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High School Students' User Skills Concerning Force and Motion Graphs[*] [**]

Lise Öğrencilerinin Kuvvet ve Hareket Konusuna Yönelik Grafik Kullanma Becerileri

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ABSTRACT

In this study, the aim was to examine Year 11 students' skills of reading-interpreting and drawing graphs of force and motion and to lay bare the relationship between graph reading-interpretation and drawing graphs. Conducted in the survey model, the study was realised with the participation of 209 Year 11 students studying at Anatolian high schools in Ankara. Graph Reading and Interpretation Skills Test (GRIST) which includes 13 multiple-choice items and Graph Drawing Skills Form (GDSF) which includes 5 open-ended items were used as data collection tools. At the end of the study, it was determined that students have an intermediate level of success in reading and interpreting graphs while they have a low level of success in drawing graphs. It was concluded that students' graph reading and interpretation skills and their graph drawing skills are related to one another.

Keywords: *Graph reading-interpretation, graph drawing, physics education.*

ÖZ

Araştırmada, kuvvet ve hareket konusuna yönelik lise 11. sınıf öğrencilerinin grafik okuma-yorumlama ile grafik çizme becerilerini incelenmesi ve grafik okuma-yorumlama ve grafik çizme arasındaki ilişkiyi ortaya çıkarmak amaçlanmıştır. Tarama modeli ile yürütülen çalışma, Ankara

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il merkezinde yer alan Anadolu Liselerinde öğrenim gören toplam 209 11. sınıf öğrencisi ile gerçekleştirilmiştir. Araştırmada veri toplama aracı olarak 13 maddeden oluşan çoktan seçmeli Grafik Okuma ve Yorumlama Beceri Testi (GOYBT) ve beş maddeden oluşan açık uçlu Grafik Çizme Beceri Formu (GÇBF) kullanılmıştır. Araştırmanın sonucunda, öğrencilerin grafik okuma ve yorumlamada orta düzeyde, grafik çizmede ise düşük düzeyde başarı gösterdikleri belirlenmiştir. Araştırmada, öğrencilerin grafik okuma ve yorumlama becerileri ile grafik çizme becerileri birbirleri ile ilişkili olduğu sonucuna ulaşılmıştır.
Anahtar Sözcükler: *Grafik okuma-yorumlama, grafik çizme, fizik eğitimi*

INTRODUCTION

Physics has always been considered to be a difficult class to understand or teach because it includes more abstract subjects than other classes (Bozkurt, 2008; Kolçak et al., 2014; Tarakçı, 2016). To make this course more effective and more easily understandable graphs can be used which present a visual table by bringing together verbal and numerical information (Aydın & Tarakçı, 2018; Tarakçı, 2016). In order for graphs, which can be used to express the relationship between different concepts of physics, to be used appropriately, the students' graphs reading-interpretation and graphs drawing skills should be sufficiently developed. (McKenzie & Padilla, 1986; McDermott, Rosenquist, & van Zee,1987; Ateş & Stevens, 2003; Bektaşlı, 2006; Lowrie & Diezman, 2007; Demirci & Uyanık, 2009; Uyanık, 2007; Gültekin & Nakiboğlu, 2016). Used for visually showing the relation between data or present data that are either too much or too complex to show in a text, graphs have a significant place both in daily life and in all disciplines (Bayazıt, 2011; Slutsky, 2014; Wang et al., 2012).

In order for graphs use to be effective in learning, people should already have skills to use graphs. Kwon (2002) divides graphing skills into three general categories. These are interpretation skills, modelling skills, and transformation-drawing skills. The skill to interpret a graph is included under the graph usage skill, and it denotes the ability to verbally express a given graph. Modelling skill, which is another graph usage skill, refers to the ability to draw a graph of an observed phenomenon. The final graph usage skill is transformation-drawing skill, and it is defined as the ability to draw a graph belonging to an event based on another event observed before. An example for this is the ability to transform-draw a velocity-time graph from a position-time graph (Demirci & Uyanık, 2009; Murphy, 1999). Studies show that students have several difficulties with graphs: they tend to draw line graphs when drawing graphs or interpreting already drawn ones; they also expect to see smooth, symmetrical, and continuous graphs; they have a tendency to start the graph at the point of origin; they usually view graphs as pictures rather than as something that shows the relationship between variables; they tend to reverse the x and y coordinates; and they misread scales (Hadjidemetriou & Williams, 2002; Kwon, 2002). In a study by Tairab & Al-Naqbi (2004), which was conducted to lay bare students' skills of drawing, reading, and interpreting graphs, it was determined that students do not have sufficient knowledge and skills when it comes to interpreting graphs. Moreover, drawing a graph is usually considered to be more difficult than reading-interpreting a graph.

When the literature is examined, it can be seen that students ranging from primary education (Friel & Bright, 1995; DiSessa, Hammer, Sherin & Kolpakowski, 1991; Lai et al., 2016; Sezgin-Memnun, 2013; Peterman et al., 2015), secondary education (Ateş and Stevens, 2003; Eryılmaz-Toksoy, 2020; Gültekin, 2009; Uyanık, 2007; Wang et al., 2012) to pre-service teachers (Beichner, 1994; Tarakçı, 2016; Taşar, İngeç, Güneş, 2002) have difficulty with the skills of reading-interpreting and drawing graphs. Examining various factors influencing students' interpretation of graphs revealed that visual characteristics of graphs (shape, animation, colour, dimension, and so on), students' knowledge of graphs, and their knowledge of the content of the data in the graph all play a role their interpretation (Friel et al., 2001; Glazer, 2011; Shah & Hoeffner, 2002). Glazer (2011) indicates that the skill to interpret graphs is necessary to understand today's world and to have scientific literacy; but also adds that interpreting graphs is a complex and difficult activity and that it is affected by various factors such as the content of the graph and the person's prior knowledge. It is also seen that mathematical knowledge influences one's ability to read graphs (Friel et al., 2001;

Özgün-Koca, 2008). Friel et al (2001) contend that there are four factors influencing students' understanding of a graph; namely, the purposes for using graphs, task characteristics, discipline characteristics, and reader characteristics. Moreover, some studies show that there is a relationship between students' logical thinking strategies and their graph drawing skills (Berg & Philips, 1994; Wavering, 1989). Other studies define graph literacy in three levels: reading the data, reading the connection between data, and reading beyond data (Charpenter & Shah 1998; Friel & Bright, 1995).

