The achieving of students' mathematical problem solving abilities in scientific learning

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Abstract. This quasi experimental research was aimed to analyze the achieving of students' mathematical problem solving abilities in scientific learning compared to direct learning. The population of this research was students of grade 7 of junior high school in South Lampung as many as 224 students that were distributed into 7 classes. All classes have balance mathematical skill. The sample was chosen by cluster random sampling technique. 29 students of 7A were as experimental class which taught by scientific learning and 29 students of 7B were as control class which was taught by direct learning. This research used the randomized pre-test and post-test control group design. The data were obtained by essay test of mathematical problem solving abilities in proportion topic. The data analysis was done by Mann-Withney U and proportion test. It was gotten that (1) the gain of students' mathematical problem solving abilities taught by scientific learning was not higher than direct learning, (2) the proportion of students who have good categorized of mathematical problem solving abilities in scientific learning was not higher than direct learning, and (3) the scientific learning was better than direct learning in achieving of indicator devising a plan and looking back. Also, the direct learning was better than scientific learning in achieving of indicator understanding the problem and carrying out the plan. Thus, the scientific learning was not better than direct learning in facilitating the achievement of mathematical problem solving abilities. The recommendation were reasoning and communicating the results to other should be the focus on scientific learning.

Keywords: mathematical problem solving abilities, scientific, direct learning

1. Introduction

Changes in the world are now entering the era of the industrial revolution 4.0 where information technology has become the basis in human life. Everything becomes borderless with unlimited use of computing power and data, because it is influenced by the development of the internet and massive digital technology as the backbone of movement and connectivity between humans and machines. This era will also disrupt various human activities, including in the fields of science and technology and education.

The World Economic Forum stated that the industrial revolution 4.0 was marked by renewal (fashion) which was able to erase the boundaries driving economic activity, both from a physical, digital, and biological perspective [1]. The Minister of Research, Technology and Higher Education of Indonesia also said that the challenges of the industrial revolution 4.0 must be responded to quickly and appropriately by all stakeholders in the Ministry of Research, Technology, and Higher Education

in order to be able to increase the competitiveness of Indonesia in the midst of global competition [2]. One effort to improve the nation's competitiveness is to increase the quality of education.

Education is the most important thing that must be passed by every individual, because with education a person able to develop his potential so that he can become an intellectual person and ready to compete globally. This is in accordance with the objectives of national education that is to develop the potential of students to become people of faith and devotion to God Almighty, noble, healthy, knowledgeable, capable, creative, independent, and become citizens who are democratic and responsible [3]. In formal education, designed subjects that contain concepts must be mastered by students to realize the goals of national education. One of them is mathematics.

Mathematics is one of the important lessons that must be mastered by students. One of the important reasons for studying mathematics is being able to improve the ability to think logically and thoroughly [4]. This logical and thorough thinking is important for students to have so that students' mathematical problem solving abilities are optimally achieved. This is in line with one of the objectives of learning mathematics is to use reasoning on the nature, to manipulate mathematics, both in simplifying and analyzing the components that exist in problem solving [5]. The ability to solve mathematical problems becomes an important goal in learning mathematics.

However, the achievement of Indonesian students in mathematical problem solving abilities is not yet optimal. This is shown from the results of the 2015 of Trend in International Mathematics and Science Study (TIMSS) in the field of mathematics placing Indonesia in 45th place out of 50 countries [6]. In addition, the results of the Program for International Students Assessment (PISA) placed Indonesia in 62nd position out of 70 countries [7]. It shows that the ability to solve mathematical problems of Indonesian students is relatively low when compared to other countries on an international scale [8].

Not yet optimal achievement of the ability to solve mathematical problems requires learning innovation. In relation to learning innovation, the implementation of 2013 Curriculum demands a paradigm shift from direct learning to scientific learning. Scientific learning that mandates the existence of 5M in learning, namely observing (*mengamati*), questioning (*menanya*), experimenting (*mencoba*), reasoning (*menalar*), and communicating (*mengomunikasikan*) is seen superior in producing Indonesian human resources better than the implementation of direct learning [9].

