Eurasian Journal of Educational Research, Issue 48, Summer 2012, 1-20

The Relationships Between Logical Thinking, Gender, and Kinematics Graph Interpretation Skills

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Suggested Citation:

Bektasli, B., & White, A. L. (2012). The relationship between logical thinking, gender, and kinematics graph interpretation skills. *Egitim Arastirmalari - Eurasian Journal of Educational Research*, 48, 1-20.

Abstract

Problem Statement: Kinematics is one of the topics in physics where graphs are used broadly. Kinematics includes many abstract formulas, and students usually try to solve problems with those formulas. However, using a kinematics graph instead of formulas might be a better option for problem solving in kinematics. Graphs are abstract representations, so a student's level of logical thinking might be an indicator for understanding a kinematics graph. This paper examines a possible connection between students' kinematics graph interpretation skills and logical thinking.

Purpose of the Study: The main purpose of this study is to search for relationships between student logical thinking, gender and kinematics graph interpretation skills.

Methods: The sample of this study is 72 grade-12 students. The Middle Grades Integrated Process Skill Test (MIPT) and Test of Understanding Graphs-Kinematics (TUG-K) were administered to collect data after the kinematics graph instruction. The study uses correlational research design.

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Data analysis includes factor analysis, reliability, descriptive statistics, correlation, and forward multiple-linear regression.

Findings and Results: Based on the data analysis, the following principal components were identified for MIPT: processing text information (MIPT: text) and processing symbolic representation (MIPT: symbolic). Similarly, two principle components were found for TUG-K: calculation and the interpretation of slope (TUG-K: slope) and area (TUG-K: area). A student's ability to determine the slope in a kinematics graph was significantly correlated with logical thinking and gender. However, there was no significant correlation to student ability to determine the area in a kinematics graph.

Conclusions and Recommendations: Students come to a classroom with different levels of logical thinking skills. It might be easier for some students to process text information rather than processing symbolic information. On the other hand, it might be easier for some students to process symbolic information instead of processing text information. For both types of students, this study recommends that students' logical thinking and gender need to be considered when kinematics graphs are taught.

Keywords: Kinematics, graphs, logical thinking, physics education

Introduction

Graphical displays are one of the most common visual representations in education. Most textbooks include graphical displays to help student understanding. Physics textbooks in particular broadly use graphical displays. Kinematics is one of the physics topics that uses many graphs. Position vs. time (p-t), velocity vs. time (v-t), and acceleration vs. time (a-t) are the three main kinematics graphs. In addition, kinematics includes many formulas; in the traditional education system students usually try to memorize these formulas to solve kinematics problems. However, solving physics problems by using mathematical formulas does not indicate that student fully understand the topic (Sengel & Ozden, 2010). In fact, students can get most of the kinematics formulas by using kinematics graphs. For example, students can calculate the distance traveled by figuring the area in the v-t graph instead of using the distance formula ($d = v*t$).

It is essential to identify the factors that affect the students' learning of kinematics graphs. There are many studies related to the understanding of kinematics graphs (Beichner, 1990; Beichner, 1994; Brasell, 1987; Brasell & Rowe, 1993; Svec, 1999). On the other hand, few studies have searched for the relationships between logical thinking and student understanding of graphs (Berg & Phillips, 1994; Wavering, 1989). However, there is a lack of research on the relationships between logical thinking and kinematics graphs interpretation skills. Therefore, the aim of the current study is to examine the relationships between the students' logical thinking, gender and kinematics graph interpretation skills.

Theoretical framework and literature review

Piaget (1964) found that development and learning are two different concepts. He said that development is a natural process, while learning is usually provoked by a teacher. Piaget defined sensorimotor, preoperational, concrete, and formal stages for his theory of development. Based on this theory, the first operations appear as a concrete operation. In this stage, the individual can operate on objects, but not on verbally expressed abstract expressions. The last stage of development is the formal operation where an individual can reason about images and abstract expressions such as graphs.

Berg and Phillips (1994) investigated the relationship between students' logical thinking structures and their ability to construct and interpret line graphs. The sample was 72 students from seventh, ninth, and eleventh grades. Berg and Phillips assigned the students to the following five Euclidean spatial structures: placement and displacement of objects, one-one multiplication of placement and displacement relations, multiplicative measurement, multiplicative seriation, and proportional reasoning. Euclidean spatial structures are concrete operational structures based on Piagetian tasks that were used to assess logical thinking. Students' graphing abilities were evaluated based on construction and interpretation of many graphs. Students with low levels of logical thinking could not construct or interpret graphs. Results showed that multiplicative seriation, multiplicative measurement, and Euclidean spatial structures highly correlated with student ability to construct and interpret line graphs.

