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THE INTERPRETING ABILITY ON SCIENCE KINEMATICS GRAPHS OF SENIOR HIGH SCHOOL STUDENTS IN SOUTH SULAWESI, INDONESIA

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ABSTRACT

This research was a descriptive case study. The purpose of this research was to describe the student's ability to interpret the kinematics graph. The subjects of the study were 347 students of class XI science in the even semester of 2018/2019 in Luwu Raya, South Sulawesi Province, Indonesia. The research data were obtained from multiple-choice test results using instruments adapted from Test of Understanding Graph – Kinematics 2.6 and the results of in-depth interviews to find out the reasons learners choose answers and casual factors. The results of the study based on descriptive data analysis were 90 students or 25.94% in the low category, and 257 students or 74.06% were in the very low category. These results indicate the ability to interpret the graphs of students were still low, with the average achievement in answering questions on each of the highest indicators was 20.99 % on indicators identifying graphs based on the description. While the lowest average achievement was11.91%, which is the indicator to identify the graph that has a different variable. Base on the qualitative data analysis, the results are students had difficulties in solving the test, as follows: a) the difficulty in distinguishing symbol of the variables on the graph, b) the difficulty in determining the formula for solving test in graphical form, c) to determine when the curve on the graph v-t decreases then the object will move with speed slowed. The factors causing these difficulties are because students did not understand deeply about how to read graphs, how to solve test in graphical form, and did not understand the formula used to solve the test.

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Keywords: interpreting; ability on science; kinematics; graphs; senior high school students

INTRODUCTION

Education is a whole learning experience that occurred in all environments and lasted forever. The National scope of education is to develop capabilities and improve the quality of life and dignity of Indonesians in efforts to achieved national goals (Mudyahardjo, 2001). In order to reach it, educational staffs play a vital role in charge of teaching, training, researching, developing, managing, and providing technical services in the field of education (Swennen & Battes, 2010). Science is a subdivision of knowledge that studies natural phenomena. Through science, these natural phenomena can be studied and understood for a better life as an attempt to uncover the secrets of it, the scientist conducting research based on scientific methods (Dresch et al., 2015).

The 2013 national curriculum in Indonesian (C-13), which applied in all levels of school, is a government effort to equip students in terms of scientific knowledge, skills, and attitudes in the earlier stage. This C-13 operationalized by applying scientific approaches to every learning activity in school (Rumahlatu et al., 2016). Through this approach, students are expected to be able to carry out scientific activities as a scientist does. It is intended that the scientific culture of students can be improved, so in the future, they will able to become scientists who produce innovative work, which will give a benefit to the community (Blackley et al., 2018). Physics is a branch

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of science discussing the physical phenomenon. This phenomenon is one of the natural events, where the explanation of theories, laws, principles, and postulates is the result of scientific activities conducted by scientists. As the process of attaining knowledge requires scientific activities, it should apply to the students through teaching activities (Gilmanshina et al., 2016).

Scientific activities in C-13 are implemented through scientific approaches or more commonly known as the Science Process Skill (SPS) (Ergül, 2018). It is characterized by experimental or activities in the laboratory, which will produce a database on the measuring of variables then presented in the form of observation tables. The table is the basis for constructing graphs. Through the characteristics graph, the measured value can found. Besides, through graphs, scientists can make predictions based on the patterns obtained (Karamustafaoğlu, 2011). Therefore, understanding the function of graphics, especially in science, considered a crucial thing (Kukliansky, 2016; Sharma, 2013). The graph is a kind of representation in summarizing data, processing, and interpreting new information from more complex data (Subali et al., 2015). Through graphs, long explanations can illustrate as concise information. Setyono et al. (2016) claimed that the ability to analyze graphs is needed by students, especially in physics education.

Furthermore, Zavala et al. (2017) asserted that making graphics and interpretations are significant because it is a crucial part of the experiment, is the heart of science itself. According to Kilic et al. (2012), one of the reasons graphs are so widely used is because graphs seem to make quantitative information readable and apprehensible more easily and quickly than the same data presented in prose. The use of graphs in explaining and correlating the concepts can be meaningful learning in the world of science (Gültepe, 2016). Hasbullah & Nazriana (2017) asserted that interpretation is a way to convert a form of information to another one. It can be sentenced to graphs or images, from sentence to number, from sentence to sentence, and etcetera. Graphical interpretation means providing cementation based on the information presented on the graph. A graphical presentation is part of the representation that shows students' conceptual understanding. According to Furwati et al. (2017) and Theasy (2017), students will be able to represent concepts using multi-perspective if students have a good mastery of the concepts. Based on some of these findings, the authors argue that the ability to interpret graphs being popular in a research study.