When discussing learning and its relation to students, the different characteristics of students demand different treatment in their learning. Not all learning is effective for every student. In relation to mathematical problem solving abilities, it has not been analyzed whether the implementation of scientific learning is effective in facilitating students' mathematical problem solving abilities compared to direct learning. Observing the description of the problem above, researchers are interested in conducting research to analyze the effectiveness of scientific learning in facilitating the achievement of students' mathematical problem solving abilities. This effectiveness will be analyzed by comparing mathematical problem solving abilities between scientific learning and conventional learning.

2. Methods

This research was conducted at one of junior high school in South Lampung, Lampung Province, Indonesia. The population of this research was students of grade 7 as many as 224 students that were distributed into 7 classes that were 7A until 7G. All classes have balance mathematical skill. The sample was chosen by cluster random sampling technique [10]. Students of 7A and 7B were selected as the sample of this research. Students of 7A were as experimental class and students of 7B were as control class. The experiment class was consists of 29 students which taught by scientific learning and control class was consists of 29 students which was taught by direct learning. This was quasi experimental research with the randomized pre-test and post-test control group design [11] which shown in Table 1.

Table 1. The randomized pre-test and post-test control group design

Group	Pre-Test	Learning	Post-Test
Experimental (*R*)	O_1	Scientific Learning	O_2
Control (*R*)	O_1	Direct Learning	O_2

Pre-test was done to measure the initial data of mathematical problem solving abilities before the learning process and post-test was done to measure the final data of mathematical problem solving abilities after the learning process. The pre-test and post-test data of mathematical problem solving abilities was measured by same essay test in proportion. The instrument test was measure 4 indicators of problem solving abilities, that were (1) understanding the problem, (2) devising a plan, (3) carrying out the plan, and (4) looking back [12].

The test instrument was prepared by the researchers themselves. The test instrument was validated by a junior high school mathematics teacher to measure content validity. The validation results showed that the test instrument was valid in terms of content validity [13]. Before being used to collect data, the test instrument was tested for students outside of sample, that were students of grade 8 of junior high school with the assumption that students were understand about topic proportion. The testing of test instrument results showed that the test instrument has a high reliability (r_{11} = 0.70), has a good discriminant power (the indexes range from 0.32 to 0.39), and the level of difficulty that has been appropriate (the indexes range from 0.29 to 0.66). The rubric score for the test of mathematical problem solving abilities [14] was described in Table 2.

Table 2. The rubric score for the test of mathematical problem solving abilities

No.	Indicators	Descriptions	Score
1.	Understanding the problem	Do not mention what is known and what is asked	0
		Mention what is known and what is asked, but not correct Mention only what is known or what is asked	1
		Mention both of what is known or what is asked, but one of them is false	2
		Mention the all what is known and what is asked completely and correctly	3
2	Devising a plan	There is no strategic plan	0
		There is a strategy but it is not relevant	1
		Mention a mathematical model but partially correct	2
		Mention a mathematical model completely and correctly	3
3	Carrying out the plan	There is no problem solving Writing down problem solving is incomplete and incorrect answer	0
		Writing down problem solving is incomplete but the answer is correct	1
		Writing down problem solving completely but the answer is incorrect	2
		Writing down problem solving completely and the answer is correct	3
4	Looking back	Not looking back the problem solving and not drawing the conclusion	0
		Not looking back the problem solving but drawing the conclusion correctly Looking back the problem solving and drawing the conclusion but incorrect	1

No.	Indicators	Descriptions	Score
		Looking back the problem solving and drawing the conclusion but one of them is incorrect	2
		Looking back the problem solving and drawing the conclusion correctly	3

The pre-test and post-test data of mathematical problem solving abilities were processed to get the gain of mathematical problem solving abilities. It processed by using this formula [15]:

$$gain = \frac{posttest\ score - pretest\ score}{maximal\ possible\ score - pretest\ score}$$

This research data analysis aims to find out whether the gain of students' mathematical problem solving abilities taught by scientific learning was higher than the gain of students' mathematical problem solving abilities taught by direct learning. It was analyzed by Mann-Whitney U [16].