Studies on graphs in physics classes

Studies focusing on the graphs used in physics classes show that students have difficulties reading, interpreting, and drawing graphs. Contending that graphs have an important role in forming the cognitive connections between mathematical equations and mechanical problem solving, Woolnough (2000) argues that skills necessary to solve mechanical problems are related to selecting the appropriate equation, deciding on what the unknown variable is, and re-designing the equation to be solved for this variable. However, he also adds that students have difficulty comprehending the relationship between mathematical processes and physics. Murphy (1999) indicates that students find it difficult to establish the relationship between position, velocity, and acceleration and thus have difficulties with position and velocity graphs. It is pointed out that the difficulties students have with reading, interpreting, and drawing graphs are mostly when it comes to motion graphs (Svec, 1995; Thornton & Sokoloff, 1990). Lai et al., (2016) determined that most students had difficulty in graph reading-interpretation and graph drawing especially in relation to science concepts. Teachers teaching "Science and Technology," who indicate that force and motion are the primary subjects in which students have maths-related difficulties, argue that students experience difficulties reading motion and force graphs and placing them within the formulae, interpreting and drawing graphs (Bütüner & Uzun, 2011). They add that students do not have enough knowledge of the slope of the force or motion graphs. Another finding in the study is that they have problems mostly with mathematical operations when it comes to their skills of drawing, reading-interpreting graphs. A similar study determines that Year 6 students learn how to draw a graph without really understanding what a graph is and what its uses are (DiSessa, Hammer, Sherin & Kolpakowski, 1991). In his study conducted to determine the difficulties university students have in interpreting kinematical graphs, Beichner (1994) designed the Test for Understanding Graphs in Kinematics (TUG-K) which consists of 20 multiple choice items. Realised with the participation of 895 students, the study concluded that students have difficulties interpreting kinematical graphs. These are as follows: when asked about the velocity of an object, whose position-time graph is provided, at a specific time taking into account the height of a graph at that point instead of calculating the slope; being unable to distinguish variables; and seeing graphs as pictures. In their study which aimed to examine the graph reading skills of students from various class levels, Wang et al. (2012) classified the information presented in the graphs as open information, confidential information, and precise information. At the end of their study, students from different class levels indicated that there are significant differences in reading any type of information but the precise information that requires the use of mathematical tools; students in the same class indicated that there are differences in their reading skills of different types of information. In her study examining the relationship between students' skills for graph drawing and understanding and their skills for interpreting kinematical graphs, Demirci &Uyanık (2009) uses Test for Understanding Kinematical Graphs (TUKG), Test for Drawing, Understanding, and Interpreting Graphs (TDUIG), and Physics Attitude Scale (PAS). At the end of this study in which 501 Year 10 students participated, it was determined that there is a meaningful relationship between students' skills for graph drawing and understanding and their skills for interpreting kinematical graphs. Aydın & Tarakçı (2018) also carried out a study to examine pre-service science teachers' skills for reading, interpreting and drawing graphs about the topics covered in "General Physics I" classes, and they developed a test with three sections consisting of multiple choice, open ended, and true/false questions. At the end of this study in which 244 pre-service teachers participated, it was determined that pre-service teachers had difficulty drawing graphs, determining the origin point of a graph, scaling the axes, merging values, and understanding and interpreting graphs. 20 Year11 students participated in Eryılmaz-Toksoy's study (2020) which aimed to determine students' skills in explaining, drawing, and interpreting graphs of motion types. As a data collection tool, she developed a test consisting of 10 open-ended questions. At the end of the study, it was determined that there is a meaningful difference in the skills of explaining, drawing, and interpreting graphs of motion types related to kinematics.

The Aim and Importance of the Study

Showing data and interpreting them has become even more significant as the importance is given to the development of scientific process skills, which also include understanding and drawing graphs (Gabel, 1993; Glazer, 2011). It is an undeniable fact that the use of graphs has a specific place especially in physics education. Graphs are important in understanding abstract concepts, especially those in physics which are deemed difficult (Çelik & Sağlam-Arslan, 2012; McDermott et al., 1987; Padilla, McKenzie & Shaw, 1986; Taşdemir, Demirbaş & Bozdoğan, 2005). In this respect, it is important that students' skills in reading, interpreting, and drawing graphs must be at a sufficient level. There are a few studies in Turkey on skills of reading-interpreting and drawing graphs of force and motion (Aydın & Tarakçı, 2018; Demirci & Uyanık, 2009; Eryılmaz-Toksoy, 2020). When the content of these studies is examined, it is seen that there is no study comparing the graph reading-interpretation and graph drawing levels of 11th grade high school students. Carried out to allay this gap in the literature, this study aims to examine high school Year 11 students' skills of reading-interpreting and drawing graphs of force and motion and to lay bare the relationship between graph reading-interpretation and drawing graphs. It is believed that this study will contribute to the literature by measuring students' skills in using graphs of force and motion. To this end, this study sought answers to the following sub problems:

1. What is Year 11 students' reading/interpretation skills level of force and motion graphs?
2. What is Year 11 students' drawing skills level of force and motion graphs?

