The Scientific Reasoning Profile of Physics Students after Following STEM Learning

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Abstract: Scientific reasoning is one of the important skills in learning science. These skills are also required in the development of science. However, some studies show that students' scientific reasoning skills are still relatively low. This study aims to find out the scientific profile of student reasoning after STEM learning. The research is a mix method research with embedded experimentation design involving 10 students of UM Physics Students. In STEM learning, students perform problem identification activities, gather information and build problem-related concepts, and end with problem solving by developing project reports. The scientific reasoning measurement instrument in this study used two-tier test of Modified Lawson Classroom Test Scientific Reasoning (MLCTSR). The results showed that students' scientific reasoning skills were dominated by early transition with mean score 6.1 (max 13). Further effort is needed to improve the scientific reasoning ability of UM physics students.

1 INTRODUCTION

Scientific reasoning is one of the fundamental thinking skills in science learning. The ability of scientific reasoning is the logical thinking process structure that underlies scientific research. (Thompson, Bowling and Markle, 2018) in his research found that scientific reasoning is a predictor of student success in college. The high scientific reasoning ability will make students have the confidence to analyze various scientific information and self-efficacy (Sigiro, Sigit and Komala, 2017), besides the students can adapt quickly to the environment and able to make decisions based on reasoning, analysis, and synthesis information. It is this scientific reasoning that is also an important factor for developing performance in science learning (Piraksa, Srisawasdi and Koul, 2014) and problem solving (Hejnová *et al.*, 2018). Scientific reasoning is also an important factor that can help students in solving problems in real-world tasks.

Several studies have reported that students' scientific reasoning abilities at various levels tend to be low. (Ding, Wei and Mollohan, 2016) found that final semester students had varying scientific reasoning abilities. Duration of college studies also has weak association with scientific reasoning ability. (Prastiwi, Parno and Wisodo, 2018) found that high school students who studied physics had low scientific reasoning ability. The low scientific reasoning ability also occurs in junior high school students (Mariana, Siahaan and Utari, 2018)

Inquiry-based learning and scientific approach is believed to improve students' scientific reasoning ability. Inquiry-based learning with computer simulation can improve students' scientific reasoning (Nugraha *et al.*, 2018). Students who follow the number of science lessons are more likely to have higher scientific reasoning abilities (Hartmann *et al.*, 2015). Structured inquiry learning, guided inquiry learning or with guided project learning and laboratory activities have also been shown to improve scientific reasoning skills (Nehru and Syarkowi, 2017). While (Nugraha *et al.*, 2017) found that problem solving based experimentation can improve students' scientific reasoning.

Science, technology, engineering, and mathematics (STEM) is one of the most widely recommended scientific studies. The study of scientific reasoning ability of students who follow STEM has not been found. This research is part of research to know the influence of STEM to physics student. This research aims to determine the scientific ability of students after following the STEM.

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2 METHOD

This research is part of the research mixed method which aims to know. Students' scientific reasoning abilities that follow STEM lessons in the Optics course. The STEM cycle is problem-based including steps (1) Problem orientation, (2) mutual learning, (3) Problem solving with project, (4) Presentation of project. At the problem orientation stage students are given a trigger problem to identify the problems encountered and the knowledge needed to solve the problem. At the stage of mutual learning, students will teach their friends on the knowledge they are responsible for. At the problem-solving stage with the project students in groups develop projects in order to solve the problems encountered. At the end of the student will present the resulting product

The instrument used is The Lawson Classroom Test of Scientific Reasoning (LCTRS). This scientific reasoning test is a two tier test with a total of 13 and a maximum score of 13. The distribution of scientific reasoning can be seen in Table 1.

Table 1: Distribution of questions of scientific reasoning.

Scientific Reasoning Indicator	Item Number
Conservation of Mass and Volume (CMV)	1, 2,
Proportional Thinking (PPT)	3, 4
Control of Variables (CV)	5, 6, 7,
Probabilistic Thinking (PBT)	8, 9,
Correlational Thinking (CT)	10,
Hypothetical-deductive Reasoning (HDR)	11, 12, 13

An item test score is 1 if the student correctly answers the question on the first tier and also true on the second tier. The score will be zero if one of the tiers or both is wrong. The category of scientific reasoning ability based on scores obtained by students is as Table 2.

Table 2: Category of scientific reasoning.

Score	**category**
0 - 4	A Concrete reasoning
5 - 7	Early transition
8 - 10	Final transition
11 - 13	A Formal reasoning

3 RESULT AND DISCUSSION

The results of the measurement of scientific reasoning ability of students after following STEM data are seen in Table 3.

Table 3: Descriptive statistics of scientific reasoning tests.

