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The Analysis of Mathematical Adaptive Reasoning (PAM) and Scientific Literacy on The 10th Grade Students' Understanding of Physics Concepts

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Abstract. The study aims to examine the relationship between mathematical adaptive reasoning (PAM) and scientific literacy due to understanding concepts. By using random sampling, the sampling was selected from three schools. Validity, reliability, level of differential, discrimination test were applied to the instrument of mathematical adaptive reasoning (PAM), scientific literacy, and understanding concepts (in form the test). The conclusion can be shown from the research that the hypothesis test ($\alpha = 0{,}05$) of mathematical adaptive reasoning (PAM) toward understanding concepts is 0,000. Scientific literacy toward understanding concepts is 0,021. Mathematical adaptive reasoning (PAM) and scientific literacy toward understanding concepts is 0,000. The score indicates students' improvement in understanding concepts effected by mathematical adaptive reasoning (PAM) and scientific literacy.

INTRODUCTION

Indonesia has a low education quality compared to other countries. This information obtained from the PISA data collection (Program for International Student Assessment) conducted in 2015. It shows that the average ability of Indonesian students is ranked 61 from 70 countries [1]. Tests issued by PISA cover three domains. They are science, mathematics, reading domain. Mathematics and science tests are an assessment of a person's ability to formulate, work on, and interpret mathematical things using their reasoning. Reading test is a person's ability to observe, analyze, and interpret the problems given so that they can be solved. The score obtained from the science domain of Indonesian students was 403 from the highest score of 556, the mathematics domain score was 386 from the highest score of 564, and the reading domain score was 397 from the highest score of 535[2]. The scores obtained from the three domains show the lack of students' cognitive ability especially in understanding concepts.

Understanding concepts is the most important part of physics learning. Students should carry out the learning process through active participation with the concepts and principles so that they can obtain the meaningful knowledge [3]. Understanding becomes the standard of an Education program that reflects competence so that it can lead students to become competent in various aspects of life [4]. The understanding of physics concepts is very necessary to analyze the phenomena that occur or even to associate the existing theories and problems to be solved. Physics is a very complex learning, one of which is the concept of Newton's law. Students are required to be able to understand the problems and symbols in the physics concepts [5]. The physics teacher of MAN 11 Jakarta states that most of the students' difficulties in physics lesson are mathematical calculation [6]. Students are still weak in mathematical calculation and get difficulties in reading physical symbols that implied in several formulas. Both of these abilities will affect the students' understanding of physics concepts. In accordance with the opinion expressed by Orlich which states that concrete concepts have clear characteristics and are easy to recognize while abstract

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concepts have different characteristics for each person [7]. In this case, the understanding of concepts in this study has concrete properties if related to the ability of mathematical adaptive reasoning (PAM) and scientific literacy, because these two things are very clear and easy to recognize by students.

Students' understanding in physics concepts can be seen from: 1) being able to restate a concept; 2) able to provide examples of a concept; 3) able to apply a concept to solve mathematical problems. Understanding concepts can explore a science and apply it to a problem, both in a lesson or daily life. The concept intended in this study is something used to analyze a problem so the students are required to understand the concept first that will be used in solving the problem. Understanding concepts also have a benefit for teachers which can make them easier to deliver various and hierarchical material.

Those three variables have a relationship with one another which becomes one of the students' difficulties in physics lesson. This thing is often used as a research material conducted by researchers to solve a problem of students' understanding of concepts in physics lessons. Fabby and Koenig (2015) in their research states that the students who have high-level reasoning would be more capable to solve physics problems [8]. In addition, Arum (2015) also states that there is a relationship between scientific literacy (reading comprehension) and students' ability to solve problems that requires high-level thinking to solve [9]. The research shows a relationship between problem solving ability and the ability to solve mathematical narrative questions as the implication of fundamental concepts in physics so that there is a relationship between reasoning ability and scientific literacy on students' understanding of physics concepts.

The solution to overcome the problems is to create the habit of reasoning and reading/literacy. Physics lesson will not be separated from mathematical concepts. Mathematics is a symbolic language used to interpret all phenomena studied in physics. So that there is a relationship between mathematical formulas and symbolic languages to achieve an understanding of physics concepts [10]. Mathematical formulas cannot be memorized, but by reasoning, it would be easier to remember the formulas [11]. The reasoning is mathematical adaptive reasoning (PAM). The ability to understand symbolic language is done by growing students' literacy skills [12]. The literacy is science literacy to find out various scientific contents, both in the form of symbolic texts (mathematical equations) and knowledge texts about physics concepts (theoretical) [13]. Both of those abilities are expected to have a good effect on the students' understanding of physics concepts.