One of the topics in physics is kinematics, which discusses straight motion without considering the causes of motion-defined as forces. The concept of kinematics includes the concepts of position, space, displacement, velocity, speed, and acceleration. The concept of physics in kinematics is an essential foundation that must be possessed by students to learn the next material (Parmalo et al., 2016). Lack of understanding of the kinematics concept results from students having a poor comprehension of further physics concepts and more abstract (Manurung et al., 2018). The concepts of physics in kinematics generally are presented in the form of abstract formulas, and students use them to solve problems.

On the other hand, physical quantities in kinematics can display in the form of correlative graphs among quantities such as graphs of correlation between position and time or velocity with time. Through graph analysis, the amount of other kinematics obtained. Thus, graphs can be used as an alternative to comprehend the concept of kinematics. Through graphs, the use of complex physical formulas can be minimized. Besides, some physical equations in kinematics can be obtained through graphs. Hence, students' knowledge about how to analyze or interpret graphs is essential to be taught.

Although plotting and interpreting graphs are seemingly trivial skills, but fundamental errors still found. An error in plotting the graph occurs if it is associated with a concept. In illustrating the position graph towards time from a motion observation, it found that students often make mistakes in plotting graphs of rest objects. These objects move at a constant speed when moving away, and then back to the reference point. The mistake occurred because students demonstrated the movements observed directly on the graph spatially without noticing the time axis. This error potentially inhibits students in understanding abstract concepts represented in the graph. Petrova (2016) revealed the fact that there were students in secondary schools, and even university students miss the ability to understand and interpret the graph in Physics. Several other studies also revealed the low ability of students to interpret graphs, including the results of research by Bunawan (2016). The study shows that the interpreting of graphs is still inadequate. Besides, the results of the study of Setyono et al. (2016) showed that the ability of students to interpret graphs is still low, with a percentage of 48.30%. Likewise, with the research results, Uzun et al. (2012) and Antwi et al. (2018) found that students have difficulty in interpreting and comprehending the information presented in the graph.

The literature study base on the scientific research finding has described found that the ability of students to interpret graphics is one of the critical skills for teachers in developing an excellent teaching method. Therefore, the ability to interpret graphs, students can find out the linking between quantities, trace other quantities, and the more complex is the ability to predict based on the presented graphs. Based on that reason, the research conducted to examine the ability of students in interpreting graphs as a consideration and recommendation for further in-depth study. Formulation indicator of the ability to interpret the graph refers to the research that has been conducted by Parmalo et al. (2016). Three indicators used to assess the student's ability to interpret graphs kinematics, namely: (a) determining the amount contained in the graph, (b) describe textually from the kinematics graph, and (c) presents the appropriate graph from the description given. These three indicators combined with Beichner's statement, which states that learning should require students to understand kinematics graphs from various variable variations and infer from one form to another (Zavala et al., 2017). Based on this study, this research has been developed into four indicators to formulate the instruments used in research data collection.

The problem of this study is how to describe the ability of senior high school students' kinematics graphic interpretation, the reasons for choosing the answer, and the factors that cause it. Thus this research was conducted to identify the ability of students to interpret kinematics graphs, the difficulties encountered, and their causal factors.

METHODS

The type of this research was a descriptive study with a case study approach. The research was conducted in the even semester of the academic year 2018/2019 with a research subject that the student of class XI senior high School 8 Luwu Utara and senior high school 1 Palopo. Both are located in Luwu Raya, South Sulawesi, Indonesia. The total subjects of this study were 347 students in the XI grade science class.

The instrument used in this study is referred to as the standard Test of Understanding Graphs-Kinematics (TUG-K) version 2.6, developed by Robert J. Beichner (Zavala et al., 2017). The instrument has adapted in the form of multiple-choice questions was then tested for validity through instrument validation using a matching technique between experts to obtain as many as 20 valid items. The test instrument is used to measure the ability to interpret the kinematics graph for students. This instrument contains four question indicators as follows. Indicator A, determine the value of specific quantities from the graph; indicator B, interpreting graphic language into verbal language; indicator C, identify graphs based on descriptions; indicator D, includes a graph identification that has different variables.

