Investigating scientific literacy of students on the topic of water pollution through STEM based 6E learning by design

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Abstract. Indonesian PISA achievement in 2015 was the lowest of the OECD countries. The average of Indonesia students’ scores on PISA 2015 for scientific literacy has been evaluated on the ranked of 62 from 69 countries. This PISA achievement must be improved in 2030. The scientific literacy competence of domain demanded students to have the ability to explain scientific phenomena, evaluate and design scientific investigation, interpret data and scientific facts, where learning stage consists of engage, explore, explain, engineer, enrich, and evaluate. The study aims to investigate scientific literacy of students on the topic of water pollution through STEM Based 6E Learning by Design. The research design used poor experimental design with The One-Group Pretest-Posttest. The research subjects were students of VII class in SMPN Bandung. The research instruments used scientific literacy test (pretest and posttest). The technique of data analysis used N-gain test. The result shows that the mean N-gain of scientific literacy is 0.60 (in medium category).

1. Introduction
Indonesia has the lowest PISA score compared to OECD countries in 2015. This PISA achievement should be improved, so by 2030 the average of Indonesia’s PISA is equal to the average of OECD countries. The average score of Indonesian students in PISA 2015 for science literacy is ranked 62nd out of 69 evaluated countries [1]. Effort that can be done to improve the average score of Indonesian students is to change the paradigm of learning where students actively explore knowledge based on the phenomenon they have experienced. Learning with new patterns that can be applied is learning based on STEM 6E Learning by Design. The model was developed by the ITEEA (International Technology and Engineering Educators Association) adopted from the 5E BSCS (Biological Science Curriculum Study) 5E by adding engineering by design in the model [2]. The 6E Learning by Design™ model leads students to understand science by making engineering designs based on science, technology, and math, so as to improve students’ literacy skills. This model is appropriately applied in STEM-based learning, because the steps of 6E Learning by Design model support the learning, the use of the Learning by Design 6E model makes learning activities more effective and efficient, and engineering design activities also support learning [3].
In PISA 2015 there are science literacy themes that serve as the context of science applications. One of the topics used as the context of science applications is environmental issue. One of the materials related to the environmental topic is water pollution. Water pollution needs to get more attention, because at this time the amount of clean water continues to decrease, where one of the causes is the community is not aware to maintain the environment, there are still many garbage or waste that pollute the river causing water pollution that impacts on the surrounding environment. If this is left continuously then we will be lack of clean water, therefore it is very important to awaken the community including students to maintain the surrounding water environment.

Several studies have been done related to the problem of science literacy achievement. Research conducted [4] showed that implementation learning experiences can increase the science literacy of junior high school students. But the result of preliminary study in one of public junior high school in Bandung that has been done by the researcher found that the students' science literacy ability is still low, therefore the researcher is interested to conduct research of the students science literacy on the theme of water pollution through STEM 6E Learning By Design.

2. Experimental Method
The research method used in this research is experimental with the type of poor experimental design. This method does not use a control group or a comparison group [5].

The used research design is the One-Group Pretest-Posttest Design. The researchers conducted a pretest to collect data before treatment, then gave treatment in the form of learning based on STEM 6E Learning by Design with the topic of Water Pollution, after being given treatment, the researchers collected posttest data with the same measurement. The diagram of this research design can be seen as follows:

| Pretest | Treatment | Posttest |
|---------|-----------|----------|
| \(O_1\) | \(X\)     | \(O_2\)  |

Note:
\(O_1\) = Pretest score of scientific literacy (before giving treatment)
\(X\) = Treatment (Learning based on STEM 6E Learning By Design)
\(O_2\) = Posttest score of scientific literacy (after giving treatment)

The population used in this study is all students of grade VII SMPN in Bandung, while the sample in this study is students of class VII-F SMPN in Bandung. The sampling technique used is non-random sampling; sampling that does not provide equal opportunity for each member of the population to be selected as a sample [5].

