Journal of Theoretical Educational Science, 15(2), 327-346, April 2022
Kuramsal Eğitimbilim Dergisi, 15(2), 327-346, Nisan 2022
[Online]: https://dergipark.org.tr/akukeg
DOI number: http://doi.org/10.30831/akukeg.975348

Analysis of Strategies Used by Students in Solving Motion Problems According to the Presentation of the Problem

Öğrencilerin Hareket Problemlerinin Çözümünde Kullandıkları Stratejilerin Problemin Sunumuna Göre İncelenmesi

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Received: 28 July 2021 **Research Article** **Accepted:** 14 March 2022

ABSTRACT: In this research, it was aimed to analyze the problem solving strategies used during solving problems related to constant speed and constant acceleration motion, which are often used in graphs, according to the presentation of the problem (text and graph). The research was carried out with 119 students studying in the 11th grade. In the research conducted in a case study pattern, data were collected using the problem solving strategies scale used in Physics at the high school level and open-ended questions about problems presented in two different ways. Scores from the scale were analyzed through the SPSS 25 program, and data from open-ended questions were analyzed by content analysis. According to the results obtained from the scales, it was determined that the problem-solving strategies used by students did not differ according to the presentation of the problem, but there was a difference in the stages of understanding the problem and organizing the problem according to the results obtained from open-ended questions. According to these results, it can be said that the way the problem is presented mostly affects the stage of understanding the problem. The understanding phase affects the solution process and the time required for the solution. Therefore, different techniques can be used to understand the problem according to the presentation of the problem during teaching.

Keywords: Physics, problem solving strategy, problem presentation, graphical representation.

ÖZ: Bu araştırmada grafiklerden sıklıkla faydalanılan sabit hızlı ve sabit ivmeli harekete ilişkin problemlerin çözümü sırasında kullanılan problem çözme stratejilerinin problemin sunumuna (metin ve grafik) göre incelenmesi amaçlanmıştır. Araştırma 11. sınıfta öğrenim görmekte olan 119 öğrenci ile yürütülmüştür. Bir durum çalışması deseninde yürütülen araştırmada *Lise Düzeyinde Fizikte Kullanılan Problem Çözme Stratejileri Ölçeği* ve iki farklı şekilde sunulan problemlere ilişkin açık uçlu sorularla veriler toplanmıştır. Ölçekten alınan puanlar SPSS 25 programı aracılığı ile analiz edilerek, açık uçlu sorulardan elde edilen veriler ise içerik analizine tabi tutularak bulgulara ulaşılmıştır. Ölçeklerden elde edilen bulgulara göre öğrencilerin kullandıkları problem çözme stratejilerinin problemin sunumuna göre farklılaşmadığı, ancak açık uçlu sorulardan elde edilen bulgulara göre problemi anlama ve problemi örgütleme aşamalarında farklılık olduğu belirlenmiştir. Bu sonuçlara göre problemin sunum şeklinin en çok problemi anlama aşamasını etkilediği söylenebilir. Öğrencilerin en fazla problemi anlama aşamasına yönelik stratejileri kullandıkları tespit etilmiştir. Anlama aşaması çözüm sürecini ve çözüm için gereken süreyi etkilemektedir. Bu nedenle öğretim sırasında problemin sunumuna göre problemi anlamaya yönelik farklı teknikler kullanılabilir.

Anahtar kelimeler: Fizik, problem çözme stratejisi, problem sunumu, grafiksel gösterim.

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Citation Information
Eryilmaz-Toksoy, S. (2022). Analysis of strategies used by students in solving motion problems according to the presentation of the problem. *Kuramsal Eğitimbilim Dergisi [Journal of Theoretical Educational Science], 15*(2), 327-346.

ISSN: 1308-1659

Problem solving in Physics education is a research topic that is often studied and still needs new research (Gürel & Körhasan, 2018). Although students sometimes understand the subject, they cannot solve physics problems (Fraser et al., 2014; İnce, 2018). This leads researchers to study the physics problem solving process of students. The problem solving process is explained in the literature through the strategies used by expert and novice problem solvers (Álvarez et al., 2020; İnce, 2018). Problem solving is defined as a process with general steps, and what expert-novice people do on these steps is defined as problem solving strategies. But this process does not always proceed in the same way, as stated in the literature (Kim & Pegg, 2019; Steele, 2007). Different characteristics of the problem can affect the problem solving process and the problem solving strategies used.