Data collection was carried out by providing diagnostic tests to students based on test instruments that have passed the validity test, then students' answers were collected and scores accumulated. The scoring was performed by giving a score of 1 if the subject chose the correct answer and giving a score of 0 if the subject chose the wrong answer. Data analysis techniques were descriptive statistical average score, frequency distribution, and percentage of the average score on each indicator.

After being given the test, the interviews were then carried out on six subjects, each of which was three people with the highest scores and three people with the lowest scores. Purpose of the interview to obtain in-depth information about the reason the subject in selecting the answer to every item matter resolved, the difficulties encountered, and causal factors. Data analysis is using a qualitative analysis.

RESULTS AND DISCUSSION

The data description of the interpreting ability on science kinematics graphs shown in table 1, table 2, and table 3, respectively. Based on table 1, it was found that the ability to interpret graphs showed that the highest score achieved was 8. The lowest score was 0, while the average score achieved was 3.45. These results indicate that the ability to interpret the kinematics graphs of students was still deficient. For more details, it can be seen in the frequency distribution table the ability to interpret the kinematics graphs for students.

Table 1. Statistical Data of XI Grade Science Students' Interpreting Ability on Kinematics Graph

Statistics	Statistics Score
The Total Number of Data	347
Maximum Score	20
Minimum Score	0
Highest Score	8

Lowest Score	0
Mean Score	3.45
Standard Deviation	1.77
Variance	3.15

Table 2 shows the frequency distribution of the ability to interpret the kinematics graphs of students. A total of 90 students can interpret graphs into the low category, and 257 students can interpret graphs into a very low category.

Table 2. Frequency Distribution of Ability to Interpret Graphs

Interval Score	Category	Frequency	Percentage (%)
17 – 20	Very High	0	00.00
13 – 16	High	0	00.00
9 – 12	Medium	0	00.00
5 – 8	Low	90	25.94
0 – 4	Very Low	257	74.06
Total		347	100.00

The following is a table that illustrates student achievement in answering tests on the ability to interpret graphs based on indicators. Based on table 3, the ability to interpret graphs was still low. The average achievement of students in answering questions on each of the highest indicators is 20.99% on indicators identifying graphs based on descriptions, while the lowest average achievement is on the indicator of identifying graphs that have different variables with 11.91%.

Table 3. Percentage of Average Score on each Indicator

Indicator	Percentage (%)	Category
Determining the measured value of the graphs	18.02	Low
Interpreting graphs into verbal language	15.50	Low
Identifying graphs based on descriptions	20.99	Low
Identifying graphs with different variables	11.91	Low

Based on the results of the descriptive analysis above, it shows that the ability to interpret kinematics graphs of students was relatively low.

After conducting the test, an interview was conducted, which aimed to find out the reasons for choosing answers, and the factors that caused students to be less able to answer questions in graphical form. The study continued by selecting six subjects from 347 students, namely three subjects with the highest scores and three subjects with the lowest scores from different schools.

The research was conducted by interviewing six students directly; some findings from the interviews are given in the following discussion. **First, students are not able to correctly identify variables.** The variable is the physical quantity asked in the question. The results of the interview show that students whose answer is wrong, generally: (a) Unable to identify the quantity known or requested from the graph. For example, when a graph presents the correlation between the position (the y-axis) and the time (x-axis) of a particle and the position is asked for a specific time, then there are students whose answers were irrational numbers. They wrote absolute numbers where the numbers were not rational on the y-axis. On the graph, the y-axis numbers start from 0 to 50, and the x-axis numbers begin from 0 to 100, if students were asked for instance what is y value if the x value is 40, then the students answered with 80 which is outside the y-axis range. It indicates that students were unable to identify the value asked in the question. The reason is that the students are not accustomed to making graphics because they are not familiar with SPS activities in experimental or lab activities. It is in line with the interview's result, where students rarely conduct experiments or practicum. The practicum has not yet fully involved the activity of interpreting graphics. Besides, some students have had difficulty in distinguishing the symbols on the graph. Errors in determining symbols of magnitudes drag the students to misinterpret the graphs. (b) Unable to determine the coordinates of the points of a graph. When the students' known value on the y-axis, but they unknown determine the value on the x-axis and vice versa. It is because of the low ability of students to determine the coordinates of two quantities on the graph. The fundamental problem is almost the same as discussed in part of the first problem.