3. Is there a meaningful relationship between Year 11 students’ knowledge of force and motion as subjects and their level of reading/interpreting/drawing graphs?

METHOD

Survey method was used in this study which aims to examine Year 11 students’ levels of reading-interpreting and drawing graphs of force and motion and to determine the problems they face, if there are any. Used to determine people’s attitudes, thoughts, and the relationships between variables, survey model is a research approach which aims to define and describe a present or past situation by recognising existing conditions. Survey model means defining or observing a subject matter without changing or affecting it (Christensen, Johnson &Turner, 2015; Karasar, 2002).

Participants

The study was carried out with the participation of 209 Year 11 students enrolled at Anatolian High Schools in Ankara during the 2018-2019 academic year Spring Semester. Schools that were included in the study were selected randomly. Criterion sampling method was used in selecting students from these selected Anatolian High Schools. In criterion sampling, all situations meeting a series of previously determined criteria. Criteria or criterion can be determined by the researcher (Yıldırım & Şimşek, 2006). Having had the teaching of motion and force was taken as the basic criterion in the study. Of the 209 students who constitute the sample of the study, 124 were female (59,3%) and 85 were male (40,7%). In addition, all these students participated in the study on a voluntary basis. To this end, students were given a child/adolescent information form and a parent consent form was procured from their families.

Data Collection Tools

Graph Reading and Interpretation Skills Test and Graph Drawing Skills Form were used as data collection tools in this study which aims to determine high school Year 11 students' level of reading, interpretation, and drawing skills for force and motion graphs.

Graph Reading and Interpretation Test

While developing the graph reading and interpretation test, related literature and physics textbooks used in classes where the application would be carried out were examined (Demirci & Uyanık, 2009; Döyen et al., 2018; Gür & Yılmaz, 2018; Uyanık, 2007; Tarakçı, 2016). Then, a 20-question question pool was created by examining questions including a graph of force and motion. These questions cover motion at constant acceleration in one dimension, motion at constant decelerating in one dimension, and motion at constant velocity. To ensure content validity of these questions, a table of specifications was formed according to Bloom's revised taxonomy; four academics from physics education and three physics teachers working at state high schools were asked to evaluate the questions in terms of their appropriateness for students' level as well as for the learning outcomes. After this evaluation, the roots of some questions in GDSF were altered and five questions were taken out of the question pool.

Pilot Study Concerning Graph Reading and Interpretation Test

GRIST pilot study which consists of 15 questions was applied to 200 Year 11 students (93 female -46.5% - and 107 male – 53.5%) enrolled at an Anatolian High School in Ankara during the 2018-2019 academic year Fall semester. It was applied to Year 11 because "Force and Motion" are covered in this year's curriculum. In the item analysis of the questions of graph reading-interpretation skill test, item discrimination indices and item difficulty indices were calculated by formulas. Item analysis results concerning this calculation are given in Table 1.

Table 1. Item Analysis Results Conducted by Using Formulae for GRIST after the Pilot Study

Item Number	Upper (27%)	Lower (27%)	*pj	**rjx
1	54	34	0,84	0,36
2	37	11	0,36	0,47
3	31	11	0,25	0,36

4	50	13	0,55	0,67
5	10	5	0,1	0,09
6	34	4	0,30	0,50
7	16	7	0,16	0,20
8	32	4	0,26	0,50
9	49	9	0,55	0,70
10	42	7	0,46	0,63
11	54	9	0,63	0,81
12	45	10	0,52	0,63
13	55	10	0,70	0,81
14	51	10	0,65	0,74
15	54	7	0,66	0,85

**pj: Item diffuculty index*
***rjx: Item discrimination power index*

Values in Table 1 show that the questions are generally either easy or of medium difficulty. At the end of the item analysis of the test, items 5 and 7 were taken out of the test since their discrimination power was low. In calculating item analysis, the second thing done was to look at item total correlations by using SPSS. Item analysis results concerning this calculation are given in Table 2.

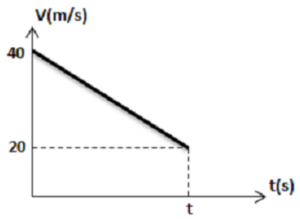
Table 2. Item Analysis Results Conducted by Using SPSS for GRIST after the Pilot Study

Item Number	Item Total Correlation
1	0,47
2	0,45
3	0,32
4	0,51
6	0,49
8	0,50
9	0,60
10	0,56
11	0,65
12	0,51
13	0,69
14	0,64
15	0,70

N=200

Table 2 shows that total correlations of items in GRIST vary between 0,32 and 0,70. It is known that items whose item total correlation value is 0,30 and higher differentiate students well, items whose item total correlation value is between 0,20-0,30 can be used by editing them if needs be, and items whose item total correlation value is lower than 0,20 cannot be used (Crocker & Algina, 2006; Büyüköztürk, 2007). According to these results, it was concluded that items in the test properly differentiate students in terms of their graph reading-interpretation skills. Moreover, z values of items were examined. Z values of the items were found to be between the -3 and +3 intervals.

Based on these results, GRIST used in the study consists of 13 items. Reliability coefficient of GRIST (its Cronbach Alpha) was calculated as 0,83. This result shows that GRIST is a reliable measuring tool to determine students' graph reading and interpretation skills. Based on the analyses on designing the GRIST and based on experts' opinions, it was decided that it is of intermediate difficulty as a test. The 1st question in GRIST is shown in Figure 1.



