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Practice rehearsal pairs with dynamic video media: Improving students' kinematics graph interpretation skills

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Abstract: This study aims to examine the impact of Practice Rehearsal Pairs (PRPs) with Dynamic Video Media (DVM) on improving students' skills to interpret kinematics graphs in Physics subjects among junior high school students in Malang. This research is descriptive with a quantitative approach. Data collection was conducted through tests, observations with open questionnaires to three classes totaling 77 eighth-grade students in Malang City. Semi-structured interview participant selection was carried out to obtain detailed and in-depth answers from the students' perspectives. The instrument used to explore kinematics graph interpretation abilities consisted of 10 kinematics graph questions taken from The Test of Understanding Graphs in Kinematics (TUG-K). The research results show that eighth-grade junior high school students in Malang have a low ability to interpret kinematics graphs, with an average initial exploration ability score of 54.6. The difficulties experienced by students include reading graphs through slope/gradient, area under the graph, and direct graph reading. The PRPs learning model with DVM can improve the ability to interpret kinematics graphs of junior high school students. In the three experimental classes, there was an increase in initial exploration ability scores and final ability test scores. The non-parametric test results using the Wilcoxon Signed Rank Test show that all three classes have a Sig. (2-tailed) value of 0.000 < 0.05, thus it can be concluded that there is a significant difference between the initial and final abilities of students in the experimental classes before and after the implementation of PRPs and the use of DVM. This indicates that the PRPs learning model with DVM can improve the ability to interpret kinematics graphs of junior high school students.
Keywords: DVM; kinematics graph; TUG-K; PRPs

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Introduction

Kinematics has received considerable attention in physics research over the past few decades (Mešić et al., 2015). It is considered a crucial skill for understanding physics in general. Moreover, it indirectly influences practical skills (Astuti et al., 2024), and the skills of scientific processes in general (Risda et al., 2023). Studies on kinematics offer an excellent framework for acquiring fundamental scientific skills such as systematic measurement and data collection. Kinematic measurements are crucial for studying comparative biomechanics and provide insights into the relationship between technological advancements and scientific progress (McHenry & Hedrick, 2023). So far, many students often struggle with concepts such as velocity, acceleration, and frames of reference. Interpreting kinematic graphs using variables like position, velocity, and acceleration seems to be the most problematic area in physics teaching and learning (Jufriadi et al., 2021b; Moyo, 2020). Therefore, many

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academics are attempting to research the conceptual understanding issues of students' kinematic knowledge (Jufriadi et al., 2021a; Sundaygara et al., 2021). Manurung & Mihardi (2016) have also researched how to enhance the understanding of kinematic concepts through hypertext learning and formal thinking skills. The application of various learning models to enhance understanding of kinematic concepts (Jufriadi & Andinisari, 2020). Various studies on kinematics have been conducted because students need the ability to translate between abstract representations in kinematic concepts and real-world representations of object motion (Hochberg et al., 2016).

Some studies have found that students' difficulties in understanding kinematic concepts are related to their ability to create graphs (Hochberg et al.; Patahuddin & Lowrie, 2019). Graphs are one type of representation commonly used in kinematics learning. Graphs are a type of mathematical expression used to depict spoken words in various contexts (Sezen et al., 2012). Graphs are representations of specific data with symbols such as lines, shapes, bars, etc (Filiz & Nazlı, 2018). The ability to read and understand graphs should be a fundamental skill for everyone. Students in elementary and secondary schools need this skill for further education, and in physics, graphs are used as visual representations of the interdependence of physical quantities (Skrabankova et al., 2020).

Kinematic graphs depict the relationship between position, velocity, and acceleration over time (Christensen & Thompson, 2012). Kinematic graphs are a mathematical application of graph knowledge. Kinematic graphs are based on the more realistic motion states of an object (Hale, 2000). Understanding kinematic graphs can be used to evaluate students' preconceptions and learning outcomes (Vaara & Sasaki, 2019).

