STEM Learning on Electricity using Arduino-Protoboard Experiment to Improve 8th Grade Students' STEM Literacy

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Abstract. This research aims to investigate the effect of STEM learning on STEM literacy in learning electricity concept. The method used in this research was Weak Experimental method. The quantitative data of this research is gained through objective test, while the qualitative data was gained by observation sheet. According to the analysis of the study, it is obtained an improvement in students' STEM literacy, especially in technology, engineering, and mathematics literacy while students' scientific literacy shows negative improvement. The increase of students' science, technology, engineering, and mathematics literacy obtained through normalized gain systematically by -0.02, 0.22, 0.12, and 0.03 categorized as low improvement. Even though students cannot relate the scientific concept occurs during the experiment, students are excited to conduct the project using Arduino-Protoboard experiment since they had the experience to use the latest kind of technology.

Keywords: STEM Learning, STEM Literacy, Arduino, Protoboard experiment, Electricity

1 Introduction

Learning is a process in which a person converts knowledge from one person or another media and applies it as a skill to achieve the learning objective. Today, this definition of learning cannot be seen as the education pillars due to the globalization. Learning is not only seen as a shallow activity as only converting knowledge, but also can improve the ability of a person to be able to adapt with the technology development to solve unimaginable problems in the future. UNESCO declares there are four purposes of learning to reshape global education, such as learning to know, learning to do, learning to be, and learning to live together. By integrating cognitive ability, provide usable skills, and exposing individual values of a person, a person's condition can contribute a lot in the citizen life [1]. Due to the urge of technology, the learning instruction should be moved from the traditional paper and chalk method into hands-on activity to obtain the learning objective above.

The content that will be taught for the students should be linked with the use of technology and enable them to engage students' understanding, skills, and performance. Science is the study of natural phenomena that should be measured systematically. Science considered the entire content because science education objective is that students are prepared to solve the real-world problems on their environment by producing appropriate solutions

MSCEIS 2019, October 12, Bandung, Indonesia

DOI 10.4108/eai.12-10-2019.2296437

[2,3]. However, during the process, there are several problems that should be faced by science educators. The assumption of science is a hard and difficult subject to learn make students are afraid to learn science and they will fail to pass on this subject, before even they trying, especially in Indonesia. This condition reflected on Wulandari and Jailani study in 2015 shows that Indonesian students have a lack of problem-solving skills, reasoning and proofing, communication, connection, and representation. Students only have great memorization, while they would not be able to apply what have they learn into real-world problems. The science learning phenomena will become worse if science educators do not innovate themselves and lead to interfering with a nation's educational ranking in global. This is proven by Indonesian's students mathematical average scores in eighth grade (this time Indonesia does not include grade IV) only 386 and ranks 38th out of 42 countries, while in science, Indonesia ranks 40th out of 42 countries with an average value of 406 based on Trends in International Mathematics and Science Studies (TIMSS) result in 2011 [4].

As the answer to the problem above, a new educational reform is made and named as STEM education. STEM is an acronym of four integrated disciplines; there are science, technology, engineering, and mathematics. STEM Education associates with the instructional process that can be applied in both formal and informal education in which science, technology, engineering, and mathematics are used as the ground of the instruction [5]. According to Bybee (2013), the aim of STEM education focuses on the fulfillment jobs in STEM professions, the ability to adapt with each STEM literacy, willingness to actively involves in STEM fields, and the increase of student achievement [6]. STEM education facilitates students to have a better understanding and meaningful learning by crosscutting the science concept with the engineering design process[7].

The electricity topic is chosen because it represents the science concept that relates to our daily life. In learning electricity, most students have difficulty in understanding the nature of electric current on the electrical circuit and its application in everyday life [8]. Based on the interview with the physics teacher in the school sample, the electricity concept usually taught using multimedia demonstration and rarely experimenting using actual electrical components. The consideration is to equipment damage in the laboratory, and conventional tools tend not to be practically used during experimental activities because it has a bigger size. Therefore, the researcher introduces the Protoboard experiment as an alternative experiment because it only needs smaller components and more comfortable to conduct rather than conventional research.