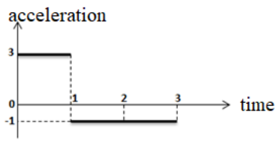
The velocity-time graph of a vehicle moving on a straight path is as shown in the figure.
If the displacement of the vehicle in t time interval is 120 meters, what is its displacement until it stops?

A)150 B)155 C)160 D)165 E)170

Figure 1. 1st question in GRIST

Graph Drawing Skills Form

Related literature and physics textbooks were examined to see how to measure Year 11 students' skills in drawing graphs of force and motion (Demirci & Uyanık, 2009; Döyen et al., 2018; Gür & Yılmaz, 2018; Uyanık, 2007; Tarakçı, 2016). At the end of this examination, GDSF with four open-ended questions was designed. To ensure GDSF content validity, a table of specifications for questions was formed according to Bloom's revised taxonomy; four academics from physics education and three physics teachers working at state high schools were asked to evaluate the questions in terms of their appropriateness for students' level as well as for the learning outcomes related to force and motion. After this evaluation, the roots of some questions in GDSF were altered and a new question was added. As such, GDSF got its final version with five open-ended questions. Pilot study for GDSF was carried out with 50 Year 11 students. At the end of this pilot study, data obtained through GDSF were analysed according to the following categories included in the Evaluation Rubric for Graph Drawings (ERGD): naming the axes according to variables, writing down the data on graph axes, forming a point on graph axes, and drawing the graph slope. At the end of the pilot study, it was decided that GDSF can measure students' skills of drawing force and motion graphs. The 3rd question in GDSF is shown in Figure 2.



The acceleration-time graph of a vehicle starting from a standstill on a straight path is as shown in the figure. Accordingly, draw the velocity-time graph of the vehicle in the time interval (0-3s).

Figure 2. 3rd question in GDSF

Data Analysis

Because the number of students who participated in the study was bigger than 40, it was accepted that the GRIST and GDSF data were fit for normal distribution (Barrett & Goldsmith; 1976; Lumley et al., 2002; Tabachnick & Fidell, 2015). Data collected by GRIST and GDSF were analysed with Pearson Correlation test by SPSS 24.0.

Data Analysis for Graph Reading and Interpretation Test

GRIST consists of 13 multiple choice questions. In the analysis, answers given to GRIST were evaluated as correct, incorrect, or blank. Scores received by students were obtained by coding the correct answers as 1, incorrect and blank answers as 0. As such, students' GRIST scores were calculated out of 13 points since there are 13 multiple choice questions in the test. GRIST was a test of intermediate-difficulty, and the average student score was 7,87. Therefore, test scores were categorised as follows: 0-2 points: very low, 3-5 points: low, 6-8 points: intermediate, 9-11 points: good, and 12-13 points: very good (Table 5 and Table 1).

Data Analysis for Graph Drawing Skills Form

Each step of drawing the graph related to the questions in GDSF were scored gradationally. To this end, scoring rubric designed by Tarakçı (2016) was used to evaluate students' graph drawings. After obtaining the necessary permits to use the rubric, it was redesigned by adding additional categories and criteria. To check whether the categories and evaluation criteria in the prepared rubric are appropriate or not, three academics specialising in the field of physics education were consulted. Following the corrections and suggestions provided by the experts, the rubric which would be used in the analysis of students' graph drawings was finalised. This rubric can be found in Table 3.

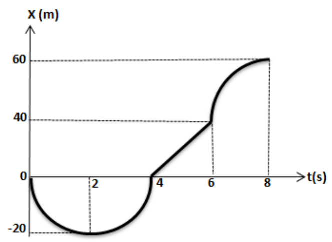
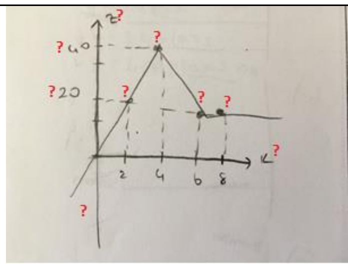
Table 3. Rubric for Evaluating Drawings of Graphs

Evaluation Criteria	Categories	Score
Naming the Axes According to Variables	*Correct (C):* Naming both axes correctly and writing down the units of physical qualities representing the axes in parentheses.	2
	Partially Correct (PC): Naming only one of the axes correctly or not writing down/partially writing down/incorrectly writing down the units of physical qualities of the axes.	1
	Incorrect (I): Naming both axes incorrectly or failing to	0

	name either axis. *Blank (B):* Leaving the question blank, lack of any drawn graph.	 0
Writing Down the Data on the Axes of the Graph	*Correct (C):* Correctly writing data on both axes.	2
	Partially Correct (PC): Writing down only one data group correctly and writing down the other incorrectly.	1
	Incorrect (I): Incorrectly writing down data on both axes or failing to write down any data.	0
	Blank (B): Leaving the question blank, lack of any drawn graph.	0
Creating a Point on the Axes of the Graph	*Correct (C):* Correctly intersecting the data on the ‘’y’’ axis with data on the “x” axis and creating a point.	2
	Partially Correct (PC): Correctly intersecting the data of only one of the axes and making a mistake in the other one.	1
	Incorrect (I): Incorrectly intersecting data in both axes.	0
	Blank (B): Leaving the question blank, lack of any drawn graph.	0
Drawing the Curve of the Graph	*Correct (C):* Drawing the whole curve of the graph appropriately for the question.	2
	Almost Correct (AC): Appropriately drawing at least 3-time intervals of the 4-time-interval part of the curve of the graph or at least 2 time intervals of 3-time-interval part.	1.5
	Partially Correct (PC): Appropriately drawing at least 2-time intervals of the 4-time-interval part of the curve of the graph, or at least 1 time interval of the 3-time-interval part of the curve of the graph.	1
	Incorrect (I): The whole curve of the graph being inappropriate.	0
	Blank (B): Leaving the question blank, lack of any drawn graph.	0
Maximum Score to Get for Each Question		8

As can be seen in Table 3, graph drawing stages belonging to each graph in GDSF were scored over 2 points. For the fourth questions, which contains three separate options, each option was evaluated separately, and students’ graph drawing scores were calculated out of 56. Since the average score in the GDSF was 19.04, the test scores were defined by the researchers categorized as very low (0-8 points), low (9-23 points), intermediate (24-32 points), good (33-47 points), very good (48-56 points). (See Table 7). The scored sample student graph was presented in Table 4.