Interpretation is part of the cognitive level of understanding, while interpretation ability is part of conceptual understanding (Nurfadhilah et al., 2023). Literally interpreted as explanation or understanding, interpretation broadly refers to the ability to interpret from a form of representation (Putri et al., 2018). Interpretation relates to the communicative representation of a configuration of ideas, which may require the interpreter to retrieve these ideas into a new configuration of thought.

Interpretation involves the ability to recognize the essence and distinguish it from less important or irrelevant aspects of the communicated information. Behavior in interpretation means students can identify and understand the main ideas contained within it, the presented information, and comprehend the relationships between ideas or concepts. Physics learning recognizes interpretation which includes (Putri et al., 2018): 1). The ability to interpret verbal statements; 2) The ability to interpret pictures, graphs, diagrams, and mathematical equations; 3) The ability to interpret various types of data; 4) The ability to make appropriate qualifications in interpreting data; 5) The ability to distinguish or contrast conclusions from a series of data. Students' ability to interpret graphs is one of the important skills for teachers in developing superior teaching methods; with the ability to interpret graphs, students can understand the relationships between variables, explore other variables, and the more complex ability is the ability to predict based on the presented graph (Amin et al., 2020).

Interpretation is part of the cognitive level of understanding (Khaeruddin & Usman, 2023). Graphic interpretation is an extraordinary thought and shows scientifically educated individuals who can understand and analyze various visual representations in today's society (Boote, 2014). Berg & Boote (2017) explained that school students are aware of the need to develop graphic skills within students so that they can evaluate scientific elements, analyze data, and detect patterns. Therefore, students must be able to read graphs to understand kinematic ideas. Reading, understanding, evaluating, and synthesizing information expressed in various visual formats are called graphic comprehension (Hochberg et al., 2020).

Several studies have found that students have difficulty in reading graphs, especially the slope of the graph and the area under the graph in the context of physics, especially kinematic concepts (Susac et al., 2018). Other difficulties in learning kinematic graphs include confusion about the slope of the graph, so students often read axis values and immediately define them as slopes (Amin et al., 2020) and difficulties in reading, interpreting, and understanding information depicted in graphs (Maries & Singh, 2013). Students experience difficulties in identifying graphs from data and predicting data (Putri et al., 2018).

Difficulties in interpreting graphs can be caused by students' lack of knowledge, explanations, and teacher practice activities regarding graph and data presentation (Putri et al., 2018) characteristics of graphs such as format, type, image, observer expectations, graph reading habits, graph content, and prior knowledge of graphs (Glazer, 2011). According to Shah and Hoeffner (2002), there are three aspects that play an important role in determining data interpretation: visual presentation quality (bar or line graphs, color or black and white, etc.), ease of understanding the graph (graph scheme), and data substance (e.g., age vs. height, time vs. distance). Data visualization such as graphs, charts, and tables are crucial for interpreting data well. This is because data visualization through graphs and interactive graphics makes information easier to understand and access. The context of data interpretation has a significant impact on graphic understanding.

Students' ability to understand graphs in the context of physics is an important study to discuss. The concept of kinematics appears in the school curriculum from the fourth grade and onwards (Núñez et al., 2022). The ability to interpret kinematic graphs can help students understand the relationships between variables, explore other variables, and the more complex ability is the ability to predict based on the presented graph (Amin et al., 2020). The ability to interpret kinematic graphs for students is important for analyzing and understanding kinematic concepts (velocity, acceleration, position, slope, area, height, etc.) (Gok & Gok, 2023). The importance of graphic interpretation is not in line with the low ability of students. Researchers have gathered information about students' abilities to interpret kinematic graphs for junior high school students. The results of the initial analysis of students' abilities in interpreting graphs for 390 MTs students showed that 88% of students still had low abilities in graph interpretation.