Arduino is a hardware platform based on a simple microcontroller that processing the specific processing language. The benefit of using Arduino is people can make prototype various electrical designs without spending a lot of costs. As an open-source microcontroller, Arduino can be used for beginners to arrange and test the electric circuit design [9,10]. Arduino experiment is a proper activity to enhance students' learning and attitude towards STEM education. The researcher assumes that Arduino might enhance students' curiosity and engage creatively to solve real-world like problems by creating many innovative things it capable of. In this research, the Arduino Protoboard-based experiment is proposed by the researcher to develop students' STEM literacy in learning electricity. Due to the limitation of electricity in the school laboratory, Arduino is the appropriate alternative tool to implies electricity concepts since it can provide an introduction to the use of current technology and engineering for students.

According to the background, this research aims to improve students' STEM Literacy in learning electricity by applying STEM Learning helped by Protoboard Based Experiment. This prior research will be conducted by designing and analyzing the lesson plan, the

worksheet, and the test instrument about STEM Literacy on electricity implemented on 8th-grade students.

2 Research Method

The research method used in this research was the Weak Experiment method using one group research without classroom control. This method was used to analyze the interrelationship within the variables and investigate external factors that might influence the research result [11]. In this research, the researcher using STEM Learning as the independent variable and students' STEM Literacy as the dependent variable.

The design was used in this research is one group pretest and posttest design. This design is able to measure the impact of the treatment given before and after getting implemented in one group research subject. This design is appropriate with the purpose of this research which to investigates the impact of STEM learning using Arduino-Protoboard Based Experiment towards students' STEM Literacy. In this research, students were given a test to know their prior knowledge or pretest, STEM Learning using Arduino-Protoboard based experiment as the treatment on the learning process, and after the concept given the treatment of the final posttest will be conducted.

The research was conducted in Private Secondary School in Bogor, which applied Indonesia National Curriculum 2013 and Cambridge IGCSE curriculum in the learning process. The population of this research was all of the 8th-grade students in the school. The sample is 16 students of class 8N which applied inclusive learning process inside the classroom. The sampling technique is Simple Random Sampling. Simple random sampling is one in which each and every member of the population has an equal and independent chance of being selected [11].

3 Result and Discussion

3.1 STEM Learning Lesson Plan Analysis

In this research, the lesson plan used as an instrument to measure the implementation of STEM learning on electricity. The researcher constructs a lesson plan through three preparation stages. The preparation stages are: analyzing the curriculum, determining the topic to be taught, and relates the lesson using STEM learning steps. First, The researcher analyzes the Cambridge IGCSE Physics syllabus to determine whether STEM learning is suitable to be implemented along with the Cambridge IGCSE curriculum that provides students enable to have a better understanding and life-long skill using current technology and enables to apply the disciplines in daily life. The objectives are suitable for STEM learning's standard to develop students' understanding through scientific practices to solve real-world problems by crosscutting science ideas and technology [12]. Second, The researcher determines the electricity topic which is taught to the sample students. The researcher limits the concept into an electrical circuit, electrical components, and electrical quantities (current, potential difference, and resistance). Then, the researcher lists the learning indicators and learning objectives for each meeting. Third, the researcher relates the activities into STEM learning

steps in this research, STEM learning used as a learning approach. The stages of STEM Learning implemented in this research are adapted based on Jolly [13] as tabulated in Table 1.

The implementation of STEM Learning was conducted in three meetings, including pre-test and posttest. During the implementation, the observation sheet used to check the learning activity whether it is consistent with the steps on the lesson plan or not. The form of observation sheet made for three meetings, with a different sequence of STEM learning at each meeting. The observation sheet is used by another observer (subject teacher and other researchers) to get an objective result in implementing the STEM learning lesson plan. Besides, the researcher also used a video recorder to obtain the students' learning activities.