METHODS

A correlation method is used in this research by using correlation analysis approach. To take the sample for collecting data, *random sampling* is used in this research. The sample here is one of senior high schools in South-Jakarta, South-Tangerang, and Bogor. The data are collected through a test which is a multiple choice test about Newton law. Non-parametric analysis is used as a data analysis technique. This research constellation is shown in a matrix shaped table consisting of 4 cells generally written as X_1 matrix for PAM ability, X_2 for scientific literacy, X_{12} for PAM and scientific literacy, and Y matrix for understanding of concept.

RESULT AND DISCUSSION

Understanding Concepts Description, Mathematical Adaptive Reasoning (PAM), and the Students' Scientific Literacy

Fig. 1 shows a profile of students' understanding of physics concepts. Understanding concepts in this research consists of three indicators: being able to restate a concept, provide examples of a concept, and apply a concept to solve mathematical problems. The second indicator is giving an example of a concept more controlled by students. Based on Fig. 1, the highest achievement of the second indicator of students' understanding of physics concepts (94%) is on the question 20 and 21 about the application of Newton's first law to a moving object. The lowest achievement is on the first indicator (81%). It is on the question 18 and 19 about the application of forces acting on an object based on the motion system and acceleration on the object.

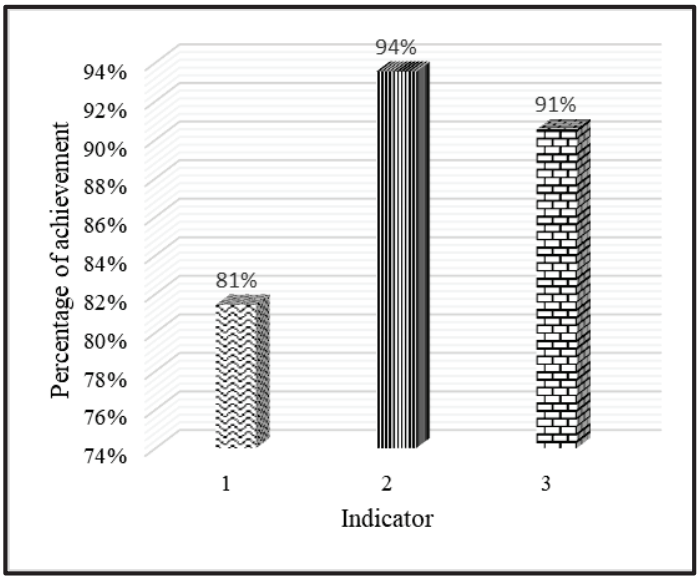

FIGURE 1. The Students' Understanding of Physics Concepts from Each Indicator

Fig. 2 shows the students' mathematical adaptive reasoning (PAM) profile. Mathematical adaptive reasoning (PAM) in this research consists of two indicators which the ability are to guess and draw logical conclusion (deductive intuitive), as well as the ability to guess and draw general conclusion based on a number of observed data (inductive intuitive). Intuitive knowledge is a type of knowledge that is not based on sufficient empirical evidence or logical arguments that are received with certainty and clarity [14]. The second indicator is giving an example of a concept more controlled by students. Based on Fig. 1, the achievements of students' mathematical adaptive reasoning (PAM) on the first indicator (61%) are on the question 1, 2, 6, 7, and 9 about the application of Newton's laws implied by an event. The achievement of the second indicator (74%) are on the question 3, 4, 5, 8, and 10 about the application of forces acting on an object based on observed data.