The research procedures include: preparation stage, implementation stage, and final stage. This paper will only explain the implementation stage in the form of learning activities. Learning activities are conducted for three times. First meeting, divided into three activities include: activity 1, students listened to "story telling" from the teacher about water pollution; activity 2, students discussed the discourse about "Polluted Citarum River", activity 3, students did a practicum of measuring water quality of some water samples (plumbing, well, river, sewer), from this learning activity students were expected to master the material of water pollution. Furthermore, students were given the task to analyze efforts that can be done to overcome water pollution. The second meeting, students made tools designed to overcome water pollution. The third meeting, the students made a redesign tool, based on the results of the initial test tool at the second meeting. Learning Stages of STEM 6E Learning by Design consists of engage, explore, explain, engineer, enrich, and evaluate. The engage, explore and explain stages were done at the first meeting, the engineer stage was done at the second meeting, while enrich and evaluate stages were done at the third meeting.
3. Result and Discuss
Learning activity based on STEM 6E Learning by Design can be seen in the following figure 1. Figure 1(a) shows that the students were identifying the substances mentioned in the story (story telling). Students were trained to identify scientific phenomena and explained scientific phenomena generally (indicators of science competence). Figure 1(b) shows that the students were discussing the discourse about “Polluted Citarum River”.

Figure 1. First meeting of learning activity based on STEM 6E Learning by Design

Students were trained to identify scientific phenomena, and explained the impact of scientific knowledge. After the first learning activity, students were expected to master the topic of water pollution. The first learning activity will create a positive classroom. Students who get a positive classroom environment, the ability scientific literacy will be increase, according to [6] that adolescents who perceived a more positive classroom environment performed significantly better on the PISA reading, mathematics, and science assessments.

Figure 2. Second meeting of learning activity based on STEM 6E Learning by Design

Figure 2(a) shows that students created tools design. In tools design activities students were trained to identify questions to be used in scientific research, to identify the design of scientific research, and to make scientific research designs (indicators of science competence). Figure 2(b) shows that students created tools according to the design they have made. In tools design activities students were trained to create research design (indicators of science competence).

Figure 3(a) indicates that students were redesigning the tool. In the redesigning activities students were trained to interpret the data appropriately, to change data from one representation to another, and to explain conclusions appropriately (science competency indicator). Figure 2(b) shows that students made tools according to the design they have made. In these activities students were trained to create research designs (indicators of science competence).
In the learning activity of redesigning tools, the water generated from the last tool test resulting that all groups obtained clear water, it indicated that the students had performed a good analysis of the deficiencies and concepts related to the tools that had been tested early, and the redesigned tool could produce clear water. All groups substituted the water purifying agent, shown in Figure 3(b) group 6 were laying the dakron on each layer of material as a barrier, and performing a precipitation method using alum before the dirty water passed through the filtration vessel/container. This is in accordance with the opinion of [9] that group with their application of core STEM concepts, appeared to facilitate, rather than hinder, students’ progression through the design phases to toward solution.

Table 2. Recapitulation Data of Increasing Domain of Student Science Competence

| Science Competence                        | Average Score | N-gain | Category |
|-------------------------------------------|---------------|--------|----------|
| Explained the scientific phenomena        | 58.33         | 85.00  | 0.64     | Medium   |
| Design and evaluate scientific inquiry    | 31.67         | 83.34  | 0.76     | High     |
| Interpret data and facts scientifically   | 61.67         | 77.22  | 0.41     | Medium   |
| Mean                                      | 50.56         | 81.85  | 0.60     | Medium   |

Table 2 shows that the N-gain value for competence of explaining the scientific phenomena included in medium category (0.64). Designing and evaluating scientific research included in high category (0.76). Interpreting data and facts scientifically included in medium category (0.41), in line with [10] that lowest gain was scored on using scientific prove 12.12%, students have difficulties in using their knowledge in real life scenario. Based on these results, it is indicated that students train to design and create the tools from the layout that had been made. Students’ abilities to design and create the tools from the layout design are included in the learning stages of STEM 6E Learning by Design which is very important because it involves aspects of science, technology, engineering, and mathematics. In line with [1] that students who are able to produce a good tool is one of the characters of students who are able to compete in the era of globalization. Indirectly, it will improve the quality of learning, if this is continuously done by students on other materials then the average of Indonesian students in 2030 is expected to be equal to the average of OECD countries in PISA assessment. Overall learning experience or active learning as has applied learning STEM based 6E Learning By Design has increased the N-gain students on domain competence scientific literacy, in line with [4] that learning experiences developed and implemented-focused on critical thinking and aiming for scientific literacy for teaching and learning science-contributed to the improvement of critical thinking and scientific literacy levels of the students involved in this study. In addition of the opinion of [11] that direct and meaningful learning in acquiring knowledge will influence students scientific literacy.
Table 3. Recapitulation Data of Domain Competence Explains Scientific Phenomena