Arduino Traffic Light as one of the interesting projects was conducted as the third activity of STEM learning implementation. All of the STEM learning implementation steps have been conducted by the researcher. At first, students were introduced to Arduino components and functions of the Arduino script. Then, students are asked to demonstrate the 'blink' function on Arduino. In this meeting, students were getting curious to manipulate the coding variables in Arduino software. Students also enable to determine their own fault while they construct the circuit. One of the groups also relates to the real situation of the traffic light in Indonesia. They mention that the red lamp duration in every traffic light is too long. The groups' project using Arduino is shown in **Figure 1**.

Fig. 1. Samples of students' Arduino traffic light project.

Table 1. Summary of STEM learning lesson plan.

Meeting	Activity	STEM Literacy Learning Indicator
1st	- Introduction (Shows students the application of electrical circuit in daily life) - Pretest - Constructing series and parallel circuit on Protoboard using the battery, Protoboard, LED, resistor, and jumper wire	**Science Literacy:** - Students state the sum of the potential difference across the components in a series circuit is equal to the total potential difference across the supply - Students state the current from the source is the sum of the currents in the separate branches of a parallel circuit **Technology Literacy:** - Students are able to use and describe the use of an ammeter - Students are able to use and describe the use of a voltmeter **Engineering Literacy:** - Students conduct an experiment to determine resistance

	- Measuring voltage, current, and resistance using a multimeter	using a voltmeter and an ammeter **Mathematics Literacy:** - Students recall and use the equation $R = V / I$
2nd	Constructing series and parallel circuit on Protoboard using YWRobot	**Science Literacy:** - Students are able to determine the energy on electrical circuit flows from the battery or power source to the circuit components then into the surroundings - Students are able to relate the current, resistor and potential difference in both series and parallel circuit **Technology Literacy:** - Students are able to measure potential difference (p.d) across a circuit component in volts using a voltmeter - Students construct electrical circuit containing sources, resistors, lamps, YWRobot, jumper wires, ammeters, and voltmeters **Engineering Literacy:** - Students draw and interpret circuit diagrams containing sources, resistors lamps, YWRobot, jumper wires, ammeters, and voltmeters
3rd	- Making Traffic Light project using Arduino - Posttest	**Technology Literacy:** - Students construct traffic light circuit containing sources, resistors (fixed and variable), lamps, Arduino, jumper wires **Engineering Literacy:** - Students draw and interpret traffic light circuit diagrams containing sources, switches, resistors, lamps, Arduino, jumper wires

3.2 STEM Test Instrument applied to STEM Learning on Electricity using Arduino-Protoboard based Experiment

To analyze the whole profile of students' STEM Literacy, the improvement of each STEM literacy needs to be processed. The test item was designed to interpret students' capability based on STEM Literacy. There are four literacy which available on the test, Science Literacy, Technology Literacy, Engineering Literacy, and Mathematics Literacy. The result shows that Science Literacy, Technology Literacy, Engineering Literacy, and Mathematical Literacy with n gain orderly -0.02, 0.22, 0.12, and 0.03 categorized as a low improvement based on Hake (1998). The increase of pre-test and post-test is depicted in **Figure 2**.

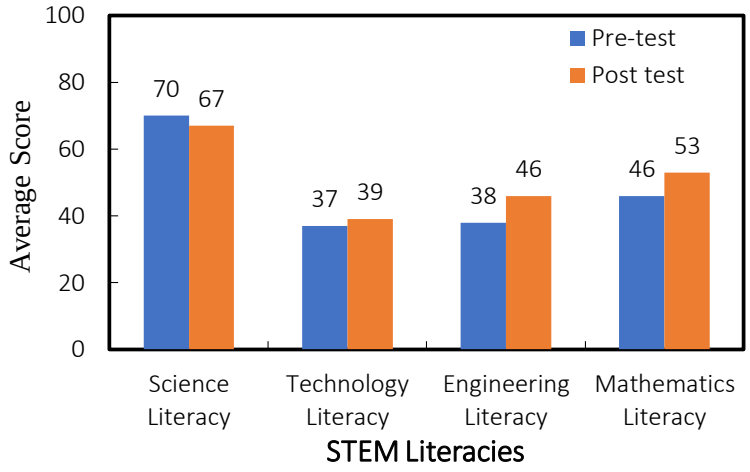

Fig. 2. Result of pretest and posttest students' stem literacy per aspect.

