Improvement of the Ability of Representation, Reasoning, and Self-Efficacy of Prospective Mathematics Teacher Students by Using Learning with A Scientific Approach

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Abstract. This research was developed aiming to (1) Analyzing the improvement of representation, reasoning, and SE skills by using a scientific approach to prospective teacher students. (Already done); (2) Analyze the association between the ability of representation and reasoning with SE. (Already done); (3) Analyzing the relationship (association) between the ability of representation and reasoning seen from the level of student ability (low, medium, and high). (Already done); (4) Designing a scientific approach and teaching materials based on the association between ability and level of student ability, in order to improve the ability of students who still have a level of concrete representation to the level of abstract representation, so as to improve reasoning. This type of research is Research and Development. the Four-D model proposed by Thiagarajan (Buhari, 2014) with a mixed method (the multiphase design), through stages: Define, Design, Develop, and Disseminate, namely the definition, design, development, and distribution. The conclusions of the research are (1) the increase in reasoning ability increased significantly at the value of 0.43 with the moderate category. (2) Increasing the ability of representation increased significantly at 0.34 with a moderate category. (3) The increase in SE increased significantly at 0.31 in the medium category. (4) There is a significant positive correlation between reasoning ability and SE, but the correlation coefficient between reasoning ability and SE is 0.338 which is categorized as weak. (5) There is no significant correlation between the ability of representation and SE, with the correlation coefficient between the ability of representation and SE of 0.228 which is categorized as very weak and the direction is positive. (6) There is a significant positive correlation between the ability of reasoning and representation in students with high ability with the correlation coefficient between reasoning and representation ability is 0.889 which is categorized very strong and the direction is positive. (7) There is a significant positive correlation between the ability of reasoning and representation in students with moderate ability with the coefficient of correlation between reasoning and representation ability is 0.838 which is categorized very strong and the direction is positive.

1. Introduction
According to the Ministry of Education and Culture (2013) the learning approach recommended in the 2013 curriculum, namely the scientific approach (scientific approach) in the learning of all subjects which includes: 1) digging information through observation, 2) asking questions, experimenting, 3) then processing data or information, 4) present data or information, 5) proceed with analysis, reasoning, 6) then conclude, and create. In relation to the 2013 curriculum, the ability of representation and reasoning is very closely related. Because the step of observing is closely related to representation, reasoning is
very closely related to the step of gathering information and conclusions. Mathematical representation leads someone to be able to reason. The link appears in the results of research in the first year which will be described later.

The learning objectives of mathematics according to the 2013 Curriculum include 4 Core Competencies, namely Spiritual Attitude Competency, Social Attitude Competency, Knowledge Competency, and Skills Competency. The purpose of mathematics is in line with the National Council of Teachers of Mathematics (NCTM) that in learning mathematics students are required to have abilities: understanding, problem-solving, reasoning, mathematical communication, mathematical representation, and mathematical disposition. To meet the above objectives, the government sets a scientific learning approach (scientific approach) that can develop all the potential of good learners that cover all aspects.

In addition to mathematical representation abilities, mathematical reasoning, self-efficacy (hereinafter referred to as SE) are important components in mathematics learning that must be developed. SE also determines the success of students in learning. As stated by Dzulfikar (2013) self-efficacy is a person's self-assessment beliefs regarding one's competence to succeed in their tasks. In this case, SE is mathematically interpreted as a student's self-confidence beliefs regarding his or her competence to succeed in mathematical tasks.

Likewise, with the results of PISA 2012 which shows that Indonesian students are still poor in their ability to reason. From the combined results of mathematics, science, and reading tests, Indonesia ranks 64 out of 65 participating countries (Agustiana, 2014). According to Pranoto (Agustiana, 2014) poor PISA results can show the following indications: 1) students are not accustomed to solving non-routine problems, 2) Students are weak in modeling real situations into mathematics and interpreting mathematical situations to real situations, and 3) levels of reasoning summarize (comprehension) and analyze very less. Though the skills that are more needed at the moment are the skills to solve problems not routinely and complex communication is more needed.

