

Students' Mental-Modeling Ability (MMA) in Concept Understanding of Vector

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Abstract— This paper explains the role of mental models in understanding the concept of physics vector. This research type is empirical research by analyzing data from individual thinking and interview with 2 high school students. Each student represents each category (High and Low). Subjects in this study were selected based on Respondent Selection Test (TSR) of vector material. After obtaining 2 respondents, then they completed a diagnostic test to measure their Mental-Modeling Ability. The result of this study describes the stages of students in solving problems in vector material. The outcome of this study shows that the high category subjects start the stage by making a diagram that leads to the completion of the solution, the medium category is making a diagram at the end of the stage, the low category starts the problem solving without making a diagram. Students' characteristics in solving the vector problems can provide an overview, the right learning model in teaching vector concepts. All categories have not been able to link information obtained at each step of completion.

Keywords—*mental-modeling ability, concept understanding, vectors, empirical.*

I. INTRODUCTION

Education is defined as a process of knowledge and regeneration of a sustainable attitude towards a better direction. As a knowledge process, it requires a good mental-modeling ability [1]. The mental model is an internal representation of a person formed from the results of self-interaction with the environment [2]. Internal representation is the idea or event in a person's mind. Hutagaol added that someone's internal representation is difficult to observe directly because it is a mental activity from someone in his mind (mind-on). However, the internal representation can be concluded or suspected based on external representation in various conditions; for example from its expression through words (verbal), through writing in the form of symbols, images, graphics, tables or through hands-on tools [3]. Representation is something that can be symbolized on an object or process [4].

There is a reciprocal relationship between the internal and external representations of a person when he is faced with a problem-solving physics including vectors. In other words, representation is a person's mental picture which is a learning process that can be understood from the mental

development of a person. According to Mansyur, the construction of internal representation is usually called mental patterns or mental models [5]. Van der Veer states that mental models are an internal representation of a person formed from environmental interactions [2].

Some researchers introduced the term Mental-Modeling Ability (MMA) to explain the mental capabilities of a person's model [6]–[8]. According to Wang and Barrow, Mental-Modeling Ability indicates the experience in generalizing and manipulating mental models [8]. Mansyur stated that Mental-Modeling Ability (MMA) is a factor that influences the construction process of mental models which then play a role in the quality of construction of external representations, especially in the early stages of problem-solving activities [6]. In other words, Mental-Modeling Ability is the ability of students to construct and utilize the abilities of their mental models and solve a problem that can be expressed to an external representation system. Rahmilia et al. in their research found that there are three types of aspects of knowledge that affect the ability of students to manipulate mental models or Mental-Modeling Ability (MMA), namely: knowledge, understanding, and the ability to connect the concepts of static electricity relate to one another [7]. Assessing students' MMA is very important. By studying the MMA of students, it is expected that learning patterns will be obtained that can improve students' MMA which is expected to have an impact on improving students' understanding, including the concept of physics vector.

II. RESEARCH METHODS

This research used a qualitative descriptive. The participants of the research were 2 grade X students SMA Negeri 2 Merauke. The students were chosen by using Respondent Selection Test (RST). The RST result were classified as high, medium and low group. Students who attain the same RST results in each group were. In each group a student chooses each categories. Furthermore, selected respondents, engage in activities thinking aloud, followed by semi structured.

Researchers in this study are acting as the main instrument. To support the researchers, supporting instruments were used in the form of respondents' selection tests, MMA diagnostic tests and interview guides. Data

derived from aloud thinking and interview results are then made in transcript form to further analyze the ability of students' mental models using the MMA exploration rubric [9].

TABLE I. Mental-Modeling Ability CATEGORIZATION RUBRIC Ref. [9]

No.	MMA Characteristics	Score
1	Producing a mental model in the form of representation diagram/graphs	2
	Producing a mental model based on the representation of diagram/graphs or other relevant form of representation	1
	Unable to generate any form of representation	0
2	Being able to manipulate mental models based propositions	4
	Having a mental model of rigid and concluded that this form of mental models cannot be changed when a new proposition is added to the model, often need to be based on the model of the concrete	2
	Unable to use this form of representation whatsoever based propositions exist	0
3	Monitoring the metacognitive process of drafting a mental model	4
	Performing self-check using other approaches to test or check the mental models to identify the error of the mental model	2
	Processing metacognitive monitor the preparation of the mental model	0
Total Max		10