After comparing the gain of students' mathematical problem solving abilities, the data analysis was also carried out to find out whether the proportion of students who have good categorized of mathematical problem solving abilities in scientific learning was higher the proportion of students who have good categorized of mathematical problem solving abilities in direct learning. The gain of students' mathematical problem solving abilities was categorized [17] based on the range of gain listed in the Table 3.

Table 3. The categories of gain of students' mathematical problem solving abilities

No.	Range of Gain	Category
1	Gain > 0.70	High
2	0.30 ≤ Gain ≤ 0.70	Medium
3	Gain < 0.30	Low

In this research, students who have good categorized of mathematical problem solving abilities was indicated by having gain of minimal in medium category [18]. The comparing of the proportion of students who have good categorized of mathematical problem solving abilities was analyzed by proportion test [16].

The analyzing of research data was done by compare the achieving of indicators of mathematical problem solving abilities before and after learning process in scientific and direct learning. It was also comparing the gain of achieving of indicators of mathematical problem solving abilities between scientific and direct learning.

3. Result and Discussion

Based on the result of data analysis, the mean of the mean of gain of students' mathematical problem solving abilities taught by scientific learning was higher than the mean of gain of students' mathematical problem solving abilities taught by direct learning. The data was shown in Table 4.

Table 4. The Data of mathematical problem solving abilities

Learning	N	Pre-test	Post-test	Gain
		Mean ± Deviation Standard	Mean ± Deviation Standard	Mean ± Deviation Standard
Scientific Learning	29	16.10 ± 4.00	29.41 ± 6.93	0.42 ± 0.20
Direct Learning	29	10.52 ± 4.24	24.90 ± 5.76	0.39 ± 0.13

By using Mann-Whitney U test, it gotten that |z| = 0.047 was less than $z_{0.45}$ = 1.65. It means that gain of students' mathematical problem solving abilities taught by scientific learning was not higher than the mean of gain of students' mathematical problem solving abilities taught by direct learning.

The data of gain of students' mathematical problem solving abilities was categorized in high, medium, or low. Based on the result of data analysis, the number of students in each category was shown in Table 5.

Table 5. The number of students in each category of gain

Category of Gain	Number of Students	
	Scientific Learning	Direct Leaning
High	**3**	**1**
Medium	**15**	**22**
Low	11	6
Total	29	29

The total of students who have good categorized of mathematical problem solving abilities in scientific learning and direct learning respectively was 18 and 23. Based on the result of proportion test, the proportion of students who have good categorized of mathematical problem solving abilities in scientific learning was not higher the proportion of students who have good categorized of mathematical problem solving abilities in direct learning.

The result of the analyzing of the achieving of indicators of mathematical problem solving abilities in direct learning showed that there was increasing achievement from pre-test to post-test. The increasing of achievement was occurred in all indicators of mathematical problem solving abilities, that are understanding the problem, devising plan, carrying out the plan, and looking back. The achievement of understanding the problem was increasing about 38.33% (from 58.91% in pre-test to 97.13% in post-test), devising a plan was increasing about 33.62% (from 3.74% to 37.36%), carrying out the plan was increasing about 28.19% (from 17.24% to 45.50%, and looking back was increasing about 22.41% (from 7.76% to 30.17%). It means that in direct learning, the highest achievement indicator of mathematical problem solving abilities was understanding the problem. The data was shown in Figure 1.

