Developing technology and engineering literacy for Junior High School students through STEM-based science learning

P Anjarsari[1], Z K Prasetyo[1] and K Susanti[1]

[1]Science Education, Universitas Negeri Yogyakarta, Sleman, Indonesia

Corresponding author: putri_anjarsari@uny.ac.id

Abstract. The 21st Century and the Fourth Industrial Revolution (4IR) require human resources to possess current life skills and technological mastery. This demand can be fulfilled through STEM-based learning. However, there are a few studies on STEM-based science learning to improve technological literacy. This study aimed at determining the effect of STEM-based science learning on technology and engineering literacy among Junior High School students. The method in this study employed a quasi-experiment with pretest posttest control group design in 2 classes. The experimental class was taught with STEM-based science learning, while, in the control class, the teacher used regular learning (scientific approach). The observation sheets of science and technology literacy were developed to measure the students' literacy skills. The analysis results showed that there was a significant difference in the technology and engineering literacy skills between the experimental class and the control class with the significance effect of STEM learning towards literacy ability was 64.10%. It indicated significant improvement from the experimental classes since STEM-based learning provided the opportunity among students to apply knowledge and to solve real-world problems through engineering processes that can enhance their knowledge mastery as well as encourage them to create something new.
Keywords: *STEM, literacy, TEL, technology, engineering*

1. Introduction

STEM stands for science, technology, engineering, and mathematics which has been used as the theme of the educational reform movement in 1990. The STEM-based learning integrates science, technology, engineering, mathematics through authentic contexts of problem-solving activities. The benefit of this learning model is promoting authentic learning since it contains the investigation process within the community/scientific environment [1]. STEM education is based on two learning theories, i.e. constructivism and constructionism. The constructivism focuses on the role of students as idea makers, while the constructionism states that the best way to generate ideas is through the construction of new products in the real world. [2].

STEM education has currently become an alternative science learning to build a generation readiness to face the 21st century challenges [3]. Science requires mathematics as a tool to process data, while technology and engineering role as science applications. Several countries have implemented STEM based learning. Broadly speaking, the purpose of STEM education in several countries is to prepare a workforce that can boost the national economy towards the changing global economic conditions. The results of STEM education are human resources that possess 21st century skills to be able to compete in the global era [4]. Actually, the current curriculum applied in Indonesia (the 2013 curriculum) has been in line with the requirements of 21st century skills and the Fourth Industrial Revolution (4IR). The STEM-based science learning design in the 2013 curriculum can develop students' critical thinking, creativity, communication, and collaboration skills, and also strengthen the character of religious, nationalist, independence and cooperation [5]. Moreover, the survey results indicate that teachers in Indonesia have realized the importance of STEM application during learning process [6]. However, it is necessary to enhance the learning approach among teachers in order to optimize the efforts in developing students' competency based on global needs.

The STEM integration can be more effective if it is completed with some strategic approaches in its implementation [4]. Some researchers have applied STEM-based learning, for example the application of STEM learning towards student achievement [7], motivation learning, creativity, and conceptual understanding of science [8], [9], STEM interests [10], students' personal intelligences profile [11], science literacy [12], as well as students' STEM literacy [13], [14]. Other researchers have also created STEM-based activity programs and tested its effectiveness towards STEM interest [10], as did by Abdurrahman through the development of STEM learning maker space to develop 21st century skills (critical thinking skills, creativity skills, and problem solving abilities) [15]. On the other hand, the studies on STEM learning to improve the technological skills and engineering literacy are still in limited number. A few studies in the United States Japan and Indonesia shows various methods of STEM implementation that have involved students in engineering design in facilitating them with technology and engineering literacy [16]. This study focuses on the implementation of STEM-based science learning as an effort to enhance the technology and engineering literacy among Junior High School students.

Technology and engineering are indeed different but there is an extremely close connection between them. Technology refers to a product from a certain engineering process, while engineering is considered as a process relating to creating or designing. Technology can be defined as a modification of the natural environment to meet human needs or desires, while engineering is a systematic and repetitive approach to design objects, processes, and systems to meet human needs and desires [17]. Engineering is also described as the knowledge about the design and creation of man-made products and the process to solve certain problems in case of time, money, material availability, environmental regulations, and others. [18]. Technology and engineering literacy (TEL) can be seen as the ability to understand and use basic knowledge and skills related to technology principles and strategies needed to achieve goals and problem-solving.

The implementation of STEM-based learning in this study was done through science learning in Junior High School by taking the topic of liquid pressure material. The three TEL areas in this study refer to [17], i.e. technology and society; design and system; technology, information, and communication. The outcomes of this model are the students' ability to understand the working principle of technology, problem solving skills, and effective communication and collaboration skills.

2. Research method

2.1. Research Design and Participant

This research employed an experimental study with pretest posttest non-equivalent control group design. In this study, the experimental class was treated with STEM based learning, while the control class with regular learning activities (without STEM based learning). The participants of this study were 7th grade of 2 Playen Junior High School consisting of 64 students who were divided into 2 classes with 32 students in each class.

2.2. Data Sources and Analysis

The measurement of students' technological and engineering literacy skills was obtained through observation sheets based on NAEP indicators. The research instrument of this study had been through the expert judgment process. The escalation of TEL was analyzed using Anava mix design with the

IBM SPSS 22 software program. It was called Anava mixed design because it combined two sub analysis within subject and between subjects. The within subject test was to examine the scores differences in one group (pre and post), while the between subject test was to reveal the testing scores differences between groups (experiment and control). The magnitude of the variable changes due to the treatment of 2 classes can be seen through pairwise comparisons, while the significance of the influence can be seen from the value of partial eta squared.