Researchers use the PRPs learning model to improve students' understanding of kinematic graphs. The PRPs learning model is a learning model that provides opportunities for students to practice their understanding based on formed experiences (Nurrika et al., 2016). PRPs are one type of active learning. The steps of PRPs are; 1) listening activities; 2) visual activities; 3) Intellectual activities; 4) Motoric activities; 5) oral activities; 6) writing activities; PRPs learning involves students to be active and ensure that each student can understand the lesson material and can exchange knowledge learned by each student.

Dynamic Video Media (DVM) is one of the appropriate media used in learning related to moving objects. Suyatna et al., (2017) research proved that the average learning outcomes of students who obtained learning using DVM were significantly higher compared to classes that received learning using static visualization media. The use of DVM is suspected to improve students' understanding of motion diagrams. The dynamic interrelation of various forms of representation in DVM can contribute to reducing foreign cognitive loads on students (Becker et al., 2020). The use of DVM learning media is expected to make learning more enjoyable and dynamic image visualization that illustrates the process sequentially so that the message can be conveyed.

This research is expected to provide an overview to physics teachers to obtain appropriate learning methods to improve students' abilities in interpreting kinematic graphs. This study aims to determine the impact of Practice Rehearsal Pairs (PRPs) with DVM on improving students' ability to interpret kinematic graphs in junior high school students in Physics subjects.

Method

This research method of this present study is descriptive quantitative. The subjects of this study are the eighth-grade students of MTs in Malang City. There are 3 classes with a total of 77 students. Data in this study were collected using tests, observations with questionnaires. Semi-structured interview participant selection was conducted to obtain detailed and in-depth answers from the students' perspectives. The instrument used to explore the ability to interpret kinematic graphs was 10 kinematic graph questions taken from The Test of Understanding Graphs in Kinematics (Beichner, 1994). The questions presented were reasoned multiple-choice questions. In this study, the kinematic graph material referred to is reading graphs through slope/gradients; b) reading graphs through the area under the graph; and reading graphs directly. The data will be analyzed to determine students' ability to interpret kinematic graphs, and the qualitative method used is interviewing several students with diverse abilities (low, medium, and high). Interviews were conducted by researchers using face-to-face interviews with semi-structured interview methods to explore the truth and depth of the reasons for the answers they provided. Initial and final student ability exploration data were analyzed using N-Gain score (Table 1) and effect size (Table 2).

Table 1. Criteria for N-Gain calculation results

Criteria	Value ‹g›
High	‹g› ≥ 0,70
Medium	0,70 > ‹g› ≥ 0,30
Low	‹g› < 0,30

Table 2. Criteria for effect sizr calculations results

Interpretation	Size ‹d›
Large	0,8 ≤ d ≤ 2,0
Medium	0,5 ≤ d ≤ 0,8
Small	0,2 ≤ d ≤ 0,5

Results and Discussion

Students' ability to understand graphs in the context of physics is one of the important studies to be discussed. The concept of kinematics appears in the school curriculum from the fourth grade onwards (Núñez et al., 2022). Test materials were selected in such a way as to determine the strengths and weaknesses of students in a material so that the results could be used as a basis for providing appropriate follow-up actions according to the students' weaknesses (Rohmah & Handhika, 2018). The measured concepts consist of gradient/slope concepts, the area under the graph, reading graphs directly, and determining kinematic quantities such as position, velocity, and acceleration. The question instrument used in this study is reliable and valid as seen in the results of reliability and validity tests in Table 3 and Table 4.