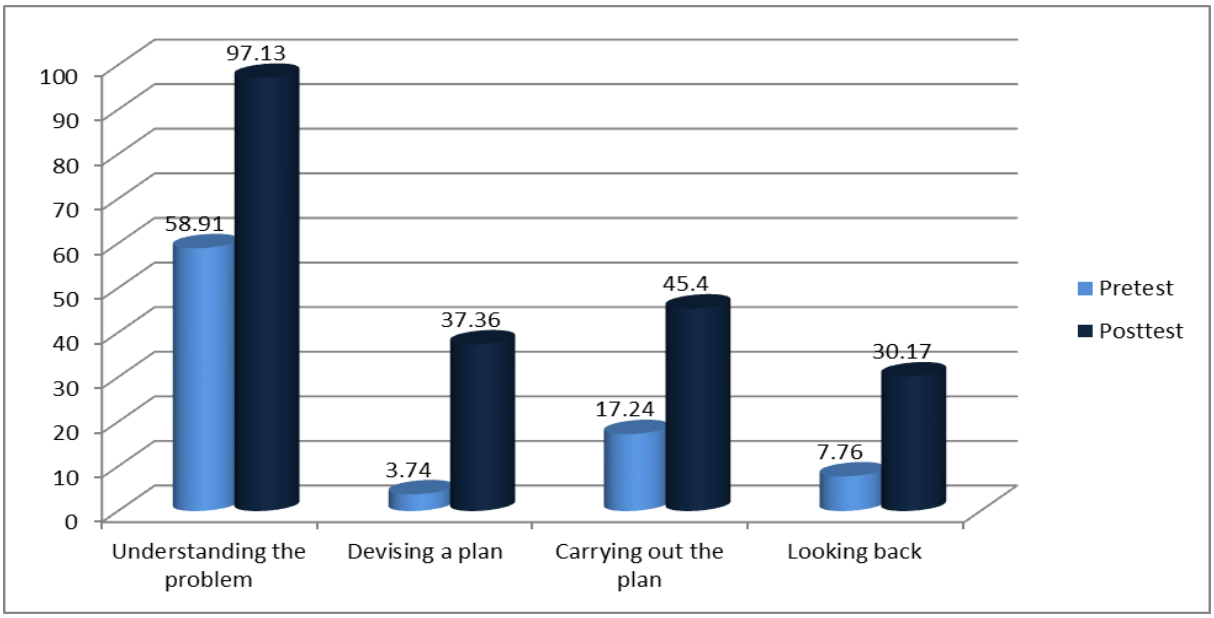

Figure 1. The achievement of each indicator in direct learning

Also in scientific learning, the result of the analyzing of the achieving of indicators of mathematical problem solving abilities showed that there was increasing achievement from pre-test to post-test. The increasing of achievement was occurred in all indicators of mathematical problem solving abilities, that are understanding the problem, devising plan, carrying out the plan, and looking back. The achievement of understanding the problem was increasing about 21.83% (from 73.28% in pre-test to 95.11% in post-test), devising a plan was increasing about 37.93% (from 12.64% to 50.57%), carrying out the plan was increasing about 21.55% (from 32.76% to 54.31%, and looking back was increasing about 29.59% (from 15.52% to 45.11%). It means that in direct learning, the highest achievement indicator of mathematical problem solving abilities was devising a plan. The data was shown in Figure 2.