Berg and Phillips (1994) concluded that a student's development of logical thinking is very important in understanding graphs. The researchers said that "without their development, students are dependent upon their perceptions and low-level thinking" (p. 340). This conclusion is consistent with the finding of a "graph as picture" error, which is one of the most common errors students make when understanding line graphs (Berg & Phillips, 1994; Brasell, 1987; Mokros & Tinker, 1987; Svec, 1999, Trumper, 1997). In addition, Berg and Phillips found that many students in junior high and secondary schools had not developed their logical thinking structures enough to understand line graphs.

Wavering (1989) studied students in grade 6 through grade 12 in both science and mathematics classrooms to find out the logical reasoning required to construct line graphs. The students were asked to draw a line graph with a positive slope, negative slope, and an increasing exponential curve. Wavering's results were consistent with Piaget's cognitive development structure. Wavering divided students' responses into nine categories. Category 1 corresponded to no attempt to make a graph and category 9 corresponded to the recognition of an increase of variables on both axes and the recognition of increase in a nonlinear graph. Wavering concluded that Category 1 refers to preoperational reasoning, categories 2 through 5 refer to concrete operational reasoning, and categories 6 through 9 refer to formal operational reasoning. Wavering said that "with the increasing use of computers to generate graphs for students, if students are not given opportunities to work their way through their own graphs, it could be that logical development and understanding of graphing may be short-circuited" (p. 379). This statement is in accord with the findings of microcomputer-based laboratory (MBL) studies. Svec (1999) reported that in MBL, since the computer constructs the graph, students have difficulty connecting one graph to another.

Crowley, Callanan, Tenenbaum and Allen (2001) found no significant gender differences for initial engagement in science activities in young children. However, compared to girls, boys heard three times more explanations from their parents during the exhibit at the California Children's Museum. The researchers concluded that the parents' behavior may not be intentional, but hearing more scientific explanations from parents may be an advantage for boys during their formal education. Similarly, Battista (1990) constructed and applied a logical reasoning test that has items related to formal operations in order to investigate the students' ability to draw conclusions in a logical syllogistic format. The researcher found no significant difference between student gender and logical reasoning when they solve geometry problems.

The Test of Logical Thinking (TOLT) was developed by Tobin and Capie (1981) to test the logical thinking abilities of middle grade and older students. The test has 10 items and every two items test one of the following reasoning modes: proportional reasoning, controlling variables, probabilistic reasoning, correlational reasoning and combinational reasoning. TOLT studies revealed some significant and non-significant results related to gender differences. Valanides (1996) found no significant gender differences for logical thinking ability. However, Valanides (1997) conducted another study and found significant difference for probabilistic thinking items in favor of male students. The author did not find any other significant gender differences related to reasoning modes or the total test score. Yenilmez, Sungur and Tekkaya (2005) reported significant differences in proportional reasoning, probabilistic reasoning and combinational reasoning in favor of males and significant differences in controlling variables and correlational reasoning in favor of females.

Silberstein (1986) suggested that students could use graphs to interpret data in all scientific disciplines. Similarly, McKenzie and Padilla (1986) said that one form of quantitative data is the line graph. They concluded that graphs are helpful for communication about concepts and relationships between variables. From their point of view, when students use graphs in kinematics they may be more comfortable interpreting the motions of bodies and better see the relationships among position, velocity, and acceleration.

Jackson, Edwards, and Berger (1993) focused on graphing and data analysis instead of focusing on the relationship between graphs. Their sample was 700 high school students from six high schools who had weak mathematics and science backgrounds. Researchers used computer-assisted graphical data analysis to answer particular questions. They found that students responded to questions with a variety of explanations and levels of achievement. Many comments from teachers and students led researchers to believe that more understanding of graph construction may help improve learning experiences in the long term.

Although graphs are essential instructional tools, students have some difficulties when they use graphs in kinematics. The most common difficulties are confusing slope and height (Brasell, 1987; Mokros & Tinker, 1987), distinguishing slope and area (Beichner, 1994), "graph as picture" error (Berg & Phillips, 1994; Brasell, 1987; Mokros & Tinker, 1987; Svec, 1999; Trumper, 1997), confusion between distance and velocity (Brasell, 1987), graph interpretation (Adams & Shrum, 1990; Beichner, 1994; Brasell & Rowe, 1993; McDermott, Rosenquist, & van Zee, 1987), graph construction (Adams & Shrum, 1990; Beichner, 1994; Brasell & Rowe, 1993), and relationships between graphs (Svec, 1999).