Table 4. Scored Sample Student Graph

The expected correct graph expected for the 1st question.	**Graph drawn by S36.**
	

It was seen that student with the code "S36" misnamed graph axises and failed to get any marks from the "naming the axis according to variables" category; the same student was partially correct in writing down the data on the graph and he received 1 from this category; he created a wrong point on the graph axises and ended up drawing the wrong graph curve and thus received zero in this category. The highest score to be received from each question was 8, and this student got a total of 1 for the first question.

Ethical Considerations

This study was carried out with the permission of Hacettepe University Ethics Committee (decision dated 04.09.2018 and numbered 35853172-300). Moreover, permits were received for carrying out interviews and research from Ankara District Directorate of National Education (decision dated 12.10.2018 and numbered 14588481-605.99-E.19187471). (Appendix A).

FINDINGS

Findings about the First Sub Problem

As the first sub problem, this study examined the level of Year 11 students' skills of reading-interpreting graphs of motion and force. To this end, analysis results of the averages and standard deviation values of students' GRIST scores are shown in Table 5.

Table 5. Averages and Standard Deviation Values of Students' GRIST Scores

	N	$\overline{X}$	ss
Total	209	7,87	3,54

Since the highest score one can get from GRIST is 13, it can be argued that students are intermediate at graph reading-interpretation as their average score is 7,87 (See Table 5). At the same time, most students had a score higher than the average score of 7,87. Students GRIST scores and their frequencies are given in Diagram 1.

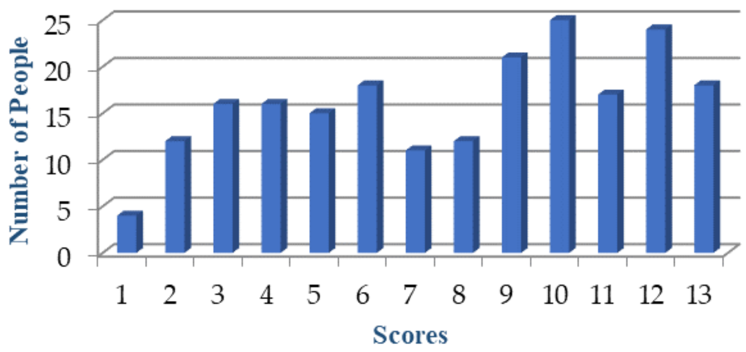


Diagram 1. Distribution of Students' Scores in GRIST Questions

Distribution of students' scores in GRIST questions show that there are 18 students (8,61%) who got a full score, which is 13, by answering all questions correctly and there are 4 students (1,91%) who received the lowest score, which is 1. (See. Diagram 1).

Findings concerning the first sub problem show that in the first question, which is the most frequently correctly answered one by the participants (171 students, 81,8%), a velocity-time graph was given, and students were asked how many metres the vehicle would move until it halts (See Table 6). In the third question, which was the least correctly answered one by the students (70 students, 33,3%), a force-time graph was given, and students were asked about displacement in the 0-3t time interval. When findings were examined, it was determined that there are no questions that were left unanswered by students. Whether questions in GRIST were correctly or incorrectly answered or left black was separately analysed, and findings were presented in Table 6.

Table 6. Frequency and Percentages of Each Question in GRIST

Questions	Correct number (f)	%	incorrect number (f)	%
1	171	81.8	38	18,2
2	106	50.7	103	49,3
3	70	33.5	139	66.5
4	127	60.8	82	39,2
5	89	42.6	120	57,4
6	102	48.8	107	51,2
7	150	71.8	59	28,2
8	107	51.2	102	48,8
9	139	66.5	70	33,5
10	130	62.2	79	37,8
11	166	79.4	43	20,6
12	141	67.5	68	32,5
13	149	71.3	60	28,7

When Table 6 is examined, it was determined that 120 (57,4%) of the students in the fifth question and 107 (51,2%) in the sixth question had difficulty in finding the displacement from the acceleration-time graph.

Findings about the Second Sub Problem

The second sub problem examined in the study is Year 11 students' skill level of drawing graphs of motion and force. Averages and standard deviation values of students' GDSF scores are given in Table 7.

Table 7. Students' GDSF Score Averages and Standard Deviation Values

	N	$\overline{X}$	ss
Total	209	19,04	13,4

Since 56 is the highest score to be received from GDSF, it can be argued that with an average score of 19,04, students' graph drawing skills is low (9-23 indicates a low level). (See table 7). At the same time, it was determined that most students had a score higher than the average score of 19,04.

Students' answers to GDSF questions were examined in Table 3 according to GDSF, and findings obtained from this examination were presented. Students GDSF scores were frequencies in these score intervals are given in Diagram 2.