III. RESULT AND DISCUSSION

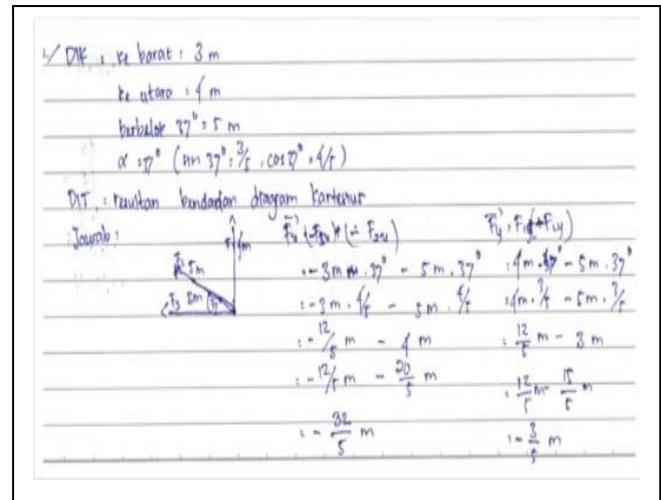
The results obtained in this study must first go through the credibility of the data. The credibility of the data used was the triangulation method analysis. Triangulation method is a technique of comparing two or more data obtained through different methods (thinking aloud and interviews). TA is used to be able to visualize the mental models of the respondent which is illustrated from the representation of students. In order to obtain clear information from the results of the existing information processing and patterns of interaction between the environment (information) and the respondent's scientific experience. Semi-structured interviews were used as verification of all data clarification from respondents. If the data analysis found that there is a difference in the TA results and the interview, then the written test data was used as a comparison.

The researchers analyzed the respondents' written answer sheet. As supporting data, an analysis of TA results and interviews with respondents was also conducted. From the treatment obtained, how students reconstruct and manipulate their mental models can be understood which also characterizes the MMA of each respondent.

A. Mental-Modeling Ability of High Category Respondents

Test and interview results for high category respondents (HCR) show the characteristics of MMA generated by respondents. It is found that the respondents understood well the stages of solving vector problems. The first step taken by the HCR is to translate the question in a form that is understood by the respondent. HCR starts by generating external representations in the form of diagrams/graphs.

HCR believed that he needed a diagram/graph to make it easier to solve a problem. According to the respondents, by describing the diagram it will be easy to determine the movement of objects so that the resultant value requested by the question can be identified.



Before painting a diagram like the one shown on the written answer sheet, the HCR shows an interesting attitude to the holding of the stationery. HCR attitude describes the pattern of internal representation of HCR. Where respondents tried to analyze the problem. High category respondents also seem hesitant when starting to draw diagrams. This can be seen in the thinking alone process carried out by HCR.

[Pulling the ballpoint held] we draw it first, from the picture we see that the object moves to the west, meaning to the left 3 meters, then to the north as far as 4 meters, turn 370 as far as 5 meters [focus to image].

Furthermore, the HCR manipulates mental models. HCR changes the form of representation in the form of symbolic representation to be included in vector mapping. This is seen in the transcript of the interview between the researcher and the HCR.

Q: How are the x component equations and formulas used?

R: Let's just say this is F1 (writing in the vector pointing north), F2 (writing in the vector pointing west)

From the interview transcript above, it can be seen that the HCR tries to reconstruct the resulting representation. But the HCR is unable to tell in detail about the symbol symbolization. The researcher interpreted the HCR behavior in which the HCR looked doubtful and was unsure of describing vector movements. The settlement strategy that is done by HCR is to look for component values first and then look for the resultant value. But when looking for the component x value, the subject again made a misconception when painting axes in the Cartesian diagram x. HCR equates

the angle of vector F2 to be used also in vector F3. This can be seen in the following interview transcript.

P: So F3 vector is positive and F2 is negative?
R: Everything is negative because of the direction to the left (adding a minus value to vector F3)

The stages carried out by the HCR have shown the correct stages in manipulating the mental models they have. But the misconceptions that have been made make the HCR unable to solve the problem properly. Ref. [9] states that Mental-Modeling Ability is also influenced by the mastery of one's concepts. Even though the steps that HCR has passed are correct, the low mastery of the concept makes the final answer to the HCR not in accordance with the desired problem.