When students see a graph as a picture they usually do not think about the variables on the graph. In other words, when *p-t* graphs and *v-t* graphs look like each other, the information they present is quite different. As can be seen in Figure 1, lines give various kinds of information in different types of graphs. For example, a line parallel to the t-axis in a *p-t* graph means there is no motion, in a *v-t* graph it means constant velocity, and in an acceleration vs. time (*a-t*) graph, it represents increasing speed. Students usually make these kinds of errors when they interpret kinematics graphs. According to Piaget's cognitive development theory, this type of student is not completely at the formal operation stage since they cannot reason on abstract representations.

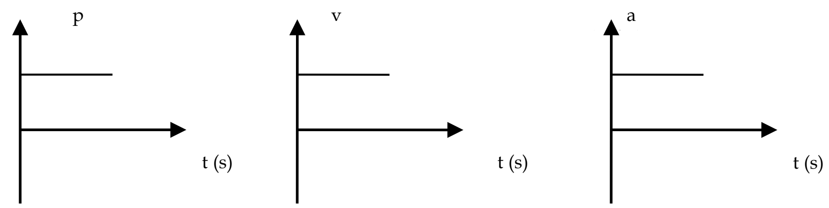

Figure 1. Similar graphs do not present the same information.

Using graphs to solve kinematics problems may facilitate student understanding and contribute to their learning. However, students may need prerequisite abilities to understand kinematics graphs. Logical thinking may be one of these prerequisite abilities that influences student understanding of kinematics graphs. This study specifically focused on kinematics graph interpretation skills instead of line graphs in general to see if there are factors that relate to students' logical thinking and kinematics graph interpretation skills. This study addresses the following questions:

1. Is there a significant relationship between student logical thinking and kinematics graph interpretation skills?
2. Are there significant differences in the relationships between student logical thinking and kinematics graph interpretation skills based on gender?

Methodology

Research Design

This study conducts correlational research, in which the relationships among two or more variables are researched without influencing the dependent or independent variables (Fraenkel & Wallen, 2000). Dependent and independent variables are determined by applying factor analysis to MIPT and TUG-K. The dependent variable was kinematics graph interpretation skills and the independent variables were gender and logical thinking.

Sample

The participants of the study were 72 grade 12 physics students (40 males and 32 females) in an urban high school. There were two different levels of students: one advanced placement (AP) class and three calculus-based physics classes. The AP class had 13 males and five females. The first CBP class had 12 males and eight females, the second CBP class had eight males and eight females, and the third CBP class had seven males and 11 females. Both AP and CBP students had a 50-minute class period every day. However, AP students had an extra 50-minute class every Thursday.

The physics and calculus taught in the AP class were more advanced than the subjects taught in CBP classes. The AP physics class was a college level course that allowed students to earn college credit if their grade was at least 4 out of 5. Both AP and CBP class students were taught kinematics from early September to late October. CBP class students were engaged in graph construction and interpretation tasks, but not as often as the AP class students.

Classroom Settings, Activities and Teaching Strategies

The physics teacher used the same room for both AP and CBP physics classes. In addition, the teacher used the hallway and the outdoor field for some activities. For example, the hallway was used to observe the rate of change of position, velocity, and acceleration.

After teaching students the preliminaries for learning kinematics graphs, the teacher engaged the students in *feeling rates of change* activities. A motion sensor and a calculator were used in these activities. Students worked in groups. One of the students held the motion sensor and calculator and gave directions to another student so as to create the right graph on the calculator. After that experience students switched positions. Each group was given a kinematics graph and asked to create it on the graphing calculator by using the motion sensor and calculator. In another activity, the description of the motion was given and students were asked to create the graph by using the motion sensor and calculator.

Instruments

Data was collected by administering the Test of Understanding Graphs in Kinematics (TUG-K) by Beichner (1994) and the Middle Grade Integrated Process

Skill Test (MIPT) by Padilla & Cronin (1985). TUG-K was administered first after the students were taught kinematics graphs. MIPT was administered after one week.

TUG-K was applied to assess student kinematics graphs interpretation skills. It has 21 multiple-choice items with seven subscales each with three items. In the first subscale a position vs. time (p-t) graph was given and students were asked to find velocity (p-t to v). In the second subscale, a velocity vs. time (v-t) graph was given and the students were asked to find the acceleration (v-t to a). In the third subscale, v-t graph was given and students were asked to find the position (v-t to p). In the fourth subscale, an acceleration vs. time (a-t) graph was given and the students were asked to find the change in velocity (a-t to Δv). In the fifth subscale, a kinematics graph was given and students were asked to identify a corresponding kinematics graph (graph to graph). In the sixth subscale, a kinematics graph was given and a text explanation of the graph was requested (graph to text). Finally, the seventh subscale gave a text explanation and the students were asked to identify the corresponding graph (text to graph). Cronbach's alpha values for the estimate of internal consistency reliability (n=72) for the seven types of subscales on the TUG-K instrument were as follows: p-t to v: 0.57; v-t to a: 0.57; v-t to p: 0.47; a-t to Δv: 0.34; graph to graph: 0.18; graph to text: 0.47; and text to graph: 0.47. Beichner found the Kuder-Richardson-20 (KR-20) reliability of the TUG-K was 0.83.