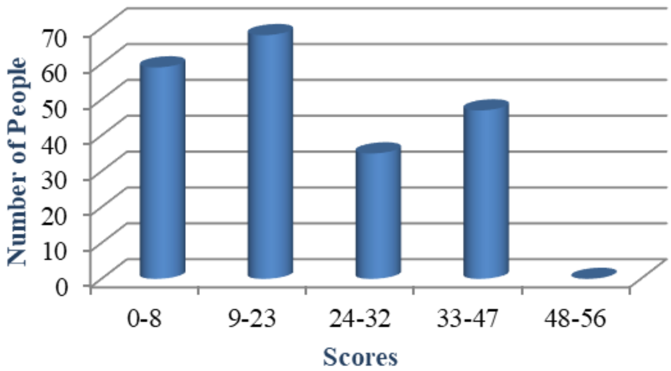
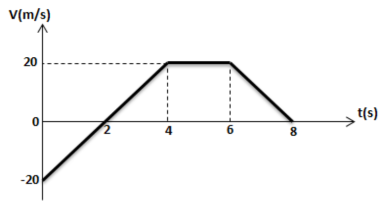


Diagram 2. Distributions of Students' GDSF Scores

Distribution of students' GDSF scores show that 59 students (28,22%) got scores within the lowest score bracket (0-8) and 68 (32,53%) received scores in the 9-23 bracket (See Diagram 2). Moreover, no student received a score within the highest score bracket, which is 48-56. It was also seen that none of the students gave a completely correct answer to questions 1, 3, 4b, and 4c; only 1 student (0,47%) answered the second question correctly; 2 students (0,95%) answered 4a correctly, 4 students (1,91%) answered the fifth question correctly. In the fifth question in GDSF, students were asked to draw an acceleration-time graph by using the chart showing the change of velocity with time. Regarding this question, it was determined that rather than drawing a graph by using the data students had difficulty converting one graph to another.

The drawings of the students for the first question in the GDSF, in which the 11st grade students were asked to transform the velocity time graph into a position time graph, were examined as an example (See Figure 3.).

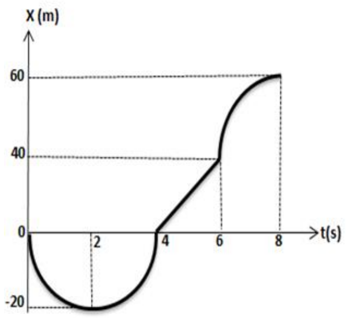
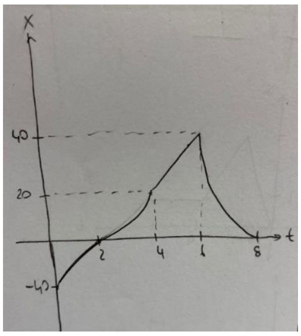
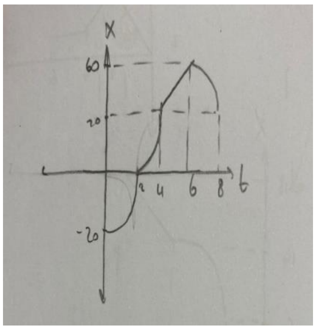


The velocity-time graph of an object, which is at its initial position at t=0 time, in the tine interval of (0-8)s is as shown in the figure. Accordingly, draw the position-time graph of the object

Figure 3. 1st question in GDSF.

The correct graph that is expected to be drawn for the first question from the students participating in the study and the examples of incorrect graphs drawn by the students are given in Table 8.

Table 8. Sample Incorrect Graphs Drawn by The Students

The expected correct graph expected for the 1st question.	Graph drawn by S34.	Graph drawn by S70.
		

Findings about the GRIST and GDSF scores show that students have a low level of success with drawing graphs while they have an intermediate level of success when it comes to graph reading-interpretation.

Findings about the Third Sub Problem

Pearson Correlation test was done for test scores at 0,05 significance level to determine whether there is a statistically significant relationship between students' levels of reading-interpreting and drawing graphs of force and motion.

Table 9. Pearson Correlation Test Concerning the Relationship between Students' Graph Reading-Interpreting Skills and their Graph Drawing Skills

The Relationship between graph reading-interpreting and graph drawing	N	*p	Pearson Correlation
	209	0,000	0,409

Findings concerning the third sub problem show that there is a positive and intermediate relationship between reading-interpreting graphs and drawing graphs (See Table 9).

DISCUSSION AND CONCLUSION

In this study where high school Year 11 students' graph usage skills related to force and motion were examined, it was determined that students have an intermediate level of success in reading-interpreting graphs and have a low level of success in drawing graphs. Similar studies show that students' graph drawing scores are lower than their graph comprehension scores and that their graph reading-interpretation and drawing skills are not at a sufficient level (Aydın & Tarakçı, 2018; Demirci & Uyanık. 2009; Uyanık, 2007; Sezgin-Memnun, 2013; Tarakçı, 2016). It is seen that the students participating in the research show that students have difficulties reading, interpreting, and drawing graphs for velocity-time, acceleration-time, position-time and force-time graphs. Students' answers in GRIST and GDSF show that students had difficulty finding displacement since they did not properly create the acceleration-time graph from the velocity-time graph. Similarly, Hale (1996) indicated that students find it difficult to find displacement by looking at the velocity-time graph. One reason for their low level of skills related to graph reading-interpretation and drawing can be their lack of enough experience in using graphs (Ercan, Coştu & Coştu, 2018). There are studies in the literature indicating that students should have a certain knowledge of mathematics and subject/field knowledge (Demirci & Uyanık, 2009; Bayazıt, 2011; Bütüner & Uzun, 2011). Moreover, there are also various studies carried out in different disciplines pointing out that knowledge of mathematics impact graph reading-interpretation (Capraro, Kulm & Capraro, 2005; Friel vd., 2001; Kaynar & Halat, 2012; Kieran, 1992; Özgün-Koca, 2008; Sezgin-Memnun, 2013). In the literature, it was also argued that graph interpretation skills are influenced by many factors such as the content of the graph and the person's prior knowledge about it (Glazer, 2011; Shah & Hoeffner 2002). Because graphs are used in mathematics, positive sciences, and social sciences, interdisciplinary studies can be conducted to examine students' graph drawing and reading-interpretation skills. In their study, Aydın & Tarakçı (2018) argued that students do not enjoy subjects containing graphs and have preconceived notions that they cannot successfully work those graphs. In his study, Beler (2009) also contended that students do not like subjects containing graphs. It is thought that students' affective characteristics such as anxiety or interest may affect their graph usage skills. In this respect, it is believed that studies focusing on the relationship between graph usage skills and these affective characteristics should be carried out.