The first finding is in line with the opinion of Nugraha et al. (2017). They said that mistakes in working on kinematics problems are because students are less thorough by transforming physical symbols and what is meant by the question.

The various symbols used in physics make it difficult for students to distinguish, some even equate variable symbols with unit symbols. According to Charli et al. (2018), factors, why students have difficulty in solving problems related to symbols that they do not understand physical symbols, hard to remember, and memorizing, is the ineffective way. This result also associated with the findings of Bektasli & White (2012), who claimed, errors occurred as they tend to see a graph as a picture. They do not take variables as consideration.

Second, the students were unable to determine specific physical quantities from the graph. The interview results showed that students' wrong answers generally because: (a) Do not comprehend how to identify physical quantities based on graphs (do not understand how to find the slope of a line). For example, a graph of the correlation between velocity and travel time, where velocity is on the y-axis, and travel time is on the x-axis. From the graph, asked how much the average acceleration for a specific time interval. Learners do not understand that the slope of the graph is a value acceleration of the ordinary object. Besides, how to find the slope of the line based on the graph is not being understood. Graph analysis through line slope is found by calculating the tangent angle between the slope (which states the correlation of magnitudes on the x-axis and the y-axis) and the horizontal line on the x-axis. This angle is acceleration. The interview data obtained that this kind of analysis has never taught before. Furthermore, the cause is as same as in the first part of the findings.

(b) There is no comprehension that the slope of a straight line on the graph indicates the average velocity or acceleration. If a graph of the correlation between position (y-axis) and time (x-axis), the slope of the straight line shows the average velocity. The average velocity obtained by finding the value of the angle tangent between the straight line and the horizontal line (x-axis). The higher the tangent angle, the average speed will be even higher. Based on the results of the interview, it revealed that these explanations have never taught.

(c) Do not understand the concept of distance correlated to the area under the line/curve of the correlative graph between velocity and time. The correlative graph between velocity and travel time has presented, and then the which area is asked. Students are not able to relate that of the equation s = v x t, where v x t is the area formula under the curve. The students are not able to understand that the area under the curve in the given time is the distance travelled. The cause of it is just as same as the previous one. The students have not yet understood how to analyze the graphs.

(d) Difficult to understand the concept of average velocity and acceleration. For instance, there is a graph of the correlation between position and travel time, wherein the graph there are several straight lines with different slopes. Based on the graph, asked how much the average velocity for a specific time interval. The students who figure out the average velocity of each line, then again being averaged. This answer is undoubtedly wrong because what is has questioned is the mean of velocity, not the velocity averaged. It is happening because students do not understand how to find the average velocity of the graph; the average velocity should be determined by finding the difference between the final position and the initial position and then dividing it by time-lapse. It also happens to the concept of average acceleration. Some of them calculated the average acceleration.

The second interviewed student has the first and second problems which are in line with Zavala et al. (2017) statement regarding some of the mistakes made by students in answering kinematics graph problems, one of them is that students often read the values of the axes and immediately set them as the slope of the curve. Pujianto (2013) states that students have an understanding that acceleration is speed divided by time. However, students did not understand the concept of acceleration; that is, if an object moves accelerated, the distance travelled every second has an increase. Another difficulty arises with the indication that students do not know the use of the area under a curve, either on velocity graph against time or acceleration graph against time. Students can use this method in answering several questions on indicator A. This is a state by Beichner (in Zavala et al., 2017) that students do not know the meaning of the area under the kinematics graph curve. Also, students do not understand the equation of straight motion (Nugraha et al., 2017).

Third, students are not able to transform information based on graphs. For example, "the acceleration with the highest negative values" in problem number 2, so most students choose answer C as the point considered as the most negative acceleration because point V is below the positive x-axis. The same finding also obtained by Nugraha et al. (2017) that students do not understand the positive and negative part of the velocity graph towards time with movement in a positive or negative direction. Parmalo et al. (2016) state that this happens because students tend to equate the Cartesian diagram with the velocity graph, so they think that all points below the zero axes are always negative. Kinematics graphs are different from Cartesian descriptions.

