STEM learning on electricity using arduino-phet based experiment to improve 8th grade students’ STEM literacy

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Abstract. Technology is the application of scientific knowledge for practical purposes, especially in industry. One way to support the development of the technology is by integrating the use of technology and build the technology with the learning process in the form of STEM (science, technology, engineering, mathematics) Learning approach. Applying STEM Learning could improve Students’ STEM Literacy. The learning approach is applied in every aspect of Learning including the application of STEM Learning in the lesson plan and worksheet. The method used in this research is weak experimental method. One group class (N=15) is taken and learn using STEM Learning approach. The topic choosen is the electricity topic which is separated into electrical circuit and parameters. The learning process is separated into 3 meetings. 15 Students are given a STEM Literacy test item before and after the lesson. The result of the normalized gain shows there are improvement in students’ STEM Literacy by <0.16 categorieed as low improvement. The most higher improvement is the students’ technology literacy, because students learn using the same technology in every meeting. This factor influences students’ technology literacy so the result is higher than another.

1. Introduction

STEM is an approach of learning that traines student to solve problems in a holistic way. The components inside the STEM consist of science, technology, engineering and mathematic. Each component has the intersection between one component and other component [1]. By using STEM learning approach, the competencies of high-tech knowledge-based economy can be done in the classroom [2]. STEM Literacy consists of 4 aspect that has been included 21st century skills into the 4 STEM literacy aspects [2]. One tool for helping students become STEM literate is STEM education [3]. STEM literacy in this research defined as: 1) Science literacy according to National science Education Standard (1996) is knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs and economic productivity [4]. 2) Technology literacy according to National Assessment Governing Board (2010) is capacity to use, understand, and evaluate technology as well as to understand technological principles and strategies needed to develop solution and achieve goals [5]. 3) Engineering literacy according to Organization for economic cooperation and development (2013) is ability to systematically and creatively apply scientific and mathematical principles to practical ends such as the design, manufacture, and operation of efficient
and economical structures, machines, processes, and systems [4].

4) Mathematical literacy according to Program for international Students Assessment, capacity to identify, understand, and engage in mathematics, and to make well-founded judgements about the role that mathematics plays in an individual’s current and future private life, occupational life, social life with peers and relatives, and life as constructive, concerned, and reflective citizen [4].

Here in the research, researcher attempts to use Arduino™ as the microcontroller of the circuit. Arduino or microcontroller is the device that can control how the component in the circuits are connect or disconnected independently. The control command can be controlled from computer or programmed by the computer using arduino’s Software. The name of Arduino is given from the original makers [6]. To support the learning process, researcher give the treatment before the project. The treatment is in the form of simulation. Students use PhET (Physic Education Technology) to simulate how to make a proper circuit. PhET is multimedia learning which serve us the interactive simulations for science and math. This program are published by University of Colorado and supported by The William and flora HEWLETT Foundation, NSF, O’Donnell Foundation, Gordon and Betty MOORE Foundation and many more. To Access the PHET Interactive Simulation, we can access it freely online or offline on www.PhET.colorado.edu.

According to the introduction, this research aims is to improve students’ STEM literacy in electricity by applying STEM learning helped by Arduino-PhET based experiment. This prior research will be conducted by designing and analyzing the lesson plan, the worksheet, and the test instrument about STEM Literacy onelectricity implemented to 8th grade students.

2. Methods

2.1 Research design and sample
The research method used in this research was mix method. We used quantitative data and qualitative data Creswell (2014). The design that used in this research is weak experiment. The research used one group pre-test and post-test design as seen in Table 1 [7].

| Pre-test          | Treatment          | Post-test         |
|-------------------|--------------------|-------------------|
| Observation₁     | STEM Learning      | Observation₂     |
| Approach          |                    |                   |

The location of this research was at an International Junior High School in Bogor. The learning process delivered in english. This school followed Cambridge International Curriculum modified with Curriculum 2013. The population in this research will be 8th grade students. The samples were one class in eighth grade which consist of 15 students. The group class consists of 7 males students and 8 females students. The sampling technique used was cluster random sampling. Cluster random sampling obtained using groups as the sampling unit rather than individuals [8].

2.2 Procedure
In order to know students STEM Literacy improvement in this research, students conducted pre-test and post test after the learning process. The learning process is delivered with STEM Learning approach. There are 6 characteristics of STEM learning that are [9]: (1) The focus of STEM learning must be on the real world problems and issues. (2) Engineering design process is the guide of STEM learning. (3) STEM learning must consist of hands-on inquiry and open-ended exploration. (4) Involving students to productive teamwork. (5) STEM learning applies an exact math and science content based on students learning. (6) STEM learning allows for multiple right answers and reframe failure as a necessary part of learning.