Mean	6.1
SD	0,99
Range	3
Min	4
Max	7

From Table 3 it can be seen that the average of scientific reasoning ability of students after following STEM is 6.1 i.e. all students have scientific reasoning ability around the early transition ability. Thus it can be said that the scientific reasoning ability of students tends to be low. The distribution of student scores can be seen in Figure 1.

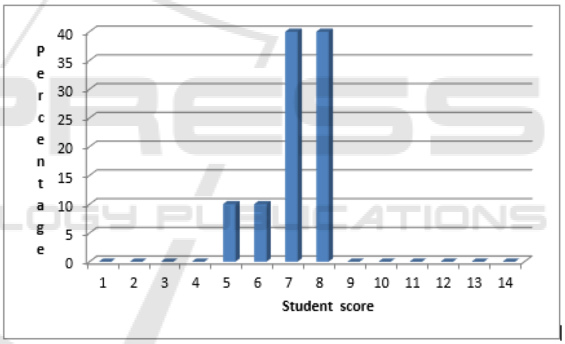

Figure 1: Distribution of students' scientific reasoning scores

Table 4: Percentage of student in every category.

Category	Percentage (%)
A Concrete reasoning	10
Early transition	90
Final transition	0
A Formal reasoning	0

Percentage of students according to scientific reasoning category can be seen in Table 4. It shows that most students are in the early transition category (90%) and the rest are in the category of a concrete reasoning. While the final category of transition and formal transition is zero percent. It also indicates the low scientific ability of the students.

The scientific reasoning ability of students per indicator can be published in Table 5. It can be seen that students have sufficient ability on CMV (70%), PPT (60%), and HDR (57%). Low student ability occurs in PBT (50%) and low on CV and CT indicators.

Table 5. Percentage of student’s scientific reasoning per indicator

Scientific Reasoning Indicator	Correct (%)
Conservation of Mass and Volume (CMV)	70
Proportional Thinking (PPT)	60
Control of Variables (CV)	20
Probabilistic Thinking (PBT)	50
Correlational Thinking (CT)	10
Hypothetical-deductive Reasoning (HDR)	57

One example of student answers can be seen in Figure 2. It can be seen that many students who answered correctly on tier 1 and tier 2 but only a few students who answered correctly on both tiers.

At the right are drawings of three strings hanging from a bar. The three strings have metal weights attached to their ends. String 1 and String 3 are the same length. String 2 is shorter. A 10 unit weight is attached to the end of String 1. A 10 unit weight is also attached to the end of String 2. A 5 unit weight is attached to the end of String 3. The strings (and attached weights) can be swung back and forth and the time it takes to make a swing can be timed.

Suppose you want to find out whether the length of the string has an effect on the time it takes to swing back and forth. Which strings would you use to find out?

a. only one string (0%)
b. all three strings (40%)
c. 2 and 3 (0%)
d. 1 and 3 (0%)
*e. 1 and 2 (60%)

because

a. you must use the longest strings. (0%)
b. you must compare strings with both light and heavy weights. (0%)
* c. only the lengths differ. (70%)
d. to make all possible comparisons. (30%)
e. the weights differ. (0%)

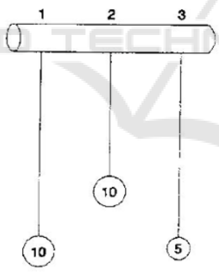

Figure 2: Example of scientific reasoning problem

Research shows that the scientific reasoning of students after following STEM is low with a mean of 6.1 of scale 13. Most scientific reasoning abilities are in the initial transition and a small part in concrete reasoning. Low scientific reasoning ability in parts CV and CT.

The results of this study are consistent with the results of other Indonesian studies which found that the ability of Indonesian students and students is low (Mariana, Siahaan and Utari, 2018; Prastiwi, Parno and Wisodo, 2018). However, the study also contradicts research (Bao *et al.*, 2009) who found that STEM can improve students' scientific reasoning abilities. The research was also slightly different from the findings (Piraksa, Srisawasdi and Koul, 2014) who found that Lowest mean score for the students' scientific reasoning abilities were HDR, CV, PPT. The time factor of the STEM implementation may be the cause of the differences in the results of this study

Seeing the results of this research, scientific reasoning should get serious attention, especially in lectures in Indonesia. Need to do a study involving more students and a longer period of time. It is also necessary to consider efforts to improve the scientific reasoning of students in Indonesia.

4 CONCLUSIONS

Through this research, it can be concluded that scientific reasoning ability of students after following STEM is still in low level. Most of students are in the early transition category, while the rest student in concrete reasoning category. There is no students are in final transition and/or formal reasoning category. Furthermore, scientific reasoning should have a serious attention in order to improve it, especially on students in Indonesia.

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