Behaviour of mathematics and physics students in solving problem of Vector-Physics context

Sardi¹, M Riza² and J Mansyur²※
¹SMA Karya Bhakti Mamboro
²Universitas Tadulako, Palu
※E-mail: jusman_mansyur@untad.ac.id

Abstract. This research aimed to describe behaviors of mathematics and physics students in solving problem of the vector concept in physics context. The subjects of the research were students who enrolled in Mathematics Education Study Program and Physics Education Study Program of FKIP Universitas Tadulako. The selected participants were students who received the highest score in vector fundamental concept test in each study program. The data were collected through thinking-aloud activity followed by an interview. The steps of data analysis included data reduction, display, and conclusion drawing. The credibility of the data was tested using a triangulation method. Based on the data analysis, it can be concluded that the two groups of students did not show fundamental differences in problem-solving behavior, especially in the steps of understanding the problem (identifying, collecting and analyzing facts and information), planning (looking for alternative strategies) and conducting the alternative strategy. The two groups were differ only in the evaluation aspect. In contrast to Physics students who evaluated their answer, mathematics students did not conducted an evaluation activity on their work. However, the difference was not caused by the differences in background knowledge.

1. Introduction
One of abilities that must be possessed by students is problem-solving ability. In the 21st century, the ability to learn, creative thinking, decision making, and problem solving skills are required to be success in the job market competition. Furthermore, problem solving skill is an important ability that must be developed in science learning [1].

The research on problem-solving ability has been conducted to map understanding and skills of pre-service mathematics teachers in solving math problem based on PISA standard. The results of the research showed that pre-service mathematics teachers have the ability to formulate the problem but having difficulties to employ and to make an interpretation [2]. A study on problem-solving skills in mathematics education students also indicated that students' problem solving skills were still low [3]. In contrast, another study showed that the ability of pre-service physics teacher to solve vector problem that is represented in different contexts was adequate [4].

Nugent and Vitale [5] stated that a problem solving activity involves identifying problems, exploring alternative solutions, implementing alternatives or selected solutions, and bringing about a result called a conclusion. Polya [6] developed four problem solving steps: understanding the problem, making a plan, implementing the plan, and re-examining the results by looking back at the completed solution. Polya [6] emphasized that problem solving skills can be taught and learned. The research showed that the Polya’s steps can guide students to solve problems [7]. Furthermore, the results of research on solution analysis of Euclidean Geometry problem using Polya’s steps showed that in the step of understanding of the problem, making a plan, and implementing the plan, a majority of students were in a good category, but in step of the looking back, most students did not make any reviews.
A link between mathematics and physics has been reported by many studies. For instance, Meltzer [9] reported that there is a positive correlation between a gain in physics and mathematics. In addition, many mathematical concepts are used to solve the problems in physics. For example, mathematical trigonometry is widely used in mechanics. Thus, it is argued that only those who have the ability in mathematics can solve mechanical problems. Furthermore, mathematical understanding including trigonometric concept is required to understand vector concept in physics, such as the magnitude of distance, direction of various vectors, vector addition, and vector subtraction, and vector multiplication.

A problem-solving behavior of student in different context and concept can be an aspect of a research. In this context, we analyzed the ability of students to solve a problem. This research aimed to describe the behavior of mathematics and physics students in solving problems of vector in physics contexts. The analysis of the behavior focused on the thinking processes during the problem solving activity.

2. Research method
This study was a qualitative descriptive research. The research focused on a description of the problem-solving behavior of mathematics and physics students toward the topic of vector in physics context based on Polya’s steps. The subjects of the study were 20 students of mathematics education and 21 students of physics education of FKIP Universitas Tadulako. The interview respondents were two students selected from each study program who got the highest score in the vector basic ability test. The data were collected through thinking-aloud activity followed by an interview. The data were analyzed using education, presentation, and conclusion steps. The credibility of the data was tested using triangulation method.

