Mathematics learning in elementary school through engineering design process method with STEM approach

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Abstract. Education is developed to prepare students to face possible problems that might arise in the future. Recent trends show that many job opportunities in the fields of Science, Technology, Engineering, and Mathematics exist in the industrial world, but most of them think that school graduates are not in line with the needs in the field. One of them is because people are too focused on one area. Therefore we need the development of learning that can integrate various subjects, especially in the fields of science, technology, engineering, and mathematic. This research is intended to describe the development of mathematics learning through engineering design process method with STEM approaches. The method used in the form of a descriptive method with research subjects for six-grade elementary school students in Indonesia. The learning is based on mathematics about surface area and natural science about electricity. Through this research, it is produced that learning based on science, technology, engineering, and mathematics can provide exciting experiences and increase their interest in learning mathematics more deeply.

1. Introduction
Science, Technology, Engineering, and Mathematics (STEM)-based learning is a learning approach that was first conceived by the United States. This idea developed because the achievement of US children's test scores in math and science continued to decline [1]. The United States Bureau of Labor Statistics stated that 80% of the professions will need technology in 2018, and 8.5 million workforce will be needed in the STEM disciplines. STEM training can help students become problem-solvers and innovative and technologically literate citizens [2,3]. Seeing the achievements of the United States, this idea was seen as being able to improve student achievement in mathematics and science by other countries, then adapted to be the basis of learning in other countries. Countries in ASEAN did not escape this trend. In Indonesia, although not directly written in the curriculum, STEM-based learning is very suitable to be applied because it is in line with the 2013 Curriculum for primary schools where learning is carried out thematically [4]. The number of training or studies on STEM in teaching students in primary schools shows that education policymakers are interested in implementing it in Indonesia.

The STEM approach can be taught through a variety of learning methods. One of them is the Engineering Design Process method. Accreditation Board for Engineering and Technology (ABET). The ABET definition states that engineering design is the process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic sciences, mathematics, and engineering sciences are applied to optimally convert resources to meet a stated objective [5]. The stages of engineering design according to TeachEngineering.org can be seen from the Figure 1.
As one part of STEM, mathematics is one of the subjects that is considered difficult by students and even tends to be avoided. This has an impact on their lack of understanding of mathematical concepts and their application in daily life, one of the problems that occur in Indonesia is the concept of multiplication of school students who are still lacking [6]. Though mathematics is always everywhere, even as far as we avoid mathematics, in the end, we will be reunited. This problem does not originate from mathematics itself but arises from someone less fortunate in getting good experiences when studying mathematics. Therefore as educators, we are required to always provide good experiences when learning mathematics.

Monotonous learning of mathematics tends to decrease interest in mathematics itself whereas Mathematics if presented with an interesting thing and the concept is close to daily life in an interesting way it will be interesting too [7-11]. the lack of application of mathematics in schools is still an obstacle in learning. Other subjects such as science allow children to often practice the concepts taught, while mathematics is still rare. Therefore, this method can provide opportunities for students to apply mathematical concepts that are integrated with other concepts when learning.

Engineering design process is an interdisciplinary learning method that integrates aspects of science, technology, engineering, and mathematics. Together with STEM, this learning method is becoming a trend because it is believed to be able to answer the challenges in the future. That is because this approach is loaded with learning processes that practice 21st century skills commonly known as 4c namely Critical Thinking, Collaboration, Communication and Creativity [12].

Mathematics in elementary schools is separated from other subjects, whereas according to the 2013 curriculum, teaching learning is carried out using thematic. one of the reasons for this is due to the lack of mathematical teaching material that can be combined with other material. Engineering design includes the process of integrating disciplines, technology, engineering, and mathematics, which arise as a result of efforts to integrate parts that have been separated in a real-world context, because, only by removing barriers between them and integrating the boundaries between scientific disciplines can prepare students to face and understand complex problems faced in real life.

Because of the quality of learning, mathematics is presented to students in an abstract form. This causes problems where students will experience difficulties in transforming mathematics lessons with daily life [13]. This method comes with opportunities to minimize this. Learning is done more meaningfully and related to its application in daily life.
2. Method

The method used in this research is a descriptive study with a qualitative approach that aims to understand and obtain a picture that occurs in the field as it is without making changes or interventions on the research objectives reveal what it is. The research subject was elementary students in Cimahi, Indonesia. students who would be included in the sample in this study who were six-grade students.

The teaching material used in this study was taken from mathematics and science as a basis. both of these areas are the best footing in learning STEM for elementary school because it can foster student interest in STEM [3]. In mathematics, basic competence is taken about explaining the building space which consists of several building spaces, their surface area and volume, and identifying the building space which is a combination of several building spaces, and their surface area and volume. For science lessons, the basic competencies chosen were to identify electrical components and their functions in simple electrical circuits and conduct simple electrical circuit experiments in series and parallel.

3. Result and Discussion

3.1. Learning

Learning is carried out by inviting students to make a matching Game Project. Students will make a box where the front contains mathematical problems and the back of a simple electrical circuit. Every question and correct answer has been connected with an electrical circuit. The connecting part consists of an electric cable and an incandescent lamp which will light up as a sign that the question and answer chosen is correct.

