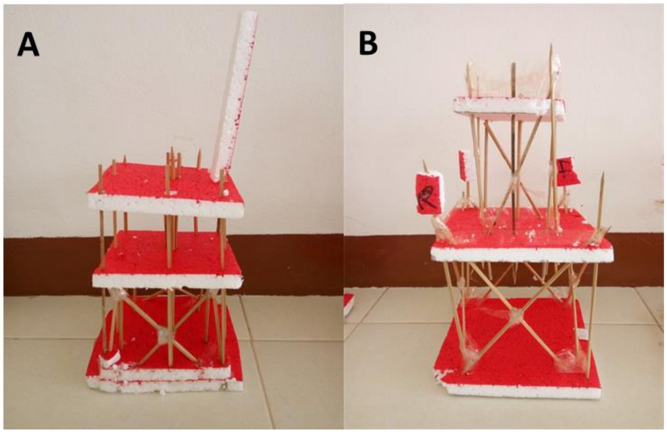

Fig. 1. The condition of the damage to the prototype of the earthquake resistant building after testing made by group 4 (A) and 5 (B).

IV. Conclusion

The application of teaching materials show the average value of engineering ability in competence in understanding the basic principles of technology in the medium category. For the use of STEM book, earthquake themes using the 4S TMD method can build students' engineering abilities. Engineering ability of students in competence to understand the basic principles of technology, the five groups get grades in the medium category. Students' engineering ability on developing competencies and achieving goals, 3 groups get high grades and 2 groups get medium grades.

Acknowledgment

The authors are grateful to Middle School Alfa Centauri who has allowed to do research at school.

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