The MIPT has 40 multiple choice items. The objectives of those items were as following: questions (six items), hypotheses (six items), ID variables (eight items), design and investigation (six items), data table (four items), graph (four items), and draw conclusions (six items). Cronbach's alpha values for the estimate of internal consistency reliability (n =72) for the seven types of subscales on the MIPT instrument were as follows: objectives: 0.35; hypotheses: 0.49; ID variables: 0.71; design and investigation: 0.20; data table: 0.71; graph: 0.01; and draw conclusions: 0.12.

Data Analysis

Factor analyses were used for the TUG-K and MIPT to identify the principal components of each instrument. The Cronbach's alpha value for the estimate of internal consistency reliability for the resulting components for each instrument was computed. In addition, a descriptive statistic was computed for the mean and standard deviation of variables. Moreover, a correlation analysis was conducted to search for significant correlations between variables. Finally, a forward multiple-linear regression was conducted to find the best predictor or set of predictors of kinematics graph interpretation skills.

Principal Components Analysis. Principal components analysis was applied to the responses from each of the two instruments to see if there were different subscales for this study. The results showed that there were two main components for each instrument. Orthogonal (varimax) rotation was used to make the variables independent from each other. The main criterion for the best solution was to select the solution that best approximated a simple structure. This would mean that the solution for the item-loading on one component would be relatively large while the item-loading on the remaining components would be relatively small or not significantly different from zero. For both instruments, the closest approximation to simple structure occurred when the number of components was equal to two. In addition, scree plots were used to help determine the optimum number of principal components for each instrument.

Principal component analyses for MIPT. Padilla and Cronin (1985) originally described the subscales as questions, hypothesis, ID variables, design investigation, data table, graph, and draw conclusion. The items on the original subscales do not group on the items of the subscales for this study. In this analysis, two principal components were found—Principal Component 1 with items that require processing of text information such as determining variables or drawing conclusion and Principal Component 2 with items that require processing of symbolic information such as numbers, graphs, and data table.

Results

Table 1 shows the reliability analysis of the resulting MIPT principal components. Principal Component 1 has 13 items and Principal Component 2 has 11 items. As can be seen from the table, the alpha value for Principal Component 1 (0.77) is bigger than the alpha value for Principal Component 2 (0.62).

Table 1

Reliability Analysis of the MIPT Principal Components

Subscale	Cronbach's alpha based on standardized items	Number of items	Number of students
MIPT: Principal Component 1	0.77	13	72
MIPT: Principal Component 2	0.62	11	71

Note. Item 4 excluded for MIPT: Principal Component 2 (zero variance).

The items that are loaded on Principal Component 1 are related to the text description. A text description of a situation was given for most of these items, and students were asked to identify the manipulated variable or draw a conclusion from the text. For example, in Item 9, a hypothesis about growing bean seeds in different trays is given and students are asked to determine how they can test the given hypothesis. Since the items in Principal Component 1 are related to processing text information, this component was named MIPT: text.

The items that are grouped for the second subscale of MIPT are related to graphical displays, data tables, or numbers. This subscale is primarily a combination of the subscales for data table, graph, and draw conclusion as originally determined by the authors. In these items the relationships between two variables are given with numbers and the students were asked to choose the correct data table for each item. For example, in Item 8, a data table is given for two variables—time after planting pumpkins and average weight of pumpkins—and students are asked to determine the graph that best describes the results in the data table. Since the items in Principal Component 2 are related to processing symbolic information, this component is called MIPT: symbolic.

Principal component analysis for TUG-K. The original TUG-K instrument as described by Beichner (1994) had seven subscales. Based on the analysis of the current study, two subscales were found for TUG-K instruments. The first subscale, Principal Component 1, involves finding or interpreting the slope of a curve or line, and the second subscale, Principal Component 2, involves finding or interpreting the area under a curve or line.

Table 2 presents the principal components for TUG-K that resulted from the reliability analysis. The reliability of Principal Component 1 (0.78) is higher than the reliability of Principal Component 2 (0.56). Also, Principal Component 1 has 13 items while Principal Component 2 only has five items.

Table 2

Reliability of TUG-K Principal Components

Subscale	Cronbachs' alpha based on standardized items	Number of items	Number of students
TUG-K: Principal Component 1	0.78	13	71
TUG-K: Principal Component 2	0.56	5	72

The TUG-K items that are loaded on principal component 1 are related to determining or interpreting the slope of a curve or line. For example, in Items 13 and 17, a p-t graph was given and students were required to determine the slope to find the velocity. Similarly, Item 7 requires students to determine the slope of the line to find the magnitude of the instantaneous acceleration of the object. Since Principal Component 1 items are related to determining the slope, Principal Component 1 is called TUG-K: slope.