The third interviewed student has a problem with an error that occurs in questions number 9, 11, and 18. In question number 9, most of the students took B as the answer. Most students did not pay attention to the initial statement of the description given which states that objects move with constant acceleration, students only focus on the term "constant velocity" after 10 seconds, so they chose graph in option B with a straight horizontal curve after 10 seconds regardless of the variable on the graph. A straight line on the s-t graph illustrates that an object is unmoving. In line with the statement; the problem often arises in learning physics is that students tend to know and memorize only graphs and basic concepts of physics, but they lack understanding of these concepts (Nugraha et al., 2017; Rahmawati et al., 2013; Vaara & Sasaki, 2019).

Fourth, students were not able to state the linking among variables. This error occurs when interpreting the correlation among scales via s-t, v-t, and a-t graphs. These faults most often found in questions number 3 and 20. In problem number 3, most students gave correct answers, option A where the graph shows objects moving at a constant speed. However, it was not appropriate to connect the velocity variable with the acceleration where the acceleration should be equal to zero when the object's speed was constant. The second most chosen answer was C, where students assumed that an increase in the curve in the s-t graph means that there was a change in the velocity of the object. They did not understand the meaning of linear curves on the graph. The same thing was happening to the fourth interviewed student who has the same answer to questions number 20, where the dominant student's answer was B fora reason, the graph curve has decreased, so to consider it by slowing down the acceleration irregularly, even though the deceleration variable is velocity which means the object with constant acceleration. Gültepe (2016) stated that one of the students' difficulties when interpreting graphs is in defining variables and connecting graphs with variables.

Fifth, learners do not understand the form of uniform velocity motion (UVM) and uniformly accelerated motion (UAM). From the students' answers, most of them are incorrect as unable to transform the concepts of UVM and UAM in graphs. The fifth student has a problem Identifying forms of UVM or UAM motion based on graphs is hard. It is found by Maries & Singh (2013) that students' difficulties related to understanding the curve's shape by assuming the same even though the graph variables are different.

Based on the previous discussion, there were five fundamental difficulties faced by students in interpreting graphs on the kinematics concept. It defines three basics: (1) unable to identify variables based on graphs correctly; (2) unable to determine physical quantities based on graphs; and (3) unable to translate information based on graphics. In the research of Parmalo et al. (2016) that revealed factors causing students' misinterpretation in kinematics-graphs include: 1) Low conceptual abilities about kinematics graphics and 2) Lack of students' spatial ability. According to Ismet (2013), spatial Intelligence in learning is related to the knowledge of students in connecting concepts, plotting graphs, diagrams, mind mapping, and modelling. This Intelligence is considered very important for the success of learning. Subali et al. (2015) stated that the interpretation ability of kinematics graphics is correlated with the ability to understand concepts, therefore to improve the knowledge of proper interpretation, it is necessary to build a good understanding of kinematics concepts (Antwi et al., 2018)

These five problems are rooted in a similar question, that is, the ability of graph analysis that does not exist. The research finding is reasonable because students have never taught how to do graph analysis. The research results about learning activities in schools, the authors obtain information if students who are the subjects of research have never practised in demanding graph analysis capabilities. Besides, the research finding also faced that the frequency of practicum activities was very minimal, and there were even students who had never conducted experiments or practicums. These indicated that the two schools which were the subject of research had not optimally applied C-13.

CONCLUSION

The results of this study show that students' ability to interpret the kinematics graph was in the shallow category. The average score of 347 observed students was 3.45, and 74.06 % of them were in the very low category, while 25.94 % were in a low category. The results show that student's scores for interpreting the kinematics graphs on every indicator given in the test were low. Besides that, the interview was conducted to six students proved that there were some difficulties faced by students when interpreting kinematics graph, they are : (1) students were not able to correctly identify variables, (2) students were not able to determine specific physical quantities from the graph, (3) students were not able to transform information based on the graphs, (4) students were not able to state the linking among variables, (5) students did not understand the form of uniform velocity motion and uniformly accelerated motion.

The research finding implies that the students have difficulties there is spatial Intelligence in learning is related to the knowledge of students in connecting concepts, plotting graphs, diagrams, mind mapping, and modelling. This Intelligence is considered very important for the success of learning as reported elsewhere that the interpretation ability of kinematics graphics is correlated with the ability to understand concepts, therefore to improve the knowledge of proper interpretation, it is necessary to build a good understanding of kinematics concepts.

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