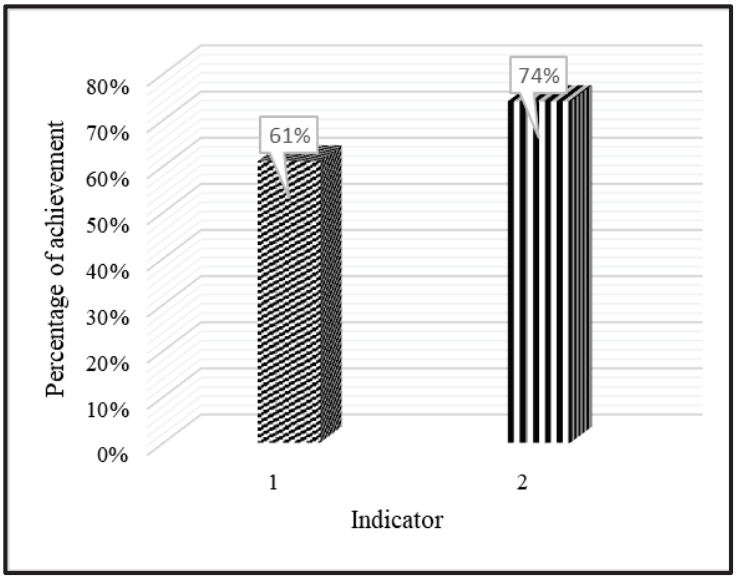

FIGURE 2. The Students' Ability of Mathematical Adaptive Reasoning (PAM) from Each Indicator

Fig. 3 shows the students' scientific literacy mastery profile. Scientific literacy in this research consists of seven indicators which is shown from Tab. 1 as follows [15]:

TABLE 1. Scientific literacy indicators

Level	The Descriptions of Students' Ability at Each Level
6 **Indicator 7**	At level 6, the students are able to **use** the knowledge of content, procedures, and epistemic to consistently explain, evaluate and design a scientific investigation, and interpret the data in **the various complex life situations** that require **a high cognitive level**. The students at this level are consistently able to **demonstrate** good science thinking and reasoning which requires the use of abstract models and ideas and also use that reasoning **in the complex and unfamiliar situations.** They are also able to **develop arguments** for criticizing and evaluating the explanation, models, data interpretation, and proposing experimental designs **in a variety** of personal, local and global contexts.
5 **Indicator 6**	At level 5, students are able to use the knowledge of content, procedures, and epistemic to explain, evaluate and design scientific investigation, and interpret data **in various life situations**, **in some - not all -** cases that require **a high cognitive level**. Students at level 5 are able **to show evidence** of **good** scientific thinking and reasoning that requires the use of abstract models and ideas, they are able to use that reasoning **in complex and unfamiliar situations**. They are also able to **develop arguments** for criticizing and evaluating the explanation, models, data interpretation, and experimental designs that are proposed **to some, but not all** personal, local and global contexts.
4 **Indicator 5**	At level 4, students are able to **use** the knowledge of content, procedures, and epistemic to explain, evaluate and design scientific investigation, and interpret the data in a variety of specific life situations that require **an intermediate cognitive level**. Students at level 4 are able to **show evidence** of scientific thinking and reasoning and also able to apply it **in unfamiliar situations**. They are also able to develop **simple arguments** to question and critically analyze explanation, model, data interpretation, and submit experimental designs that are proposed **in several** personal, local, and global contexts.
3 **Indicator 4**	At level 3, students are able to **use** the knowledge of content, procedures, and epistemic to explain, evaluate and design scientific investigation, and interpret the data **in some certain life situations** that require **an intermediate cognitive level**. Students at level 3 are able to **show some evidence** of scientific thinking and reasoning that is usually applied **in familiar situations**. Students are able to **develop some arguments** for questions and critically analyze the explanation, model, data interpretation, and experimental designs that are proposed **in several** personal, local and global contexts.
2 **Indicator 3**	At level 2, students are able to **use** knowledge of content, procedures, and epistemic to explain, evaluate and design scientific investigation, and interpret the data **in some familiar life situations** that require **a low cognitive level**. Students at level 2 are able to **develop some arguments** for questions and able to **comment** on the explanation, model, data interpretation, and different experimental designs that are proposed **in several** personal, local, and global contexts.
1b **Indicator 2**	At level 1b, students are able to **demonstrate little evidence** to use knowledge of content, procedures, and epistemic to explain, evaluate and design scientific investigation, and interpret the data **in some familiar life situations** that require **a low cognitive level**. Level 1b students are able to **try** to transform and explain **simple** data and **apply it directly** to **a few familiar situations.**
1a **Indicator 1**	At level 1a, students are able to **use a bit** knowledge of content, procedures, and epistemic to explain, evaluate and design scientific investigation, and interpret the data **in some familiar life situations** that require **a low cognitive level**. Students at level 1a are able to transform and explain **some** simple data and apply it directly to **some familiar situations**. They are able to comment on the explanation, model, interpretation of data, and different experimental designs that are proposed **in some very familiar** personal, local and global contexts.

Based on Fig. 3, the highest achievement of students' scientific literacy at level 3 indicator (98%) is on the question 13 about the application of Newton's law in creating a technological product. The lowest achievement is at level 6 indicator (62%), is on the question 15 about mathematical equations in the concepts of string tension presented in a narrative.