2.3. Experimental and Control Group Treatments
The experimental class was treated with STEM-based science learning, while the control class used the regular learning process, i.e. a scientific learning approach, by the teacher. Both were given the same material on the liquid pressure. The prominent difference from the experimental class was on the students' assignment to design technology in the form of submarine with surrounded objects, while the design control class had no this kind of instructions.

3. Results and Discussion
In the experimental class, the students started the learning activities by assessing the material to be used for the experiment. It was followed by making a design and engineering process with the available tools and materials. After that, they realized their design and communicated them in class with some technology device. Through these activities, the students had the opportunity to understand knowledge related to the basic principles of technology where it can be seen through the students' ability to provide solutions to a problem in technology and through product development. The learning activities were carried out in groups to encourage students in completing their tasks collaboratively and to arouse the students' communication skills with peers through the use of technology, i.e. making media presentations. Technology such as ICT can be leveraged to communicate, collaborate, solve problems, accomplish task and as construction material [2]. The STEM-based learning activities were done with each component as listed in table 1 below. The science learned by students used as basic knowledge for technology development, while technology served as tools to gain knowledge [19].

Table 1. STEM-based learning activities.

Components	Activities
Science	Liquid pressure (Archimedes laws)
Technology	Submarine
Engineering	Making submarine with surrounded objects
Mathematics	Calculating buoyancy force

During learning activities, the students carried out activities guided by worksheets including tables to help the design process. The table consisted of columns containing tools/ materials, usages, quantities, and information. After students filled out the table, they also wrote down the procedure to realize their designs into a technology product. The design was also made in the form of images to make it easier for create creation. Figure 1 shows one of the results from the submarine design created by students. After students designed a submarine, they made it into a technological product and tested the final product they created. The trial activities were also carried out to direct students to have contact with mathematics, i.e. buoyancy force calculation.

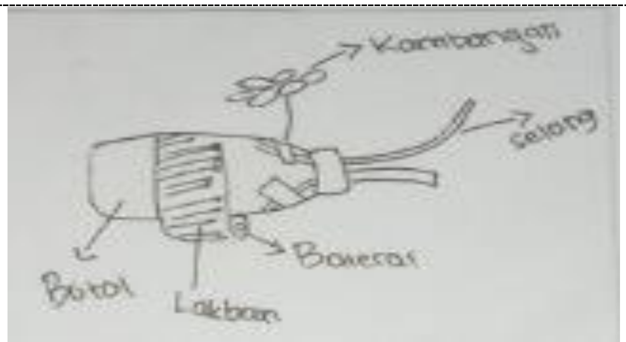

Figure 1. Examples of submarine designs by students (materials used in submarine designs: bottles, duct tape, batteries, buoys, hoses).

Based on the analysis results using Anava mix design, it can be concluded that the partial eta squared value was the student's TEL ability with 0.641, it indicates that STEM-based science learning can enhance the students' technological and engineering literacy by 64.10%. The effect of STEM learning on TEL ability in each aspect is presented in table 2 below.

Table 2. The analysis results on the effect of STEM-based science learning on each aspect of technological and engineering literacy.

TEL Aspects	The significance influence of (Partial Eta Squared)
Understanding the basic principles of technology	52.00 %
Creating solutions to achieve goals	17.20 %
Communication and collaboration skills	89.50 %

The biggest influence of STEM learning occurred on the aspects of communication and collaboration, followed by aspects of understanding the basic principles of technology and creating solutions to achieve goals. STEM learning had a great effect on communication and collaboration skills because students experienced new things, so they were eager to share their ideas and design. The ability to understand the basic principles of technology emerged from the authentic problems conveyed by the teacher so that students were able to propose solutions and alternatives. One indicator of developing solutions to achieve goals was designing and making products with the right processes and tools. In this case, the students were not optimally able to develop their abilities because the students were not familiar with the activities of product design and manufacture, so they found it difficult during this process. They usually conduct experiments with common instructions given by the teacher. The learning that involved the design and engineering process needs to be accustomed to the students in order to make them able to think critically and to solve problems creatively through products creation.

The research result is accordance with the previous research stating that STEM learning through designing boat project gives a large effect in improving the technology-engineering literacy [14]. This is consistent with the theory that the focus of integrated STEM is on the fostering innovation and invention as well as promoting technology literacy [2]. In addition, to optimally involve students in the STEM education programs, it should be included in curriculum, learning, and assessment as well as by integrating technology and engineering in the science and mathematics curriculum and emphasizing scientific inquiry and engineering processes within learning activities [20].

4. Conclusion

Based on the analysis results, the STEM-based science learning applied has a positive effect on technology literacy skills and engineering among the students of Junior High School. It means that the technology and engineering literacy can be developed through STEM-based learning. The biggest influence was on the aspects of communication and collaboration, followed by the aspects of understanding the basic principles of technology, while the smallest influence was on the aspects of understanding solutions to achieve goals.

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Acknowledgments
We would like to express our gratitude to faculty mathematic and natural science, Yogyakarta state university who have provided research grant and State Junior High School 2 Playen who have supported this research activity.