Table 3. Reliability test results

Cronbach's Alpha		Spearman-Brown Coefficient	Guttman Split-Half Coefficient
Item No	Value		
Question A 1,2,3,4,5	0,126	0,456	0,453
Question B 6,7,8,9,10	0,395		

Table 4. Validity test results

Item No	r-Value	r-Table
1	0,214**	0,113
2	0,432**	0,113
3	0,396**	0,113
4	0,152**	0,113
5	0,582**	0,113
6	0,366**	0,113
7	0,367**	0,113
8	0,399**	0,113
9	0,565**	0,113
10	0,503**	0,113

Based on the test results, the average score of the students is 3.62, which is still far below the passing grade. After analyzing and reviewing the answers of eighth-grade students of MTsN regarding their ability to interpret kinematic graphs, several reasons for student errors were found (Table 5). It is known that there were 19 students who showed improvement after the implementation of PRPs and the use of DVM, there was 1 student who showed a decrease in score after the implementation of PRPs and the use of DVM, and there were 2 students who had the same initial and final abilities (no change). The reasons for errors are summarized in Table 6.

Table 5. Initial-final ability ranks

		N	Sum of Ranks
Final Ability - Initial Ability	**Negative Ranks**	1[a]	3.50
	Positive Ranks	74[b]	206.50
	Ties	2[c]	
	Total	77	

Table 6. Reasons for errors in each item

Analysis Unit	Reasons for Errors
Ability to determine motion acceleration or constant velocity	• Students assumed that the object moved with increasing velocity regularly because the graph showed that the object changed its position and continued to increase
Ability to determine motion acceleration or constant velocity	• Students assumed that a horizontal or flat graph indicates that the object moves at a constant speed • Students assumed that a constant acceleration graph can only be depicted in a velocity graph with a sloping line and acceleration with a straight line
Ability to determine speed over time (Same Motion)	• Students assumed that a horizontal graph on the right indicates that the object moves with regularly increasing and constant velocity • Students assumed that a horizontal graph indicates that the object moves constantly and its acceleration is not zero
Ability to determine velocity versus time (Straight, Same Motion)	• Students assumed that a decreasing diagonal graph indicates an object moving with regularly decreasing acceleration • Students assumed that a decreasing diagonal graph indicates that the object's speed decreases over time, so its acceleration decreases, the slower it gets
Ability to determine distance versus time graph	• Students immediately calculate the difference in intervals without paying attention to the graph details • Students immediately calculate the difference in intervals and multiply without considering the initial and final velocities
Ability to determine velocity versus time graph	• Students assume the same speed and acceleration in the graph representation

The analysis and review of the answers from class VIII-M students in Malang regarding their ability to interpret kinematic graphs revealed three common mistakes made by students in understanding kinematic graphs, based on the three questions most frequently answered incorrectly by students. First, students' error in interpreting a graph showing the velocity of a moving object, as illustrated in Figure 1.

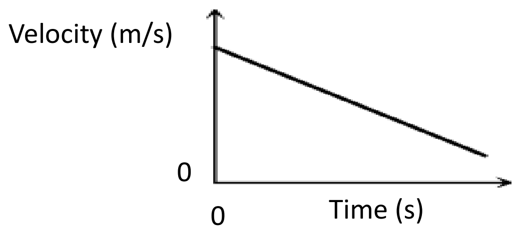

Figure 1. Graphics with the most misinterpretations

Students were asked to interpret the graph. Only 4 students or 13.79% gave the correct answer. 85.19% of students made a mistake by interpreting the graph as representing an object moving with steadily decreasing acceleration. The main reason given by most students was that the acceleration decreased regularly because the graph appeared to decrease. The reasons and explanations provided by the students indicate that they did not correctly understand the equation of Same Motion. This research also demonstrates that many students construct their own interpretations that are not consistent with the concept, thus categorizing them as students who have a poor understanding of the material because they provide answers that are not relevant to the correct answer.

The second mistake is when students were asked to interpret a graph regarding the distance traveled by an object over a specific time interval (from time t1 to time t2). As shown in Figure 2.