Data submitted by the Director-General of Teachers and Education Personnel (GTK) as reported by the Public Daily "Mind of the People" (May 23, 2016) that based on the results of the Teacher Competency Test (UKG) conducted at the end of 2015 the average value was 53.02 of the Ministry of Education and Culture's target of 55 Competencies tested are Professional competence and Pedagogical competence. Based on these data, it still needs improvement in terms of teachers in Indonesia as a whole. The competencies tested are professional competence and pedagogic competence. Based on the data, it is still necessary to improve the quality of teachers in Indonesia, Darta & Saputra (2018, p. 2).

Based on the explanation above, it is necessary to apply a scientific approach systematically to improve the ability of prospective mathematics teachers in tertiary institutions to improve the representation, reasoning, and SE abilities of students so that in the future they can also gradually improve their students' mathematical abilities. Thus, this research can improve the ability of representation, reasoning, and SE of Mathematics Education Study Program students, so that the policies to be implemented receive adequate research support in various lines, both in terms of students, prospective teachers, and mathematics teachers.

This research was developed aiming to (1) Analyzing the improvement of representation, reasoning, and SE skills by using a scientific approach to prospective teacher students. (Already done); (2) Analyze the association between the ability of representation and reasoning with SE. (Already done); (3) Analyzing the relationship (association) between the ability of representation and reasoning seen from the level of student ability (low, medium, and high). (Already done); (4) Designing a scientific approach and teaching materials based on the association between ability and level of student ability, in order to improve the ability of students who still have a level of concrete representation to the level of abstract representation, so as to improve reasoning.
2. Methods
This type of research is Research and Development. the Four-D model proposed by Thiagarajan (Buhari, 2014) with a mixed method (the multiphase design), through stages: Define, Design, Develop, and Disseminate, namely the definition, design, development, and distribution.

2.1. Develop
The development phase is the stage to produce product development, which is carried out in two stages as follows.

2.2. Expert Appraisal
Expert/practitioner assessment of learning tools with a positive approach and research instruments including format, language, illustrations, and content. Based on input from experts, learning material was revised to make it more precise, effective, easy to use, and has high quality.

2.3. Developmental testing
Trials to obtain input in the form of responses, reactions, student comments, and observers to the learning device. Trials, revisions, and trials are carried out until a consistent and effective learning tool is obtained. Analyze the improvement of representation, reasoning, and SE skills by using a scientific approach to prospective teacher students.

Analyzing the association between the ability of representation and reasoning with SE. Analyzing the relationship (association) between the ability of representation and reasoning seen from the level of student ability (low, medium, and high). Designing a scientific approach and teaching materials based on the association between ability and level of student ability, to improve the ability of students who still have a level of concrete representation to the level of abstract representation, to improve reasoning.

3. Results and Discussion

3.1. Increased Reasoning Ability

| N-Gain Reasoning | N  | Minimum | Maximum | Sum   | Mean  | Std. Deviation | Variance |
|------------------|----|---------|---------|-------|-------|----------------|----------|
|                  | 61 | 0.06    | 0.92    | 30.15 | 0.4943| 0.22796        | 0.052    |

In Table 1, we can describe that the number of samples was 61 students who contracted Algebra and Trigonometry Courses. Descriptive statistics measures include: the minimum value of reasoning ability improvement is 0.06 and is in a low category, then the maximum value is 0.92, and is in the high category. Then the average increase is 0.4943 and is in the medium category.

To find out the increase in reasoning ability increased significantly in the value category 0.4943, which is moderate or not, then inferential statistical analysis is needed, namely a one-sample t-test (one-sample test). The following is an analysis of reasoning improvement with SPSS 23.00.

| N-Gain Reasoning | t   | df | Sig. (2-tailed) | Mean Difference | 95% Confidence Interval of the Difference |
|------------------|-----|----|----------------|-----------------|-----------------------------------------|
|                  | -.001 | 60 | .999           | -.00004         | -.0584 - .0583                          |
In Table 2, with a test value = 0.4943 taken from the average value, it is concluded that the increase in reasoning ability does not increase significantly at that value, because of the value of Sig. (2-tailed = 0.999) > 0.05. Then we analyzed again to find out that the increase in reasoning ability increased significantly by lowering the test value to 0.43.