The results for the rotated matrix loading show that the items in Principal Component 2 require students to determine or interpret the area under a curve or line. For example, in Item 16, students need to calculate the area in a-t graph to find the correct answer. Similarly, in Items 4 and 20, a v-t graph was given and students were expected to determine the area to find the distance. The items in Principal Component 2 are related to determining the area in a kinematics graph; therefore this component is called TUG-K: area.

Descriptive Statistics

Table 3 gives the output of the descriptive statistics for the dependent variables (TUG-K: slope and TUG-K: area) and the independent variables (gender, MIPT: text and MIPT: symbolic). As can be seen from the table, TUG-K: area has much less variability than TUG-K: slope. Similarly, MIPT: symbolic has less variability than MIPT: text.

Table 3

Mean, Standard Deviation, and Sample Size for Gender, TUG-K: slope, TUG-K: area, MIPT: text and MIPT: symbolic

	Gender	TUGK: slope	TUGK: area	MIPT: text	MIPT: symbolic
N	72	72	72	72	72
Mean	.56	7.43	4.78	11.11	9.53
Std. deviation	.50	3.28	1.13	2.30	1.99

The following difficulties were identified based on the average of the incorrect responses for certain items. First, students have more difficulty calculating the slope in a kinematics graph than calculating the area. Second, students have difficulty deciding if they need to calculate the slope or the area in a kinematics graph. Finally, students see the graph as a picture because they do not pay attention to the variables on each axis.

Correlations

Table 4 shows the inter-correlations between and among dependent and independent variables. Three significant correlations were found at the $p \leq 0.01$ level. In the first one, MIPT: symbolic was significantly positively correlated with TUG-K: slope ($r = 0.35$, $p \leq 0.002$). Students who are more successful in processing symbolic information are more likely to be successful on TUG-K: slope items. In the second correlation, TUG-K: slope was significantly positively correlated with TUG-K: area ($r = 0.30$, $p \leq 0.10$). This shows that determining the slope and area in a kinematics graph is interconnected. Therefore kinematics graph interpretation is related to understanding slope and area. Finally, TUG-K: slope was significantly positively correlated with gender ($r = 0.31$, $p \leq 0.09$). Therefore, we can conclude that male students performed better than females on TUG-K: slope items.

The only significant correlation found at the $p \leq 0.05$ level was between MIPT: text and TUG-K: slope ($r = 0.25$, $p \leq 0.035$). TUG-K: area was not significantly correlated with any of the independent variables. One reason for that might be that TUG-K: area has six items and a reliability of 0.56, while TUG-K: slope has 13 items and a reliability of 0.78. In addition, as seen in Table 3, TUG-K: area has the smallest variability among dependent and independent variables. The results reveal that students with high logical thinking skills perform better on kinematics graph interpretation tasks related to slope than students with low logical thinking skills.

Table 4

Correlation of Variables

		Correlations[a]			
		MIPT: text	MIPT: symbolic	TUGK: slope	TUGK: area
MIPT: symbolic	Pearson Correlation	.15			
	Sig. (2-tailed)	.209			
TUGK: slope	Pearson Correlation	.25*	.35**		
	Sig. (2-tailed)	.035	.002		
TUGK: area	Pearson Correlation	.10	.06	.30**	
	Sig. (2-tailed)	.394	.622	.010	
gender	Pearson Correlation	-.10	-.02	.31**	.07
	Sig. (2-tailed)	.387	.896	.009	.548

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

a. Listwise N=72

Forward Multiple Linear Regression

Table 5 presents the best set of predictors for TUG-K: slope. MIPT: symbolic, gender and MIPT: text is the set of independent variables that best predicts the dependent variable TUG-K: slope. These predictors account for approximately 27 percent of the variance. There was not any set of predictors for TUG-K: area.

Table 5

Best Set of Predictors of TUG-K: slope Resulting from Forward Step-wise Multiple Linear Regression Analysis

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df 1	df 2	Sig. F Change
1	.35[a]	.12	.11	3.10	.12	9.91	1	70	.002
2	.47[b]	.22	.20	2.94	.10	8.64	1	69	.004
3	.52[c]	.27	.24	2.86	.05	5.04	1	68	.028

a. Predictors: (Constant), MIPT: symbolic

b. Predictors: (Constant), MIPT: symbolic, gender

c. Predictors: (Constant), MIPT: symbolic, gender, MIPT: text

As can be seen from Table 6, MIPT: symbolic is the best single predictor for TUG-K: slope (*Beta* = 0.35). MIPT: symbolic is still the best predictor within the set of two predictors (*Beta = 0.36*). However, within the set of three predictors, gender has a slightly higher influence on prediction (*Beta* = 0.34). Therefore it is clear that understanding the slope in a kinematics graph is related to logical thinking and gender. Processing symbolic information is a good predictor for determining slope in a kinematics graphs. However, processing text information is not a predictor for determining slope in kinematics graphs. No predictor was found for the dependent variable TUG-K: area.