Those 6 characteristic are distributed into 3 times of meeting. To achieve the goals of STEM learning, which make students become STEM literate there must be paradigm which have to be built in teaching
learning setting. There are 4 paradigm steps for promoting STEM literacy, such as: (1) Use of audio/visual media to introduce engineering concept. (2) Didactic lecture to students about engineering theory and applications through problem based learning. (3) Abstract project assignments. (4) Group presentation based upon group project. According to the characteristic of STEM Learning and STEM Literacy paradigm steps, we combine the activity in STEM learning based on the characteristic that is almost similar with STEM Literacy. The detail of the students’ activity shown in Table 2.

| STEM Literacy steps                                      | Activity          | Topic                                      |
|----------------------------------------------------------|-------------------|--------------------------------------------|
| Use of audio/visual media to introduce engineering concept.| Making Circuit using PhET Simulation. | Electrical Parameters and Circuit          |
| Didactic lecture to students about engineering theory and applications through problem based learning. | Making Parallel and series circuit | Electrical Circuit, Series and parallel circuit |
| Group presentation based upon group project. Abstract project assignments. | Making Traffic Light Project | Electrical Circuit |

Table 2. Learning activity

![Figure 1](image.png)

**Figure 1.** a) Making circuit using PhET Simulation b) Modification of traffic Light Project

In the implementation of STEM Learning approach, students are interested in using the technology provided as teaching materials. There are 4 aspects measured in this research including scientific literacy, technology literacy, engineering literacy and mathematics literacy. To measure those STEM literacies, researcher constructs the test instrument consisting of 25 questions.

2.3 Data analysis

To analyze the STEM literacy test data, researcher calculated the normalized gain of the test in order to know the result of students improvement in every aspect of STEM literacy. The averages of the pretest score and post test score are compared and calculated into normalized gain. From the normalized gain, it can be found students’ STEM literacy improvement.
3. Result and Discussion

In order to investigate students’ improvement in STEM Literacy, we find out the score of normalized gain $\langle g \rangle$ in General from the pretest and post test. In the beginning of the meeting, students are given the treatment, the average score of the pretest is 53.06 while after the implementation of the STEM learning, the average score of the test (posttest) is 60.8. It can be concluded that, students STEM literacy after learning by STEM Learning is increased.

The difference before and after the treatment is stated by the value of normalized gain $\langle g \rangle$. The value of normalized gain in this research is 0.16. According to Hake (1999) 0.16 is categorized as low improvement. [5]

The specific aspect from the STEM literacy devided into 4 aspects. The detail of students’ normalized gain $\langle g \rangle$ in every aspect STEM literacy before and after the treatment is shown in Table 3

| Table 3. Normalized gain aspects of STEM literacy |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| Pre-test | Post-test | $\langle g \rangle$ | Category |
| Scientific Literacy | 36.6 | 52.5 | 0.25 | Low |
| Technology Literacy | 62.67 | 78.67 | 0.42 | Medium |
| Engineering Literacy | 70 | 70 | 0 | Low |
| Mathematics Literacy | 36.6 | 52.5 | 0.25 | Low |

According to Table 3, students’ STEM Literacies have been improved. This can be seen from the 

score of the normalized gain $\langle g \rangle$ in every aspect. Those normalized gains show the value more than 0 showing the STEM Literacy improvement. Even though the improvement is mostly categorized as low improvement, the result shows that STEM learning using PhET multimedia learning as the pre-treatment can improve students STEM literacy.

The higher improvement is found in students’ technology literacy. The normalized gain $\langle g \rangle$ score for technology literacy is 0.42 categorized as medium improvement. This aspect is higher compared to other aspect. It happened because the contents of the technology activity in every meeting are always included and it was repeated in every meeting. Even though the media is different, the basic principle of technology activity in every meeting is same. This repetition is the reason why the students’ technology literacy higher than other aspects.

Engineer aspect is the only aspect that not improve in students’ literacy. It can be seen from the normalized gain $\langle g \rangle$ score of the Engineering literacy which is obtained 0 score. It can be analyzed that students need more practice in designing an electrical circuit. Because designing is relate with other aspect such as creativity so they need more time to think and designing.

Different from the engineering activity, every meeting students design an electrical circuit, they have also do technology activity. Designing might be exist in every meeting. However, the designs are different in every meeting. Meanwhile technology, they have used the same tools in every meeting. Even though in the first meeting the media used is multimedia learning. But, the simulation is totally similar with the tools in the real one.

Since students have learned STEM for 80 minutes in every meeting with different activities. The learning duration was not enough to think properly for designing their own circuit. Unless they only need to modify the design and it’s already been told by the teacher. In the 3rd meeting they modified the design only in the form of time and how many bulbs can be installed. None of them modify the circuit becoming the traffic light for T-junction. This shows that students’ engineering literacy are lack and should be further improved.

4. Conclusion

The implementation of STEM learning as an approach supported by the application of combined PhET-Arduino in the worksheet and lesson plan in learning electricity topic can improve students’ STEM literacy. It can be noticed from the result of the normalized gain score 0.16 categorized as low
improvement. Students improvement could be more higher with the extension of learning duartion. This shows that STEM learning approach can be the alternative to improve students’ STEM Literacy.

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