Table 3. Analysis of TV Reasoning Capability Improvement 0.43 One-Sample Test with Value Test = 0.43

| N-Gain Reasoning | t   | df  | Sig. (2-tailed) | Mean Difference | 95% Confidence Interval of the Difference |
|------------------|-----|-----|----------------|-----------------|------------------------------------------|
|                   | 2.202 | 60  | .032           | .06426          | .0059 - .1226                             |

In Table 3, with a test value = 0.43, it was concluded that the increase in reasoning ability increased significantly at the value of 0.43 with a moderate category because of the value of Sig. (2-tailed = 0.032) < 0.05.

3.2. Increased Representation Ability

Table 4. Descriptive Statistics Improved Representation Capabilities

| Descriptive Statistics | N  | Minimum | Maximum | Sum  | Mean   | Std. Deviation | Variance |
|------------------------|----|---------|---------|------|--------|----------------|----------|
| N-Gain Representation  | 61 | .06     | 1.00    | 24.06| .3944  | .20501         | .042     |

In Table 4, we can describe the descriptive statistical measures including the minimum value of increasing the ability of representation is 0.06 and is in a low category, then the maximum value is 0.92, and is in the high category. Then the average increase is 0.3944 and is in the medium category.

If you want to know an increase in the ability of representation to increase significantly in the value category 0.3944, which is moderate or not, then inferential statistical analysis is needed, namely a one-sample t-test (one-sample test). The following is an analysis of reasoning improvement with SPSS 23.00.

Table 5. Increased Representation Capability Analysis One-Sample Test with Value Test = 0.3944

| N-Gain Representation | t   | df  | Sig. (2-tailed) | Mean Difference | 95% Confidence Interval of the Difference |
|-----------------------|-----|-----|----------------|-----------------|------------------------------------------|
|                       | .001 | 60  | .999           | .00003          | -.0525 - .0525                           |

In Table 5, with a test value = 0.3944 taken from the average value, it is concluded that the increase in reasoning ability does not increase significantly at that value, because the value of Sig. (2-tailed = 0.999) = 0.05. Then we analyzed again to find out that the increase did increase significantly by lowering the test value to 0.34.
Table 6. Increased Representation Capability Analysis One-Sample Test with Value Test = 0.34

|                | T  | df | Sig. (2-tailed) | Mean Difference | 95% Confidence Interval of the Difference |
|----------------|----|----|-----------------|-----------------|------------------------------------------|
| N_Gan Representation | 2.073 | 60 | .042            | .0543           | .0019 - .1069                            |

Increased Representation Capability Analysis in Table 6, with a test value = 0.34, it was concluded that the increase in reasoning ability increased significantly at the value of 0.34 with the moderate category because of the value of Sig. (2-tailed = 0.042) < 0.05.

3.3. Increased Self-Efficacy

Table 7. Descriptive Statistics Improved Self-Efficacy

|                | N  | Minimum | Maximum | Sum  | Mean | Std. Deviation | Variance |
|----------------|----|---------|---------|------|------|----------------|----------|
| N_Gain_SE      | 61 | .06     | .53     | 20.93| .3431| .09190         | .008     |
| Valid N (listwise) | 61 |         |         |      |      |                |          |

In Table 7, we can describe descriptive statistical measures including the minimum value of Self-Efficacy (SE) increase is 0.06 and is in a low category, then the maximum value is 0.53, and is in the medium category. Then the average increase is 0.3431 and is in the medium category.

To find out that the increase in SE increased significantly in the value category 0.3431, which is moderate or not, an inferential statistical analysis is needed, namely a one-sample t-test (one-sample test). The following is an analysis of reasoning improvement with SPSS 23.00.

Table 8. Improved Analysis of Self-Efficacy One-Sample Test with Value Test = 0.3431

|                | t  | df | Sig. (2-tailed) | Mean Difference | 95% Confidence Interval of the Difference |
|----------------|----|----|-----------------|-----------------|------------------------------------------|
| N_Gain_SE      | .001 | 60 | .999            | .00001          | -.0235 - .0236                            |

In Table 8, with a test value = 0.3431 taken from the average value, it is concluded that the increase in SE did not increase significantly at that value, because the Sig. (2-tailed = 0.999) > 0.05. Then we analyzed again to find out that the increase did increase significantly by lowering the test value to 0.31.