Table 6

Coefficients for the Best Predictors of TUG-K: slope Resulting from Forward Step-wise Multiple Linear Regression Analysis

Coefficients[a]												
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B		Correlations		
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part
1	(Constant)	1.90	1.79		1.06	.29	-1.68	5.48			
	MIPT: symbolic	.58	.18	.35	3.15	.00	.21	.95	.35	.35	.35
2	(Constant)	.68	1.75		.39	.70	-2.81	4.18			
	MIPT: symbolic	.59	.17	.36	3.36	.00	.24	.94	.35	.37	.36
	Gender	2.05	.70	.31	2.94	.00	.66	3.44	.31	.33	.31
3	(Constant)	-2.59	2.24		-1.16	.25	-7.07	1.88			
	MIPT: symbolic	.53	.17	.32	3.08	.00	.19	.87	.35	.35	.32
	Gender	2.21	.68	.34	3.24	.00	.85	3.56	.31	.36	.33
	MIPT: text	.34	.15	.24	2.24	.030	.04	.64	.25	.26	.23

a.Dependent Variable: TUGK:slope

Discussion and Conclusion

In the current study participants are at a formal operation stage in which they are expected to reason on images and abstract representations such as graphs. However, some students still have problems correctly interpreting kinematics graphs. The results of this study reveal that logical thinking is one of the main reasons for that.

The principal component analysis showed that interpreting kinematics graphs is related to how students determine the slope and area in a kinematics graph. The order of kinematics graphs for calculating the area is: a-t, v-t, and p-t. On the other hand, the order of kinematics graphs for determining slope is reverse: p-t, v-t, and a-t. The slope variable starts with a simple kinematics concept (position) and gets more complex as students learn velocity and acceleration. That might be one of the reasons for beginning teaching kinematics with p-t graph, and progress to the v-t graph and then the a-t graph. However, the results of the current study showed that students had more difficulty on slope items than area items, so beginning teaching kinematics with reverse order, namely first a-t, then v-t, and finally p-t graph might be the correct order. Another study might be necessary to clarify this point.

Another finding of the study is that students who did well on TUG-K: slope items also did well on TUG-K: area items. This result shows that determining the slope and/or the area in a kinematics graph are interconnected. Therefore, it can be concluded that kinematics graph interpretation skills are related to understanding the slope and area in a kinematics graph.

The results reveal that students have difficulty deciding if they need to calculate the slope or the area in kinematics graphs. This conclusion is in accord with Beichner (1994). In addition, students have more difficulty calculating the slope in a kinematics graph than calculating the area. Moreover, students do not pay attention to the variables on each axis. For example, some students did calculations where they mistakenly considered a p-t graph to be a v-t graph. This leads students to have the most common error in interpreting kinematics graphs—graphs as picture error (Berg & Phillips, 1994; Brasell, 1987; Mokros & Tinker, 1987; Svec, 1999; Trumper, 1997).

Student logical thinking comprised processing text (MIPT: text) and symbolic information (MIPT: symbolic). This finding is very important because graphs are symbolic representations. The results showed that processing symbolic information had a significant relationship with interpreting kinematics graphs. This result suggests that understanding kinematics graphs is related to processing abstract information. Berg and Phillips (1994) noted that "without their development students are dependent upon their perceptions and low level thinking" (p.340). Therefore that type of student has difficulty processing symbolic information. As a result, students who are not at the formal operation stage will have problems when they construct or interpret kinematics graphs.

Piaget noted that operation is very important for the development of knowledge. Students have different types of operations for processing text and symbolic representations. MIPT: symbolic, gender, and MIPT: text were identified as the best set to significantly predict TUG-K: slope. It is clear that understanding the slope in a kinematics graph is related to logical thinking and gender. Therefore, processing text or symbolic information is important for students' understanding of kinematics graphs.

Male students did significantly better than female students on TUGK: slope items. One of the reasons for this might be related to different previous experiences. Male students are generally more active in the physical world than female students, and male students tend to be more interested in studying science while female students tend to be more interested in social science (Miller, Blessing, & Schwartz, 2006). In this study, no significant correlation was found between students' logical thinking and gender.