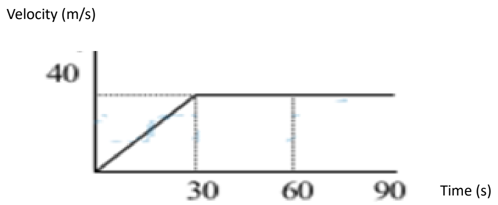

Figure 2 Graph With the Most Interpretation Errors II

Then, 20 or 74.07% of students made a mistake by interpreting that the distance traveled during the time interval between the 30th minute and the 60th minute was 20 km. 4 students or 11.11% answered that the distance traveled was 30 km. Only 4 students or 13.79% gave the correct answer. It is evident that students made an error in calculating the distance value on the graph. Students seemed to only calculate 40/2 directly (40 km divided by 2, where the value 2 is obtained from 60/30), so the distance traveled was 20 km. Students did not consider the initial position and the line indicating the change in speed. Based on the analysis of students' answers, it was found that many students were confused in determining the starting point of the graph, looking at the starting point of the graph, and understanding the illustration. This indicates that students generally assume that the curve shape of the velocity versus time graph can directly determine the distance traveled by dividing the time interval. Students did not pay attention to or ignored the graph shape in different time intervals. These answers indicate misconceptions, leading students to have difficulty in interpreting the graph by assuming that the velocity variable on the velocity versus time graph will not change the curve shape of the position versus time graph. The difficulty students experienced in solving graph problems is related to their understanding of the graph problem itself. The third mistake is when students were asked to show graphs of constant motion and non-zero acceleration. 21 students or 72.41% gave incorrect answers, and only 8 students or 27.59% gave correct answers. The most common mistake made by students was choosing answer E, which indicates answers III and V.

These results align with Susac et al.'s statement (2018) that one of the common problems students face when learning kinematic graphs is the difficulty in representing constant acceleration on the a vs. t graph and distinguishing between different types of motion graphs. Based on the above analysis, it is evident that the ability to interpret kinematic graphs among eighth-grade students is still relatively low.

Susac et al., (2018) stated that after conducting a written test, interviews were conducted to determine the factors that cause students to struggle with graph-based questions. Interviews were conducted with 4 students, where two students represented high scores and two represented low scores. For students with the highest scores, when asked to explain answer no. 4, they explained that because the graph is linear, the object's speed decreases steadily, thus its acceleration is constant. In the graph, the position graph appears to decrease, indicating a steady decrease in speed. In uniformly accelerated linear motion, the speed decreases while the acceleration remains constant. It can be concluded that both students are able to understand and interpret the graph with the correct concept. When asked to explain answer no. 8, students clearly stated that constant motion with non-zero acceleration is represented by Uniformly Accelerated Linear Motion (UALM), which corresponds to option II. Meanwhile, because graph V is a straight line, this indicates that its acceleration is non-zero and constant.

The ability to interpret is related to students' ability to understand concepts. These results are consistent with what Vaara & Sasaki (2019) stated, that in physics learning, students tend to only know and memorize graphs and basic physics concepts, but they do not truly understand the graph concepts. To improve students' interpretation skills, a good understanding of kinematic concepts needs to be developed. The idea of building students' understanding of physics concepts is based on several theoretical conceptions: physics is a subject that is always changing; learning physics is not about memorizing facts but understanding them; in physics learning, students are required to solve problems; and to solve problems and apply knowledge, positive attitudes and understanding are prerequisites. After understanding the basic concepts of kinematics, it is expected that students will have a thorough understanding of kinematic concepts and be able to solve kinematic graph problems (Gok & Gok, 2023).

Conclusion

This study demonstrates that Practice Rehearsal Pairs (PRPs) with Dynamic Video Media (DVM) have an impact on improving students' ability to interpret kinematic graphs in Physics subjects for junior high school students. Common errors often encountered in interpreting kinematic graphs include: students not properly understanding the equations of Same Motion; confusion in determining the starting point of the graph, observing the starting point of the graph, and understanding the illustration; and students not paying attention to or disregarding the graph shape in different time intervals.

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