| Indicator of Competence Explains Scientific Phenomena | Pretest (%) | Category | Posttest (%) | Category |
|-------------------------------------------------------|-------------|----------|--------------|----------|
| Identify the scientific phenomena                    | 72.22       | High     | 91.11        | High     |
| Make an accurate prediction                          | 48.33       | Medium   | 95.00        | High     |
| Explain the effect of scientific knowledge            | 54.44       | Medium   | 68.89        | Medium   |

Based on these data, it can be seen that students' ability to make predictions and explain the impact of scientific knowledge before learning was medium compared to Identify the scientific phenomena (high category), but after learning, it experienced a very large increase. This was because students got learning that was able to strengthen their ability to make predictions. In line with [12] that prediction as the tools of a basic scientific literacy. Predicting is the reverse process: here we take ideas, concepts, theories about the natural world-its structure and functioning-as a given and ask.

Table 4. Data Recapitulation of Domain Competence in Designing and Evaluating Research

| Indicators of Competence in Designing and Evaluating Research | Pretest (%) | Category | Posttest (%) | Category |
|---------------------------------------------------------------|-------------|----------|--------------|----------|
| Identify the design of scientific inquiry                     | 26.67       | Low      | 96.67        | High     |
| Identify the questions used in scientific inquiry             | 36.67       | Medium   | 70.00        | High     |

Based on these data it can be seen that the ability to identify the design of scientific research before learning and after learning has increased than the ability to identify questions that will be used in scientific research. This is due to the fact that students to sharpen their skills in identifying scientific research designs through STEM based 6E Learning by Design, especially on stage ‘engineer’. Identify the design of scientific inquiry its part of engineering design. Engineering design provides a basic for creating connections to concepts and practices from mathematics or science [13]. The ability to identify the design of scientific research involving the psychomotor domain skills. This ability is very important owned by the students because technological advances quickly change the psychomotor domain skills needed [14].

Table 5. Data Recapitulation of Domain Competence in Interpreting Data and Facts Scientifically

| Indicators of Competence in Interpreting Data and Facts Scientifically | Pretest (%) | Category | Posttest (%) | Category |
|-------------------------------------------------------------------------|-------------|----------|--------------|----------|
| Explain the conclusion appropriately                                   | 61.67       | Medium   | 81.67        | High     |
| Intrepret data accurately                                               | 60.00       | Medium   | 70.00        | High     |
| Change the data of a representation to other data                       | 63.33       | Medium   | 80.00        | High     |

Based on these data it is seen that the ability to interpret data correctly included in the lowest compared to the ability to explain conclusions appropriately and changes data from a representation to other data. The students' ability to explain the conclusion appropriately before learning was medium category, but after learning, it experienced a very large increase. This was because students got learning that was able to strengthen their ability to explain the conclusion appropriately. In line with [15] that the key factor is opportunities to explanations, alone and together with peers, and to discuss the explanations with other students and with teachers. Students need training in using theories and models in their explanations, both in text and visual, and to translate between them.
4. Conclusion

Learning based on STEM 6E Learning by Design as a whole can increase students' scientific literacy on domain competence. Scientific literacy of students in domain competence after learning based on STEM 6E Learning by Design on the topic of water pollution has increased. The result shows that the mean N-gain of scientific literacy is 0.60 (medium). However, there is still a need for further research on the obstacles that arise in this study. Suggestion for further research is to consider the time of learning so that students are able to identify, discuss, design tool models, and make tools better. In addition design lesson that train students to interpret data and facts scientifically.

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