The results of the current study reveal that TUG-K: slope is significantly correlated with logical thinking (MIPT: text and MIPT: symbolic) and gender. Students must develop cognitively to understand abstract representations such as the kinematics graphs in this study. In other words, students need to be at a formal operation stage to have a better understanding of the kinematics graphs that are related to determining the slope.

Some students come to the classroom with a high level of logical thinking and some do not. The important point here is that students at this age level (16-18) have already developed their cognitive thinking skills; they are expected to be thinking formally and should be able to work with images and abstract representations. Teachers need to realize that a student with low logical thinking skills may experience problems understanding kinematics graphs. This student may need extra help to move to an upper level of logical thinking to understand the kinematics graphs.

Kinematics is generally taught in one of three ways: using kinematics formulas, using kinematics graphs, or using a combination of kinematics formulas and graphs. It is very important to determine the differential characteristics of these three instructional techniques and the resulting understanding of kinematics graphs. The results of such study can be used to improve curriculum materials such as textbooks, instructional techniques, instructional sequences, and the connections between the mathematics concepts of slope and area under a graph and the physics concepts of time, position, velocity, and acceleration.

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Öğrencilerin Mantıklı Düşünme, Cinsiyet ve Kinematik Grafiklerini Yorumla Yetenekleri Arasındaki İlişkiler

(Özet)

Problem Durumu

Kinematik konusu fizikte grafiklerin en sık kullanıldığı konulardan birisidir. Bunun yanı sıra kinematik konusu çok sayıda matematiksel formül içermektedir. Geleneksel eğitim sisteminde öğrenciler genellikle soyut olan bu formülleri kullanarak problemleri çözmeye çalışmaktadırlar. Öte yandan, kinematik problemleri formül kullanmak yerine aslında grafikler yardımıyla çözülebilirler. Bu çalışmada adı geçen kinematik grafikleri konum-zaman (p-t), hız-zaman (v-t), ve ivme-zaman (a-t) grafikleridir. Belirtilen kinematik grafiklerini doğru çizmek ve doğru yorumlamak çok önemlidir. Örneğin hız-zaman grafiğinde eğri altında kalan alan yer değiştirmeyi verirken, eğrinin eğimi hesaplandığında ivme değeri bulunacaktır. Grafikler soyut olduğundan dolayı öğrencilerin bunları anlayabilmesi için Piaget nin belirlemiş olduğu biçimsel işlemleri yapabilme aşamasında olmaları gerekmektedir. Bu çalışmada yer alan öğrenciler 16-18 yaş arasında olup Piaget nin biçimsel işlemler için belirlemiş olduğu yaş sınırındadırlar. Bu alanda yapılan çalışmalar mantıklı düşünme ile grafik yorumlamalarını genel olarak ele alırken, bu çalışma özellikle kinematik grafiklerinin mantıklı düşünme ile ilgili bağlantısını ele almıştır.

Araştırmanın Amacı

Bu araştırmanın temel amacı lise 12. sınıf fizik öğrencilerinin mantıklı düşünme yetenekleri, cinsiyetleri ve kinematik grafiklerini yorumlama yetenekleri arasındaki ilişkileri araştırmaktır. Bu bağlamda, mantıklı düşünmenin ve kinematik grafiklerinin bağlı olduğu muhtemel değişkenleri tespit etmek ve bu değişkenler arasındaki bağlantılara bakmak önem arz etmektedir. Ayrıca öğrencilerin kinematik grafiklerini yorumlarken ne tür zorluklarla karşılaştıkları veya ne tür yanılgılara sahip oldukları da önemlidir.

Araştırmanın Yöntemi

Bu çalışma lise 12. sınıfta okuyan ve fizik dersi alan 40 erkek ve 32 kız olmak üzere toplam 72 öğrenci ile yapılmıştır. Veriler Test of Understanding Graphs-Kinematics (TUG-K), ve Middle Grades Integrated Process Skill Test (MIPT) testleri uygulanarak toplanmıştır. Bu çalışmanın araştırma yöntemini korelasyonal araştırma tasarımı oluşturmaktadır. Faktör analizi yapılarak MIPT ve TUG-K için ana bileşenler tespit edilmiştir. Bu ana bileşenlerin önceki çalışmalarda bulunan ana bileşenlerle farklılıkları ortaya konulmuştur. Ayrıca her test için güvenilirlik analizi yapılmıştır. Bunlara ek olarak, betimleyici istatistik, korelasyon, ve ileri-çoklu lineer regresyon analizleri kullanılmıştır.