3. Result and discussion
The results of the current research were described in the following paragraphs.

3.1. Understanding the problem
Both respondents have similarities in understanding the given problem, by re-reading the problem, translating in the form of a diagram and then identifying the known and the asked variables. In general, both respondents understood the given problem. Through the re-reading the problem, the students were trying to compile, dig and collect the information included in the problem statement. According to Kief [10], a person can be said to be able to think critically if the person identifies the faced problem and able to draft the concept, meaning the thinking activity to obtain or capture the understanding of the data that has been known. Then the two respondents identified the problem by digging the information through the drawing sketch, understanding the problem by visualizing in the form of a sketch or drawing an indicator. An student can solve a problem into the useful explanatory category as revealed [11] that is an explanation of the problem should include known and unknown information, declares the appropriate symbol for the sum, states the destination or target quantity, visualization (sketches or drawings), states the qualitative objectives, states the coordinate system and selects the system.

3.2. Making a plan
Based on the results of thinking-aloud activity, the two respondents can determine alternative solutions, especially on the determination of a resultant of two vectors, using different ways. Mathematics students revealed that to find the resultant, for example, vector \( \vec{u} \) and vector \( \vec{v} \), the respondent wrote the formula \( \vec{u} \cdot \vec{v} = |u| \cdot |v| \cdot \cos \theta \). From the written plan, the respondent wrote the multiplication formula of the dot product of the two-vector for a scalar product. In physics, the formula can be used to determine the magnitude of work denoted by W, performed by force F on an object moving as far as s. The work can be formulated as \( W = (F \cdot \cos \theta) \cdot s = Fs \cdot \cos \theta \).

Then the physics student revealed the plan according to the way of determining the resultant, through the value of \( F_x \) and \( F_y \) as well as \( F_{x2} \) and \( F_{y2} \) then determining \( F_x \) and \( F_y \).

For determining the displacement, both respondents used the same method as the Pythagoras’s theorem. Likewise, the determination of the direction and magnitude of the resultant, the two
respondents looked for each of the values $F_1$, $F_2$, and $F_3$ on the x-axis and the known y-axis of each angle and then searched for the resultant.

Both respondents can make a plan for solving the problem. The step is an important part in critical thinking and empowering skills or cognitive strategies in determining goals [12]. The process is passed after setting goals, considering, and referring directly to the target.

From the alternative problem-solving set by both respondents, the using of the method by remembering the problems that have been solved to the vector concept in a physics context. This is in line with the expressed by Rahmat, Muhardjito, and Zulaikah [13] that in working on the problems of physics, students often guess the formula used and memorize examples of problems that have been done to do other problems.

3.3. Carrying out a plan
The answers of each respondent in implementing the plan are presented as follows:

3.3.1. Determination of a resultant force.
Students of mathematics can apply the planned idea by substituting all known values into the formula

$$\vec{u} \cdot \vec{v} = |\vec{u}| \cdot |\vec{v}| \quad (s. \quad \text{Figure 1}).$$

![Figure 1. Answer sheet of mathematics student in the determination of resultant force.](image)

Respondents wrote the solution in accordance with the planned alternative solutions, only the way set by the respondents was not a way to determine the resultant. The respondent wrote the formula (dot product) in physics was used to determine the resultant.

In determining the resultant force, physics student firstly found the values of $F_{x1}$ and $F_{y1}$ as well as $F_{x2}$ and $F_{y2}$ and then defined $F_x$ dan $F_y$ (s. \ Figure 2).

![Figure 2. Answer sheet of physics student in the determination of resultant force.](image)
Gradually, respondent applied the way to follow the plan, but the respondent did not complete the answer to getting the resultant force and made an error in the calculation of the value of $F_x$.

3.3.2. The displacement (1)
In problem-solving of the displacement of both respondents apply the way according to the plan of solving using Pythagoras theorem. The answer of both respondents can be seen as follows:

![Image](image1)

**Figure 3.** Answer sheet of mathematics student about displacement (1).

![Image](image2)

**Figure 4.** Answer sheet of physics student about displacement (1).

Different answers for both respondents only on the use of symbols in applying the Pythagoras’s theorem. Students of mathematics used these symbols while physics students directly wrote the settlement without using symbols.