The learning gives students the opportunity to be creative with imagination, giving rise to the creativity of each student where the results of the project are different. In line with the demands of 21st century learning To take advantage of future career opportunities, individuals need to develop 21st century skills, which include critical thinking, teamwork, problem solving, creativity, analytic reasoning, and communication [14].

Making subtle changes in the design and arrangement of lessons makes a fundamental difference in what students learn [15]. During learning, students look very motivated because they are given the freedom to improvise when doing projects. When referring to mathematics learning, project-based learning processes are very rarely implemented when compared to natural science learning. However, with engineering design process, every mathematical concept has the opportunity to be applied more in learning. Applying learning in different ways like this also increases learning motivation, as seen from the large number of students participating together giving ideas in making projects.

STEM education requires programs to include rigorous curriculum, instruction, and assessment, integrate technology and engineering into the science and mathematics curriculum, and also promote scientific inquiry and the engineering design process. All students must be a part of the STEM vision, and all teachers must be provided with the proper professional development opportunities preparing them to guide all their students toward acquiring STEM literacy [16]. The first problem that arises is indeed from the curriculum, mathematics that is learned separately becomes a new thing for teachers and students when they have to be taught together and look for connectedness and then look for ideas so that the relationship can be integrated.

Engineering design can enhance student creativity in making problem solving. The learning process through this approach gives students the freedom to plan their problem solving. Unlike conventional learning which usually contains worksheets that contain the process of applying information into the exact same form in an experiment with the aim of proving it.

3.2. Teacher

One reason for learning in elementary mathematics is separate due to the difficulty of finding topics or ideas that are in line with other subject topics. Integrating Mathematics with other subjects is difficult, as evidenced by the lack of mathematical material that can be collaborated with other subjects. Even so, the teacher becomes challenged to make this learning plan because it can reflect the connectedness that reflects the way the world works outside of school and helps students to develop their knowledge and ability to deal with changes and challenges in ways that make sense [17]. The way of thinking of teachers
who still cannot collaborate with other fields makes it difficult for them to follow the challenges of the times. The teacher is not accustomed to making big ideas that contain teaching material from various subjects. On the other hand, in practice learning separate ways of learning create difficulties for students because each subject teacher runs on their own.

The background of teachers who have expertise only in certain fields also influences learning. Before teaching integrated learning from several lessons, the teacher should have basic skills for the lesson. Basic engineering is difficult for teachers to understand, such as understanding the principles of engineering, understanding energy sources and their applications, machine systems, and the uniqueness of a material [18]. This is needed, because teachers will be required to have the ability to plan course content, select applicable teaching materials, and assign appropriate coursework is important since engineering teachers are responsible for developing curriculum and teaching new skills students.

3.3. Student

In the normal learning process, the opportunity to get meaningful mathematics learning is very minimal. Students are often confronted with numbers and the number processing. The application of practices related to daily life rarely appears in mathematics learning. According Australian Office of The Chief Scientist [19] this will affect student interest in mathematics at the next level because of the poor experience gained when meeting mathematics.

When teaching students with the engineering design process, students learn mathematics by applying it in real life, not only playing numbers but doing something about their mathematical calculations. During mathematics learning looks transparent and explicit, but even so engineering design is able to involve mathematics more in learning. The theoretical rationale for engineering design behavior as part of the STEM approach comes from curriculum integration theory. Integration curriculum or integrated teaching methods seem important for STEM education in terms of covering the interconnected nature of the four disciplines and real life [20].

Through engineering design behavior, students can learn from a big idea [21], and develop relationships that can realize these ideas. The idea can be related to other subjects outside mathematics and the integration of lessons can be a way to develop ideas. Each student shows interest when learning mathematics presented in the form of a project with the STEM approach. This can be seen from the amount of student participation when working on projects. However, in terms of technique, female students are more passive. Female students' interest in mechanics seems to be more minimal than male students.

Implementation of engineering design process method with STEM approach also has a significant impact on students’ cognitive learning outcomes. Moreover, the percentage of students mathematics learning outcomes for four meetings is presented in Table 1.

| Grade | Meeting |         |
|-------|---------|---------|
|       | Pre-test| Post-test|
| A     | 32%     | 81%     |
| A-    | 42%     | 19%     |
| B+    | 26%     | -       |
| B     | -       | -       |
| B-    | -       | -       |

Table 1 shows that 81% of 31 students on fourth meeting gain grade of A with excellent category while 19% gain grade of A- with good category.

4. Conclusion

Based on the results and findings of research such as the conclusions of this study, 1) Engineering design process can be an alternative for teachers in teaching mathematics. Mathematics learning that is usually
abstract and numerical will be directed to be applied to matters relating to daily life through the process of integration of several aspects. 2) Basic skills engineering is required for teachers when teaching with engineering design process, especially female teachers who are usually less interested in engineering. 3) Engineering design process can improve student creativity because students are required to come up with their respective ideas in making problem solving plans. Moreover it also have a significant impact for increasing students’ mathematics learning outcomes in cognitive domain.

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