Another result obtained in the study is that there is a positive and intermediate relationship between students' skills of drawing graphs and their reading-interpretation skills of force and motion graphs. Considering other studies in the literature, this is an expected result. Demirci and Uyanık (2009) also got a similar result in their study and found out that there is a positive relationship between kinematical graphs comprehension scores and the ability to draw, understand, and interpret graphs. Tairab & Khalaf Al-Naqbi (2004) contend that students' graph reading-interpretation skills are not as developed as desired and thus are these students do not have good graph drawing skills, either. Glazer (2011) indicates that reading-interpreting graphs and drawing graphs are related but graphs are complex and difficult activities. In this respect, it is believed that reading-interpreting graphs and drawing graphs should not be considered separately.

SUGGESTIONS

At the end of the study, it was seen that high school students have difficulties in reading, interpreting, and drawing graphs of motion and force. It was determined that students are less successful in drawing graphs than they are in reading-interpreting graphs. Keeping in mind the relationship between scientific process skills and graph reading-interpretation and drawing skills, it is evident that students have not acquired enough graph reading-interpretation and drawing skills even though these skills are included in curriculums (Ministry of Education, 2018). If activities steering students to acquire scientific process skills starting from primary education first stage, then students' skills of graph drawing, reading, and interpretation skills could be enhanced. For this, it is thought that both ready-made graphics and graphic drawings of the students should be included, for example, in showing the relationships between the information in which many data are included in the lessons. It is believed that the graphs that students will draw in order to interpret the relationship between the variables, based on the data, will facilitate conceptual understanding. It is believed that if teachers use pre-prepared graphics in their lessons, they should plan activities that improve their teaching and critical thinking skills so that students can understand the relationships between variables. It is also thought that students' misconceptions about force and motion may be negatively influential in their graph reading-interpretation and drawing. For instance, if a student falsely beliefs that "an object under the influence of a constant force would move at a constant velocity," it is highly likely that this student will have difficulty reading, interpreting, or drawing velocity-time graphs or even make mistakes. It is believed that studies examining whether there is a relationship between reading-interpreting and drawing graphs and misconceptions, which negatively impact meaningful learning, would contribute to the field education. There should be more activities in physics classes targeting reading-interpreting and drawing graphs. In this study, students' skills in using graphs of force and motion were examined. However, it is believed that the factors affecting these skills should also be determined, students' skills of reading, interpreting, and drawing graphs related to other physics topics should also be examined. Teachers should emphasise that the questions related to force and motion can be solved by using graphs without resorting to using formulas. In order to attract students' interests, to engage them in graphics and to increase their ability to use them, questions about force and motion can be solved by using graphs first before using formulas.

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GENİŞ ÖZET

Giriş

Fizik eğitiminde grafik kullanımının önemli yere sahip olduğu yadsınamaz bir gerçektir. Grafikler çok miktardaki verileri özetlemesi bakımından, özellikle fizik derslerindeki soyut kavramların daha iyi anlaşılmasında önemli yer almaktadır (Lowrie ve Diezman, 2007; McDermott vd, 1987; Padilla, McKenzie & Shaw, 1986). Bu sebeple öğrencilerin grafik okuma yorumlama ve çizme becerilerinin yeterli düzeyde olması oldukça önem taşımaktadır. Alanyazın incelendiğinde kuvvet ve hareket konusuna yönelik grafik okuma-yorumlama ve çizme becerileriyle ilgili yapılan araştırmaların az sayıda olduğu görülmektedir (Aydın & Tarakçı, 2018; Demirci & Uyanık, 2009; Eryılmaz-Toksoy, 2020). Bu araştırmaların içeriği incelendiğinde 11. sınıf lise öğrencilerinin grafik okuma-yorumlama ile grafik çizme düzeylerinin karşılaştırıldığı bir çalışmanın bulunmadığı görülmektedir. Alanyazında bu konuya yönelik eksikliği tamamlayabilmek için yapılan bu araştırmanın amacı, kuvvet ve hareket konusu ile ilgili 11. sınıf öğrencilerin grafik okuma-yorumlama, grafik çizme becerilerini incelenmesi ve grafik okuma-yorumlama ve grafik çizme arasındaki ilişkiyi ortaya çıkarmak amacıyla yapılmıştır. Bu kapsamda araştırmada aşağıdaki alt problemlere yanıt aranmıştır:

1. *11. sınıf öğrencilerinin kuvvet ve hareket konusu ile ilgili grafik okuma-yorumlama becerileri ne düzeydedir?*
2. *11. sınıf öğrencilerinin kuvvet ve hareket konusu ile ilgili grafik çizme becerileri ne düzeydedir?*
3. *11. sınıf öğrencilerinin kuvvet ve hareket konusu ile ilgili grafik okuma-yorumlama ile grafik çizme düzeyleri arasında anlamlı bir ilişki var mı?*

Yöntem

Araştırma, 2018-2019 eğitim ve öğretim yılı bahar döneminde Ankara il merkezinde yer alan Anadolu Liselerinde öğrenim gören toplam 209 11. sınıf öğrencisinin katılımıyla gerçekleştirilmiş ve bu araştırmada tarama modeli kullanılmıştır.