Table 9. Improved Analysis of Self-Efficacy One-Sample Test with Value Test = 0.31

|                | t  | df | Sig. (2-tailed) | Mean Difference | 95% Confidence Interval of the Difference |
|----------------|----|----|-----------------|-----------------|------------------------------------------|
| N_Gain_SE      | 2.814 | 60 | .007            | .03311          | .0096 - .0567                            |

In Table 9, with a test value = 0.31, we conclude that the increase in SE increased significantly at the value of 0.31 in the medium category because of the Sig. (2-tailed = 0.007) < 0.05.
3.4. Association between Reasoning and Representation Capabilities with Self-Efficacy

Associations here are divided into 2 types:

3.4.1. Bivariate Association

Correlation between reasoning and representation ability, reasoning ability and SE, as well as representation and SE ability.

**Table 10. Bivariate Correlation between Reasoning, Representation, and SE Capabilities**

|                  | Postest Reasoning | Postest Representation | Postest SE |
|------------------|-------------------|------------------------|------------|
| Postest Reasoning| Pearson Correlation | 1                      | .818**     |
|                  | Sig. (2-tailed)    | .000                   | .008       |
|                  | N                  | 61                     | 61         |
| Postest Representation| Pearson Correlation | .818**     | 1          |
|                  | Sig. (2-tailed)    | .000                   | .077       |
|                  | N                  | 61                     | 61         |
| Postest SE       | Pearson Correlation | .338**     | .228       |
|                  | Sig. (2-tailed)    | .008                   | .077       |
|                  | N                  | 61                     | 61         |

**. Correlation is significant at the 0.01 level (2-tailed).**

In Table 10. The correlation coefficient between reasoning and representation ability is 0.818 with a very strong category and positive direction, the conclusion can be drawn from the value of sig. (2-tailed) i.e. 0.000 < 0.005, meaning that there is a significant positive correlation between reasoning and representation abilities.

The correlation coefficient between reasoning ability and SE is 0.338 with a very weak category and positive direction, the conclusion can be drawn from the value of sig. (2-tailed) i.e 0.008 < 0.05, meaning that there is a significant positive correlation between reasoning ability and SE.

The correlation coefficient between the ability of representation and SE is 0.228 with a weak category and positive direction, the conclusion can be drawn from the sig value. (2-tailed), that is 0.077 > 0.05, meaning that there is no significant positive correlation between reasoning ability and SE.

3.4.2. Partial association

Correlation between reasoning ability and representation with SE as the control variable.

**Table 11. Partial Correlation between Reasoning Ability, and Representation, and SE as a Control Variable**

|                  | Postest Reasoning | Postest Representation |
|------------------|-------------------|------------------------|
| Postest Reasoning| Correlation       | 1.000                  | .808       |
|                  | Significance (2-tailed) |          | .000       |
|                  | Df                 | 0                     | 58         |
| Postest SE       | Correlation       | .808                  | 1.000      |
|                  | Significance (2-tailed) |          | .000       |
|                  | Df                 | 58                    | 0          |

In Table 11. The correlation coefficient between reasoning ability and representation with SE as a control variable is 0.808 with a very strong category and positive direction, the conclusion can be drawn from the value of sig. (2-tailed) is 0.000 < 0.005, meaning that there is a significant positive correlation between reasoning ability and representation with SE as a control variable. However, the correlation
the correlation coefficient is smaller than the correlation coefficient before it is given SE as a control variable. Therefore SE should not be used as a control variable.

3.4.3. Association between Reasoning and Representation Capability seen from the KAM Category (Superior, Medium, Asor)

Table 12. Bivariate Correlation between Reasoning Ability, and Representation in Higher Students

| Posttest Reasoning | Posttest Representation |
|--------------------|-------------------------|
| Pearson Correlation| 1                       |
| Sig. (2-tailed)    | .889*                   |
| N                  | 5                       |

In Table 12, the correlation coefficient between reasoning and representation abilities is 0.889 with a very strong category and positive direction, the conclusion can be drawn from the value of sig. (2-tailed), that is 0.044 < 0.05, meaning that there is a significant positive correlation between reasoning ability and representation in high ability students.

Table 13. Bivariate Correlation between Reasoning Ability, and Representation in Medium Students

| Posttest Reasoning | Posttest Representation |
|--------------------|-------------------------|
| Pearson Correlation| 1                       |
| Sig. (2-tailed)    | .838**                  |
| N                  | 46                      |

In Table 13, the correlation coefficient between reasoning and representation abilities is 0.838 with a very strong category and positive direction, the conclusion can be drawn from the value of sig. (2-tailed) that is 0.000 < 0.05, meaning that there is a significant positive correlation between reasoning and representation skills in students with moderate ability.