3.3.3. The displacement (2)
Both respondents can apply the way according to the predetermined split plan. They began the process by identifying all the information, making sure the direction of the wind and then proceeding sketch and added the known information to determine the displacement.

![Image](image3)

**Figure 5.** Answer sheet of mathematics student about displacement (2).

![Image](image4)

**Figure 6.** Answer sheet of physics student about displacement (2)
3.3.4. The magnitude and direction of resultant force

In applying a way to determine the magnitude and direction of resultant force, the two respondents also commonly had a similarity. Likewise, they also experienced the same calculation error at the end of the process, especially in summing the root number (see Figure 7).

![Figure 7. Answer sheet of mathematics student in determining a magnitude and direction of a resultant force](image)

![Figure 8. Answer sheet of physics student in determining a magnitude and direction of a resultant force](image)
Both respondents applied the way according to the plan that has been set in the previous step. In other words, they can apply the ideas to solve the problem. The behavior emphasized a statement of Albrecht [14] that a person needs to be critical in problem solving if the person is a capability of making decisions, prioritizing and selecting ideas, ideas, understandings, knowledge or answers between known choices. This is shown by the second process of the respondents in implementing carry out a plan.

From the given problem, the respondents still have misconception and miscalculation, especially in determining the resultant force. This finding in line with the research of [3] that for the determination of a resultant, in general, students were able to determine a formula to solve a problem, but they still often make a mistake because of miscalculation and incorrect determination of angle value.

3.4. Looking back at the completed solution
Both respondents were different in terms of re-evaluating the result or solution that has been obtained. The mathematics student has not done an evaluation of the solution. In this context, the respondent was convinced by the answer. The physics student re-read the problem, identified the known variable based on the sketch, looks at each completion step and then concluded the solution. In general, the behavior of the two respondents was different in terms of re-examining the solution. However, the difference was not caused by the difference in the students’ background of the study program.

4. Conclusion
Based on the data analysis, it can be concluded that the two respondents did not show fundamental differences in problem-solving behaviors, especially in the steps of understanding the problem (identifying, collecting and analyzing facts and information), planning (looking for alternative problem-solving), and implementing the plan alternative troubleshooting. Both respondents were different in terms of re-examining answers where the mathematics student did not conducted an evaluation activity on his/her work, but the difference was not caused by the differences of students’ background knowledge.

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References
[1] National Science Teachers Association 1980 NSTA Handbook Science-Technology-society: Science Education for the 1980's (Washington, DC: National Science Teachers Association, 1985) pp 46-49
[2] Nissa I C and Lestari P 2015 J. Kependid. 14 45
[3] Kurniawan H 2015 Pros. Sem. Nas. Pendidik 11 34
[4] Sari M 2015 J. Pendidik. Fis. Tadulako 3 4
[5] Nugent P M and Vitale B A 2008 Fundamental Success: A Course Review Applying Critical Thinking to Test Taking (USA: F. A. Davis Company)
[6] Polya G 1981 How to Solve It (Princeton University Press. New Jersey Princeton)
[7] Arcana I N 2012 Magister Sci. 32 18
[8] In’am A 2014 Int. Educ. Stud. 7 7
[9] Meltzer D 2002 Am. J. Phys. 70 12
[10] Kief J 1999 Berpikir Apa dan Bagaimana (Surabaya: Indah Surabaya)
[11] Lynn J 2009 Development and Validation of a Physics Problem-Solving Assessment Rubric (The University of Minnesota)
[12] Halpen 1996 Memahami Berpikir Kritis (Bandung: Artikel Pendidikan)
[13] Rahmat M, Muhardjito, and Zulaikah S 2014 J. Fis. Indonesia 18 54
[14] Albrecht K 2008 Daya Pikir (Semarang: Dahara Prize)