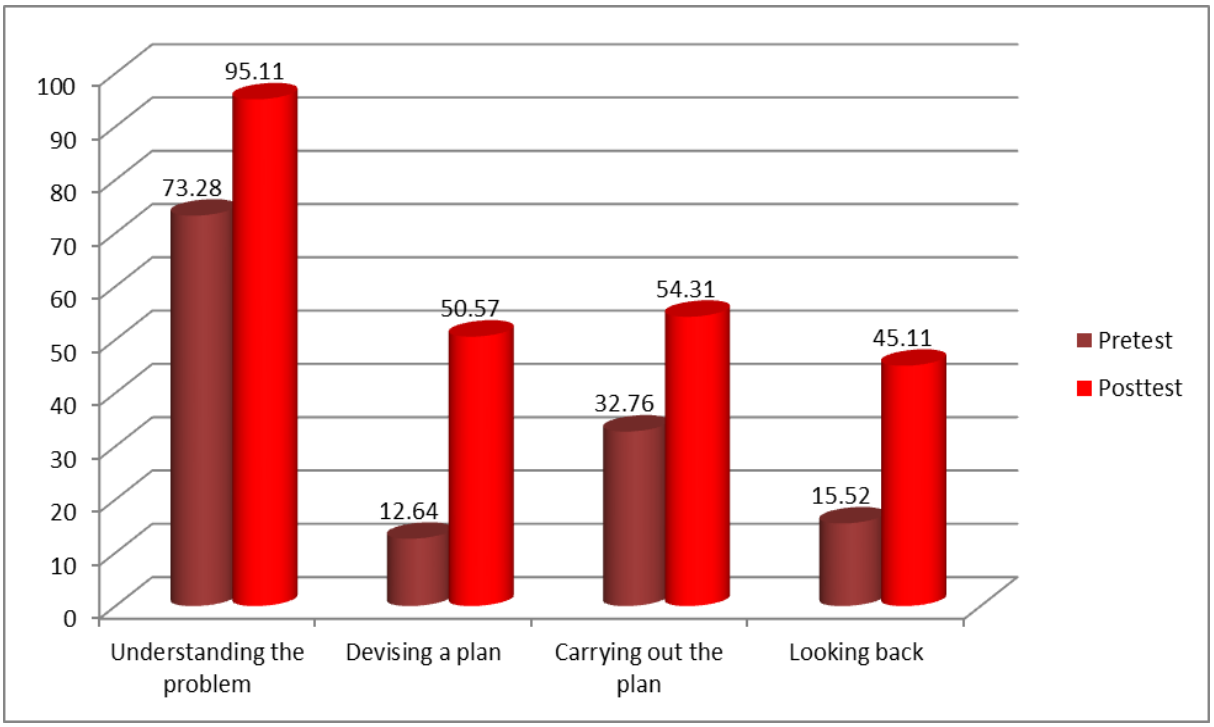

Figure 2. The achievement of each indicator in scientific learning

The last analysis was comparing the gain of achieving the indicator of mathematical problem solving abilities between scientific learning and direct learning. Based on the data of indicator achievement in pre-test and post-test, for indicator understanding the problem, the achievement in scientific learning was lower than the achievement in direct learning (0.82 versus 0.93). The second indicator is devising a plan, the achievement in scientific learning was higher than the achievement in direct learning (0.43 versus 0.35). The third indicator is carrying out the plan, the achievement in scientific learning was lower than the achievement in direct learning (0.32 versus 0.34). The last indicator is looking back, the achievement in scientific learning was higher than the achievement in direct learning (0.35 versus 0.24). Based on the data analysis, the scientific learning was better than direct learning in indicator devising a plan and looking back. Also, the direct learning was better than scientific learning in achievement indicator understanding the problem and carrying out the plan. The data was shown in Figure 3.