Table 14. Bivariate Correlation between Reasoning Ability, and Representation in Lower Students

| Posttest Reasoning | Posttest Representation |
|--------------------|-------------------------|
| Pearson Correlation| 1                       |
| Sig. (2-tailed)    | -.589                   |
| N                  | 10                      |

In Table 14, the correlation coefficient between reasoning and representation abilities is -0.589 with a strong enough category and the direction is negative, the conclusion can be drawn from the value of
sig. (2-tailed), that is 0.073 < 0.05, meaning that there is no significant negative correlation between reasoning ability and representation in students with low ability.

In this second year the article with the title: Indicators that influence prospective mathematics teachers representational and reasoning abilities (Journal IOP Conf. Series: Journal of Physics: Conf. Series 948 (2018) 012053 doi: 10.1088 / 1742-6596 / 948/1/012053 ) , indexed Scoopus and can be downloaded at the address: http://iopscience.iop.org/article/10.1088/1742-6596/948/1/012053/pdf.

3.5. Analysis of Student Work Outcomes After Getting Learning With A Scientific Approach

In general, there are still students who do not give good arguments in the form of suggestions / comments / additions / refutation of the answers that have been presented when discussing answers in teaching materials. It is assumed that there is a relationship between the teaching material of the scientific approach and the mathematical representation ability of students, meaning that some students do not answer the question because student representation is still low according to the results of the first year research, but not a few students who have good reasoning and representation skills which is shown by being able to convey his argument in every activity both in oral and written discussions.

![Figure 1](image1.png)

**Figure 1.** Frequently Answered Questions Not Related to Giving an Argument

There are groups that only write a little information from the observations. Students have difficulty in reasoning the problem being observed, so that information from the problem being observed is very little that can be written. It can be seen from the answers of students who only write information that has data in the form of numbers, not trying to write information in visual or image form.

![Figure 2](image2.png)

**Figure 2.** Writing a Little Information

Many groups make the questions do not match the problem. Seen from the answers of students who write questions that are out of sync between the problem with the questions made.
There are groups that can create other similar problems, but still have difficulty in arranging these problems into good sentences. Many groups have difficulty in drawing conclusions from problems that have been found, as seen from the answers of students who fill the conclusions with the same answers, namely answering that the conclusions they wrote are material that can be modeled, and solving real-life problems. The rest are no other statements that are unique, and specific.

There are also several groups that conclude that the problem is not consistent with the sub topics being discussed, for example students conclude that the material is an evaluation of the trigonometric function, and trigonometric identity, even though the problem is still simple and has not entered into the material earlier.
However, not all students are less able to develop their reasoning power, which is indicated by procedural and rigid answers following the example. There are a number of students who give answers that meet several good reasoning indicators. The following is an example of a pretty good student answer.

Figure 5. Good reasoning in the Material of Quadratic Equations

In Figure 4 it can be seen that the subject uses the Square Root Search Formula (ABC Formula), which differs from most other subject answers. In order to more easily understand the subject line of thinking, we must go back to question No. 3, namely "Make questions that fit the theme of the section of the problem". At this number the subject makes the question "In what year was the average entrance ticket price of $6.50?". This is different from most other subjects which make questions relatively easy such as, "What is the average entrance ticket price in 2009?". This kind of question is even too easy because it only substitutes the value of \( t \) into a known quadratic equation so that it only slightly meets the indicator mathematical reasoning.

Although at a glance just behind the question, the question "In what year was the average entrance price of $6.50?" Having a higher level of complexity because the equation that is known to be a quadratic equation requires a Square Root Search Formula (or other method which is certainly more complicated). The level of complexity increases again because the coefficient of the quadratic equation that is known is not an integer.