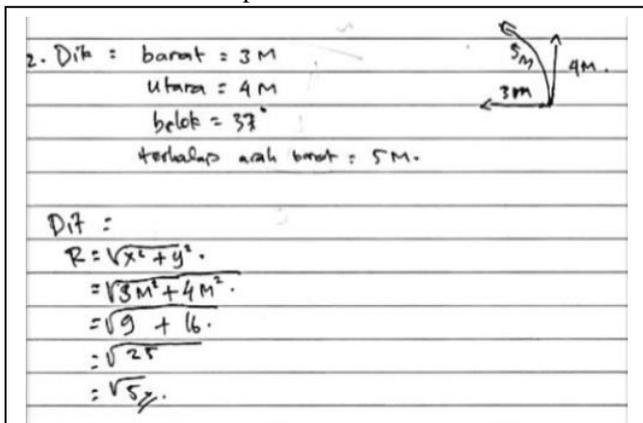
The last stage of problem-solving based on the mental-modeling ability of students is to monitor the reconstruction process metacognitively. Especially at this stage, it can be seen that in the HCR there is no metacognitive monitoring process.

B. Mental-Modeling Ability of Low Category Respondent

The initial step of the low category respondent (LCR) in solving vector problems begins with organizing the information provided by the problem. In the interview transcript, the LCR steps were shown in solving vector problems.

Q: What is known about the problem above?
R: Known (pointing to the question) to the west as far as 3 meters, to the north as far as 4 meters and turned 370 towards the west as far as 5 meters
Q: what is the next question asked?
R: he asks how the resultant object is and the travel picture is included in the Cartesian diagram.

From the transcript, it is shown that the LCR explained while pointing at the question. The researcher interpreted what the LCR did as a form of representation from the LCR which tried to understand what the problem wanted. On the transcript, it was also seen that the LCR could properly mention the information asked. But on the LCR answer sheet only write answers in the form of known and questioned, then solve the problem by using an external representation in the form of a diagram representation then continued with the use of mathematical representations.



On the answer sheet, it appears that the LCR has chosen the right step by first describing the object's travel vector. From this, we can find out that the LCR has a good understanding of the direction of the wind so that the travel vector image of the object described is appropriate. However, the LCR made a mistake in translation because it did not first describe the Cartesian diagram when starting to draw the vector, but rather directly described the vector of travel of the object formed without the Cartesian diagram. At the stage of producing representations in the form of diagrams, the LCR has been able to do it. Even though there are errors in describing vector travel diagrams. In addition, at the stage of manipulating mental models, LCR made a mistake by directly using the resultant formula, according to the following transcript:

Q: Is the next step to solving this problem?
R: Hmm (smiling) using resultant, R = sqrt(X^2 + Y^2)
Q: What is the form of the formula if the value is entered?
R: (Silent, look at the matter)
P: For which X value does the vector mean?
R: 3
Q: For the Y value?
R: 4
P: Means that the vector X ny moves west while the one to the north is vector Y
R: (silent) Yes
Q: So the trip to the north is unused?
R: (smiling, nodding) no, just know like this

The second step in measuring the mental abilities of students' models is by manipulating the mental models produced by students. On the LCR transcripts, the formula is right for finding the resultant values of three vectors. Respondents make a mistake because they do not look for vector component values first but instead look for the resultant value. In addition, it is also found that because it only uses the value of two vectors that move west as a vector x while the vector y moves north, while the vectors that turn west with an angle of 370 are not used. Supported by the LCR statement on the transcript which said that "Just know like this" so that it appears that the LCR has not fully understood the concept of the vector and working on the question depends on the understanding of the LCR.

IV. CONCLUSION

This study attempts to analyze the Mental-Modeling Ability (MMA) of students. Both respondents showed how the mental abilities of the models of each respondent. It was obtained that the two respondents, both high and low categories, did not have the mental ability of the model in the good category. This can be seen from the final answer from the two respondents. Although both respondents produce an external representation in graphical form and can manipulate the mental models in the form of other representations. However, both respondents could not find the final answer according to the desired problem. Both respondents did not monitor the mental models produced.

The low mental-modeling ability possessed by both respondents showed that respondents did not have mastery

of concepts, problem-solving strategies, and good numeracy skills. Learning is needed with a pattern that allows students to be able to understand vector material well. This is in accordance with the research findings obtained by the references [7], [9].

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