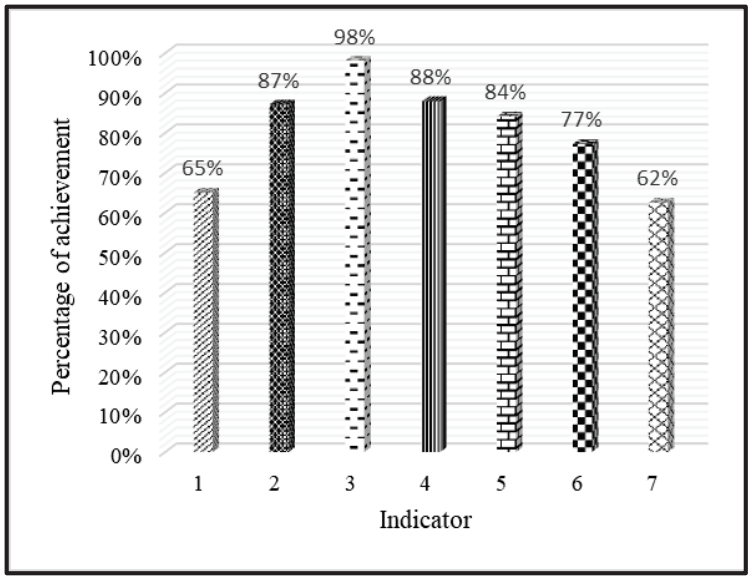

FIGURE 3. The Students' Ability of Scientific Literacy from Each Indicator

Test Results Prerequisite for Statistical Analysis

The test result of mathematical adaptive reasoning (PAM), scientific literacy, and students' understanding concepts of Newton's law material which has been processed by using SPSS-22 shown in the Tab. 2.

TABLE 2. Test Score Processing Result

Explanation	PAM	Scientific Literacy	Understanding Concepts
Mean	67,6	80,3	88,34
Deviation Standard	9,58	12,72	10,78
Normality Test *Shapiro-Wilks*	0,091	0,033	0,003
Homogeneity Test *Levene Statistic*	0,001	0,174	0,818
Hypothesis Test *Mann-Whitney U Kruskal Wallis*	**PAM on the Understanding Concepts**	**Scientific Literacy on the Understanding Concepts**	**PAM dan Scientific Literacy on the Understanding Concepts**
	0,000	0,021	0,000
Regression Test	**PAM**		**Scientific Literacy**
Understanding Concepts (Y) – *Constant* (82,157)	0,31		0,103

Tab. 2 shows mathematical adaptive reasoning (PAM) of students with normal distribution. While scientific literacy and understanding of physics concepts are not normally distributed. In this case, the hypothesis test uses non parametric analysis (*Mann Whitney* test for one independent variable and *Kruskal Wallis* test for more than one independent variable. The result of hypothesis test shows there is an effect on mathematical adaptive reasoning (PAM) and scientific literacy on understanding concepts. The result of the regression test is used to find out how

independent variable has an effect on dependent variable. The results of the statistical hypothesis test state that H_0 is rejected and H_1 is accepted. The meaning of the statistical hypothesis are there is a relationship between mathematical adaptive reasoning (PAM) and understanding concepts, there is a relationship between scientific literacy and understanding concepts, and there is a relationship between mathematical adaptive reasoning (PAM) and scientific literacy on understanding concepts. The result of this research is supported by other researches which state that the importance of teaching science, technology, and literacy, it is caused that later someone is able to understand and master the understanding of science and technology through their literacy skill (Kiyici, 2017). In addition, other researches state that groups with high level reasoning have higher problem-solving ability than the groups with average and low-level reasoning (Koenig, 2016). Both researches show a relationship between high level of reasoning skill and literacy on understanding concepts and solving science problem. The result of the regression test concludes if mathematical adaptive reasoning (PAM) increases, the average of students' understanding of physics concepts will also increase 0,031 (3,1%), whereas if scientific literacy increases, the average of students' understanding of physics concepts will also increase 0.103 (10.3%).

CONCLUSION

Mathematical adaptive reasoning (PAM) and scientific literacy significantly affect students' understanding of physics concepts. If there is an increase in mathematical adaptive reasoning (PAM), the students' understanding of physics concepts will also increase 31%, whereas if there is an increase in scientific literacy, the students' understanding of physics concepts will also increase 10.3%. The students master understanding concepts more in indicator two which is able to provide example of a concept.

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