From the process of working on the problem, the subject has fulfilled several indicators of mathematical reasoning according to Romberg and Chair (in Andriani, 2012), including; (1) Estimate the answer and the solution process. The subject knows that the answer to the question is not simple and is required to use a certain formula or process; (2) Use patterns and relationships to analyze mathematical situations, draw analogies, and generalize. The subject uses his knowledge of finding square roots and analyzes the relationship with quadratic equations; (3) Follow the rules of inference.
In the topic of Linear Inequality it is found that there are some students who still have difficulty in distinguishing between equality problems and inequality problems. The topic of Linear Inequality and the topic of Linear Equation make it possible to have the same situation and facts. Therefore such a subject is difficult to distinguish between inequality problems and equality problems. The following in Figure 5 is presented one of the answers of subjects that do not fit into the topic of Linear Inequality.

Subject's answer to Problem No. 3 regarding questions that fit the theme of this section namely Linear Inequality is incorrect. The subject's answer, "What was the average salary for elementary school teachers in the United States in 2003?" Is a matter of linear equations. Neither with the second answer, which is "In what year was the average salary for elementary school teachers in the United States of $36.35 (thousand)?".

However for the same facts, linear inequality problems can be formed with similar sentences, such as "Since what year has the average salary of elementary school teachers in the United States exceeded $30.00 (thousand)?"

Subject error shows the inability of the subject to fulfill two indicators of mathematical representation in NCTM (2000), namely; (1) Selecting, applying and interpreting between mathematical representations to solve problems. The subject is not able to present the linear inequality problem; (2) Use representations to model and interpret physical, social, and mathematical phenomena. The subject misinterprets the problem of linear inequality with the problem of linear equations.

The subject's answers also did not meet the indicators in Romberg and Chair's mathematical reasoning (in Andriani, 2012), namely; use patterns and relationships to analyze mathematical situations, draw analogies and generalizations.

Inaccurate subject in mathematical situation analysis and view it the same as the problem of linear equations. For the same topic, namely linear inequality with scientific learning, there have been students who provided answers that showed good reasoning and representation, as in Figure 6 below.

**Figure 6. Error in Mathematical Representation and Reasoning**

In the topic of Linear Inequality it is found that there are some students who still have difficulty in distinguishing between equality problems and inequality problems. The topic of Linear Inequality and the topic of Linear Equation make it possible to have the same situation and facts. Therefore such a subject is difficult to distinguish between inequality problems and equality problems. The following in Figure 5 is presented one of the answers of subjects that do not fit into the topic of Linear Inequality.

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Inaccurate subject in mathematical situation analysis and view it the same as the problem of linear equations. For the same topic, namely linear inequality with scientific learning, there have been students who provided answers that showed good reasoning and representation, as in Figure 6 below.
Figure 7 Example of a good Representation and Reasoning in Linear Inequality

This subject makes two questions with the same topic as the previous subject which is lacking in representation and mathematical reasoning, the answer is shown in Figure 12. The subject's answers in Figure 13 are in accordance with the problem of linear inequality, namely:

- In what year was the average salary of elementary school teachers in the United States between $32.5 (thousand) to $42 (thousand)?
- Since what year has the average salary of elementary school teachers in the United States exceeded $54 (thousand)?

Subjects have been able to meet the three indicators of mathematical representation according to NCTM (2000), namely; (1) Creating and using representations to organize, take notes, and communicate mathematical ideas. The subject can create and represent mathematical ideas about inequality; (2) Selecting, applying and interpreting between mathematical representations to solve problems. The subject can interpret the mathematical inequality problem correctly in the answer; (3) Use representations to model and interpret physical, social, and mathematical phenomena.

In addition to mathematical representation, the subject has also fulfilled at least three indicators of mathematical reasoning according to Romberg and Chair (in Andriani, 2012), namely; (1) Provide an explanation using models, facts, traits, and relationships. (2) Estimate the answer and the solution process use patterns and relationships to analyze mathematical situations, draw analogies and generalizations.

4. Conclusions

The conclusions of the research are (1) the increase in reasoning ability increased significantly at the value of 0.43 with the moderate category. (2) Increasing the ability of representation increased significantly at 0.34 with a moderate category. (3) The increase in SE increased significantly at 0.31 in the medium category. (4) There is a significant positive correlation between reasoning ability and SE, but the correlation coefficient between reasoning ability and SE is 0.338 which is categorized as weak. (5) There is no significant correlation between the ability of representation and SE, with the correlation coefficient between the ability of representation and SE of 0.228 which is categorized as very weak and the direction is positive. (6) There is a significant positive correlation between the ability of reasoning and representation in students with high ability with the correlation coefficient between reasoning and
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