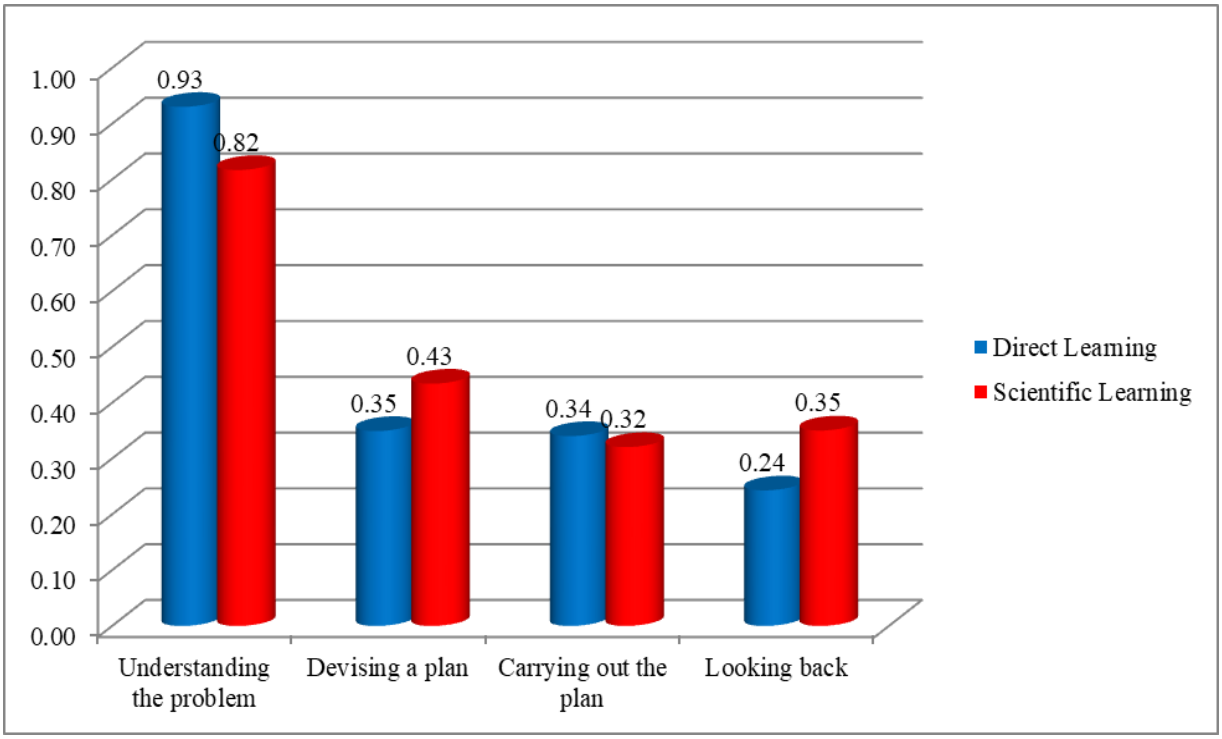

Figure 3. The gain achievement of each indicator in scientific and direct learning

The implementation of scientific learning with observing, questioning, experimenting, reasoning, and communicating the result were not better than direct learning to facilitate the achieving of mathematical problem solving abilities. It was indicated by the gain of students' mathematical problem solving abilities taught by scientific learning was not higher than the mean of gain of students' mathematical problem solving abilities taught by direct learning and the proportion of students who have good categorized of mathematical problem solving abilities in scientific learning was not higher the proportion of students who have good categorized of mathematical problem solving abilities in direct learning.

In the implementation of scientific learning, students must be active to observe, question, experiment, reason, and communicate the result to all members of class. This activities could not give full meaning without the high contribution of student to construct their understanding. By having optimally understanding, student could be able to solve the mathematical problem [19]. The scientific learning process without supporting student's contribution would be same with direct learning.

The obstacles in the implementation of scientific learning in this research were students are not able to give the reason and communicate their ideas to all students in the class. Although students are success to observe, give the question, and do the experiment, it was not ensure that students are able to give the reasons and communicate their result to other. Optimization of this activities make students are not able to devising a plan. The reasoning skill are needed to make students are able to devise a plan in solving the mathematical problem [20]. In devising a plan, students are expected to be able to relate the information that is known to the information that is asked. There may be additional problems that must be determined if the information that is known is not directly connected to the information requested. The end of this step is a plan must be found to find solutions to these problems [12].

Also, by the activity in communicating the result to other, students would get the suggestion or the other idea to solve the mathematical problems. The discussion proses in communicate their ideas to all students in the class would support students to look back their problem solving process [21]. In the looking back, students should able to check the solution obtained. Check the result, check the

argument, and derive the solution differently. Also try to think, can you see it at a glance? can you use the result, or the method, for some other problem [12].

Relate to the achievement of indicators of mathematical problem solving abilities, the scientific learning was better than direct learning in indicator devising a plan and looking back. In other hand, the direct learning was better than scientific learning in achievement indicator understanding the problem and carrying out the plan.

4. Conclusion

Based on the result of data analysis, it can be concluded that the scientific learning was not better than direct learning in facilitating the achievement of mathematical problem solving abilities. It was indicated by:

1. The gain of students' mathematical problem solving abilities taught by scientific learning was not higher than the mean of gain of students' mathematical problem solving abilities taught by direct learning.
2. The proportion of students who have good categorized of mathematical problem solving abilities in scientific learning was not higher the proportion of students who have good categorized of mathematical problem solving abilities in direct learning.
3. The scientific learning was better than direct learning in indicator devising a plan and looking back. In other hand, the direct learning was better than scientific learning in achievement indicator understanding the problem and carrying out the plan.

Relate to the conclusion, the recommendations of this research were reasoning and communicating the results to other as the main activities in scientific learning should be the focus on learning process. Teachers should be able to support students to be able in reasoning and communicating the results to other after observing, questioning, and experimenting.

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