Students' Science Literacy Analysis. There is a negative improvement in science literacy after STEM learning being implemented. Students' science literacy normalized gain value during the posttest is lower than science literacy normalized gain during the pretest. The decrease of science literacy in students' STEM literacy occurred due to the leakage of content development. From three meetings, only in the first meeting, the researcher develops students' science literacy. The teacher mostly focuses on technology use rather than develop the science concept for each concept.

Students' Technology Literacy Analysis. There is an improvement in students' technology literacy after STEM learning being implemented. The normalized gain <g> value is 0.02. It shows that STEM Learning affects students' technology literacy at a small level. The improvement of students' technology literacy occurred due to the use of different types of technology for each meeting. In the first meeting, students are introduced to use different kinds of electrical components, such as breadboard, LED, resistor, and jumper wire. In the second and third meetings, students were focused on operating the technology, such as YWRobot and Arduino. Students were very interested in using Protoboard and other electrical components because they can explore the use of each component on the circuit. Tseng et al. (2008) on his previous study supports that students have a great interest in working with new technologies because it can be very beneficial for them to use it in society.

Students' Engineering Literacy Analysis. There is an improvement in engineering literacy after STEM learning being implemented. The normalized gain <g> values of students' engineering literacy are 0,12. It is shown that STEM learning affects students' engineering literacy at a small level. The improvement of students' engineering literacy occurred due to the implementation of the engineering design process at each meeting. For each meeting, students have to solve problems related to the circuit. Students have to develop their idea and make the design to solve the problem. For example, in the first meeting, students are given a figure about series and parallel circuits. Before students construct the circuit, they have to analyze the type of circuit, how the circuit can produce the light, and circuit arrangement as

part of their problem. After analyzing the circuit, students have to arrange the circuit diagram on the worksheet as part of the design. Then, students construct the circuit regarding their design. If there is any mistakes happen, they have to identify the error and solve the problem.

In the second meeting, students are challenged to construct the circuit based on the diagrams. Then, they have to interpret component symbols such as LED, voltmeter, ammeter, battery and attach the component into the breadboard. In the third meeting, students are challenged to modify the traffic light circuit by using various components and modify the variable on Arduino sketches. These activities show that students require to tear up their logical thinking so that they are able to solve the problem systematically and assumed they have meaningful learning from it. Anwari [7] study showed that the scientific process will occur naturally by breaking down their logical thinking. Thus students enable to answer the question of electromagnet and magnetism implementation in real life.

Students' Mathematics Literacy Analysis. There is an improvement in students' mathematics literacy after STEM learning being implemented. The normalized gain <g> values of students' mathematics literacy are 0.03. It shows that STEM Learning affects students' mathematics literacy in a small level. According to Hammonds [14], the implementation of technology and engineering improve students' understanding of science and mathematics. The improvement of students' mathematics literacy in students occurred because they engage the technology such as Arduino, LED, YWRobot, breadboard, jumper wire, a resistor with the knowledge of current, voltage, and resistance. Students enable to interpret the measurement data from multimeter into a table and interpret the Ohm's law formula.

4 Conclusion

The test instrument towards STEM learning implementation shows a definite improvement in students' technology literacy, students' engineering literacy, and students' mathematics literacy while it shows a negative increase in students' science literacy. It can be noticed by processing students' normalized gain for each aspect by -0.02, 0.22, 0.12, and 0.03. The improvement obtained by focusing on technology and engineering activities rather than giving the science concept.

Based on the findings of the research that has been conducted and concluded, there are several recommendations that necessary to be undertaken by the researchers, some of them are First, at assign students' working group, the teacher should be able to know the characteristic of students. The teacher should give attention to motivational factors and provides an intensive learning process. Second, the research instrument should be completed by student's interview and questionnaire to gain students' experience in STEM learning, Third, The research duration should be conducted in the more extended period to increase the students' engagement on electricity concepts and technology. Fourth, to other researchers who also have the same interest to implement STEM learning, it is recommended to research with advance physics educators to sharpening students' concepts.

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