Araştırmanın Bulguları

Faktör analizi sonucunda MIPT ve TUG-K testleri için ikişer adet ana bileşen bulunmuştur. MIPT için metin bilgilerinin işlenmesi ile bağlantılı olarak MIPT: text ana bileşeni tespit edilmiştir. Grafik, veri tablosu gibi simgesel bilgilerin işlenmesi için ise MIPT: symbolic ana bileşeni bulunmuştur. TUG-K için ise kinematik grafiğinde eğimin hesaplanması ve yorumlanması ile ilgili olarak TUG-K: slope ve alanın hesaplanması ve yorumlanması ile bağlantılı olarak TUG-K: area olmak üzere iki ana bileşen tespit edilmiştir. Bağımlı değişkenler (TUG-K: slope ve TUG-K: area) ile bağımsız değişkenler (MIPT: text, MIPT: symbolic, ve cinsiyet) arasında anlamlı korelasyonlar bulunmuştur. İleri-çoklu lineer regresyon analizi sonucunda MIPT: symbolic, cinsiyet ve MIPT: text değişken grubunun TUG-K: slope için en iyi tahmin seti olduğu ortaya çıkmıştır. Bu sonuca göre kinematik grafiklerinde eğim hesabıyla ilgili soruların öğrencinin mantıklı düşünme yeteneği ve cinsiyetiyle bağlantılı olduğu ortaya çıkmıştır. Öte yandan, kinematik grafiklerinde alan hesabı için saptanan TUG-K: area değişkeni için herhangi bir tahmin edici değişken bulunamamıştır. Bunun en temel nedenlerinden birisi olarak TUG-K: area ile ilgili soru sayısının sadece beş soru ile sınırlı olması gösterilebilir.

Araştırmanın Sonuçları ve Önerileri

Sonuçlar mantıklı düşünmede metin ve simgesel bilgilerin işlenmesinin önemli rol oynadığını ortaya koymaktadır. Ayrıca öğrencilerin kinematik grafiğindeki eğim ve alanı nasıl hesapladıkları ve yorumladıkları da kinematik grafiklerini anlamak açısında çok önemlidir. Bu araştırma sonucuna göre öğrenciler kinematik grafiklerinde eğim hesaplarken alan hesabına göre daha çok zorlanmaktadırlar. Öte yandan eğim sorularını doğru yapanların alan sorularını da doğru yaptıkları tespit edilmiştir. Ayrıca bazı öğrenciler kinematik grafiğinde alan mı yoksa eğim hesabımı yapmaları gerektiğini tespit etmekte güçlük yaşamaktadırlar. Son olarak daha önce yapılmış çoğu çalışmada olduğu gibi öğrenciler grafiği, grafikten çok resim olarak görmektedirler. Bunun en temel nedenlerinden birisi öğrencilerin kinematik grafiğini yorumlarken özellikle y-ekseni üzerindeki değişkene dikkat etmemeleridir. Örneğin x-eksenine paralel bir doğruyu öğrenci konum-zaman, hız-zaman ve ivme-zaman grafiklerinde aynı şekilde yorumlamaktadır. Cinsiyet faktörü ele alındığında kinematik grafiklerinde eğim hesaplanması gerektiren sorularda erkek öğrencilerin kız öğrencilerden daha başarılı oldukları tespit edilmiştir. Öte yandan alan hesabı

gerektiren sorularda kız ve erkek öğrenciler arasında anlamlı bir fark bulunamamıştır. Sonuçlar kinematik grafiklerinin yorumlanmasında mantıklı düşünme yetenekleri yüksek olan öğrencilerin düşük olan öğrencilerden daha başarılı olduklarını ortaya koymuştur.

Grafikler arasındaki geçişler dikkate alındığında konum-zaman grafiğinden hız-zaman grafiğine ve hız-zaman grafiğinden ivme-zaman grafiğine geçişin eğim hesabıyla olduğu bilinmektedir. Öte yandan ivme-zaman grafiğinden hız-zaman grafiğine ve hız-zaman grafiğinden konum-zaman grafiğine geçiş sırasında eğri altında kalan alan hesabı yapılmaktadır. Bu çalışmanın sonuçları kinematik grafikleri arasındaki geçişleri yaparken alan ve eğim hesabının önemini statiksel olarak ortaya koymuştur. Mevcut eğitim sisteminde önce konum-zaman sonra hız-zaman ve son olarak ivme-zaman grafikleri öğretilmektedir. Bunun basitten karmaşığa doğru giden bir sıralama olduğu kabul edilmektedir. Öte yandan bu sıralama takip edildiğinde eğim hesabı yapılmaktadır ve bu çalışmanın sonuçlarına göre öğrenciler eğim hesabı yaptıklarında alan hesabına göre daha çok zorlanmaktadırlar. Sonuç olarak bu sıralamaya bir açıklık getirmek açısından başka bir çalışmanın yapılması gerekli görünmektedir.

Anahtar Sözcükler: Kinematik, grafikler, mantıklı düşünme, fizik eğitimi