Araştırmada veri toplama aracı olarak Grafik Okuma-Yorumlama Beceri Testi (GOYBT) ve Grafik Çizme Beceri Formu (GÇBF) kullanılmıştır. 13 sorudan oluşan GOYBT'nin pilot çalışma sonucunda güvenirlik katsayısı (Cronbach Alpha) 0,83 olarak hesaplanmıştır. Bir diğer veri toplama aracı olan GÇBF ise toplam beş adet açık uçlu sorudan oluşmaktadır. GÇBF pilot çalışmanın sonucunda öğrencilerin kuvvet ve hareket konusuna yönelik grafik çizme becerilerini ölçebileceğine karar verilmiştir. Araştırma kapsamında geliştirilen Grafik Çizimlerini Değerlendirme Rubriği'nde (GÇDR) yer alan, eksenlerin değişkenlere göre isimlendirilmesi, grafik eksenlerine verilerin yazılması, grafik eksenlerinde nokta oluşturma, grafik eğrisinin çizilmesi kategorilerine göre analiz edilmiştir.

Bulgular, Tartışma ve Sonuç

Araştırmada birinci alt problem olarak 11. sınıf öğrencilerinin kuvvet ve hareket konusu ile ilgili grafik okuma-yorumlama becerilerinin ne düzeyde olduğu incelenmiştir. GOYBT'den alınabilecek en yüksek puanın 13 puan olduğu göz önünde bulundurulduğunda, öğrencilerin 7,87 ortalama puanla 6-8 puan aralığında puan aldıkları için genel olarak grafik okuma-yorumlamada orta düzeyde oldukları söylenebilir.

Araştırmada ikinci alt problem olarak 11. sınıf öğrencilerinin kuvvet ve hareket konusu ile ilgili grafik çizme becerilerinin ne düzeyde olduğu incelenmiştir. GÇBF'den alınabilecek en yüksek puanın 56 olduğu göz önünde bulundurulduğunda, öğrencilerin 19,04 ortalama puanla genel olarak grafik çizme becerilerinin düşük düzeyde (9-23 puan arası düşük düzey) oldukları söylenebilir. Aynı zamanda öğrencilerin çoğunun ortalama puan olan 19,04'ün altında puan aldıkları belirlenmiştir.

Araştırmada üçüncü alt problem olarak 11. sınıf öğrencilerinin kuvvet ve hareket konusu ile ilgili grafik okuma-yorumlama ile grafik çizme düzeyleri arasında anlamlı bir ilişki olup olmadığını belirlemek amacıyla test puanlarına 0,05 anlamlılık düzeyinde Pearson Korelasyon testi yapılmıştır. Araştırma sonucunda grafik okuma-yorumlama ve grafik çizme arasında pozitif yönlü ve orta düzeyde bir ilişki bulunduğu belirlenmiştir.

Araştırmaya katılan öğrencilerin hız-zaman, ivme-zaman, konum-zaman ve kuvvet-zaman grafiklerine yönelik grafik okuma-yorumlama ve çizmede sorunlar yaşadığı görülmektedir. Benzer araştırmalar incelendiğinde, öğrencilerin grafik çizme puanlarının grafik anlama puanlarına göre daha düşük olduğu ve grafik okuma-yorumlama ve grafik çizme becerilerinin yeterli düzeyde olmadığı görülmektedir (Aydın & Tarakçı, 2018; Demirci & Uyanık. 2009; Uyanık, 2007; Sezgin-Memnun, 2013; Tarakçı, 2016).

Alanyazındaki çalışmalar göz önünde bulundurulduğunda, araştırma sonucuna benzer şekilde öğrencilerin grafik okuma-yorumlama ve grafik çizme düzeyleri arasındaki pozitif yönlü bir ilişkinin bulunduğu görülmektedir. Demirci ve Uyanık (2009)'un benzer bir sonuç olarak araştırmalarında grafik çizme, anlama ve yorumlama yeteneği ile kinematik grafiklerini anlama beceri puanları arasında pozitif bir ilişki olduğunu tespit ettikleri görülmektedir. Tairab & Khalaf Al-Naqbi (2004) ise araştırmalarında öğrencilerin grafik okuma-yorumlama ile ilgili yeterli düzeyde olmadıklarını ve bu nedenle grafik çizme becerisinde de iyi olmadıklarını belirtmişlerdir. Glazer (2011) ise grafik okuma-yorumlama ve grafik çizmenin birbiriyle ilişkili olduğunu ifade etmiştir.

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Contribution of Researchers

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Conflict of Interest

The researchers do not have any personal or financial conflicts of interest with other individuals or institutions related to the research.

Ethics Committee Declaration

This study was conducted with the approval of Hacettepe University Ethics Commission dated 04.09.2018 and numbered 35853172-300.

Appendix

Tarih: 11.09.2018 14:45
Sayı: 35853172-300-E.00000222327

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T.C.
HACETTEPE ÜNİVERSİTESİ
Rektörlük

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Konu : Betül Şeyma YELTEKİN Hk.
(Etik Komisyon)

EĞİTİM BİLİMLERİ ENSTİTÜSÜ MÜDÜRLÜĞÜNE

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Bilgilerinizi ve gereğini saygılarımla rica ederim.

e-imzalıdır
Prof. Dr. Rahime Meral NOHUTCU
Rektör Yardımcısı

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