There are studies investigating how the structure of problems affects the problem solving process. Fortus (2009) determined that experts had difficulty solving unstructured problems at the end of the study in which experts in field knowledge examined structured and unstructured (real-life) physics problem solutions. Shin et al. (2003) investigated the skills needed to solve structured and unstructured problems and concluded that they both required different skills. Kim and Pegg (2019) examined the reasoning that elementary school students use in solving two different types of problems that they call simple and complex related to physics topics, and found that higher-level reasoning is used in solving a simple problem. Tekbıyık and Akdeniz (2010) concluded that context-based problems do not make a difference in students' problem-solving achievements, but that context based problems are more comprehensible and interesting. Being more comprehensible may affect the types of information used at the problem understanding stage and problem solving strategies. As Milbourne and Wiebe (2018) stated, the path students choose in problem solving may depend on how they perceive the problem. The presentation format differentiates students' approaches to problem solving and performance (Carotenuto et al., 2021; De Cock, 2012; Hung & Wu, 2018; Ibrahim & Rebello, 2012; Kohl & Finkelstein, 2005, 2006; Maries, 2013). The form of expression of a problem is expressed as the representative format (Kohl & Finkelstein, 2005). A problem can be presented using text, graphics, symbols, images, or diagrams (Bollen et al., 2017). As Hung and Wu (2018) noted, there is no clear information about how the presentation of the problem affects the problem-solving process.

Meltzer (2005) determined students' performance in solving problems presented in different ways (verbal, symbolic, graph, diagram) through multiple-choice and explanation-required quizzes. Koedinger and Nathan (2004) found that students use different problem-solving strategies when solving problems presented in the form of verbal and symbols. De Cock (2012) determined that students use different strategies to solve problems presented in the form of verbal, graphic and picture by solving three isomorphic problems that require multiple choice and subsequent explanation. Moreno et al. (2011) determined that the use of abstract and concrete representations in problems solved during teaching related to electrical circuits affects problem solving through their research through three different groups. According to the results of these studies, it is seen that the way of presentation of the problem (text, images, graphics, tables, etc.) affects the information used in solving problems and the steps followed.

In the studies, the problem solutions of the students on paper were examined in general. However, the solution of the problems alone may not give sufficient information about the strategies followed in the solution process. It is very difficult to understand from the solution on the paper, at which stage the student implements which strategy and for what purpose. For this reason, it is necessary to examine the data collected differently regarding the solution process of students' problems presented in different ways. In this study, different from those in the literature, it is tried to determine the strategies followed by the students in solving the problems presented in a different way, with the help of scales and open-ended questions.

It can be said that one of the presentation forms of physics problems is graphs. Handhika et al. (2019) determined that students had difficulty in solving math problems presented in graphical form. It can be said that a similar situation applies to the physics course. Students have difficulty understanding graphs in which physical quantities are presented indirectly (Erceg & Aviani, 2014). Students' lack of reading and interpreting graphs also negatively affects their success in physics (Planinic et al., 2012). Many students have difficulty in solving kinematic problems due to their inability to interpret motion graphs (Rosenquist & McDermott, 1987).

The fact that students' problem-solving strategies are insufficiently known by teachers and that teachers are unable to adapt their teaching strategies to students' thinking/learning processes is the source of many challenges (McDermott, 1993). In Erceg and Aviani's (2014) study, the fact that teachers' estimates of the answers given by students differ from the answers given also supports this situation. According to the research, teachers believe their students will give more accurate answers. The researchers noted that teaching strategies should be shaped according to the problem-solving strategies that students use. Defining the problem-solving strategies that students use offers important recommendations for planning the learning process (Arsal, 2009). As Gürel and Körhasan (2018) noted, teachers sometimes think of their students as themselves and are unaware of their readiness. For this reason, it is important to determine which strategies students use for solving the problems presented in different ways. Suggestions can be reached on how teachers can support their students in solving problems presented in different ways.

This research aimed to examine the problem solving strategies used during the solution of problems related to constant speed and constant acceleration motion, which are often used in graphs, according to the presentation of the problem (text and graph). Research questions created for this purpose are as follows:

1. What are the problem solving strategies that students use to solve problems presented in text and graphical form?
2. How do the problem solving strategies that students use to solve problems presented in text and graphical form differ?

Method

In this research, which was conducted in mixed research method, the strategies used in the solution of constant speed motion and constant acceleration motion problems were discussed. The relationship of this situation with the presentation of the problem was tried to be determined by the scale of problem solving strategies used in Physics at the high school level (HSL-PPSSS) and open-ended questions about solving problems presented in two different ways. Mixed method design is an appropriate research method in the case of research problems that cannot be answered by only qualitative or quantitative data (McMillan & Schumacher, 2010, p. 395). So this method provides advantages about reaching more comprehensive data (McMillan & Schumacher, 2010, p. 397). In this research method data can be collected in different way. In this research qualitative and quantitative data was collected at the same time.

Participants

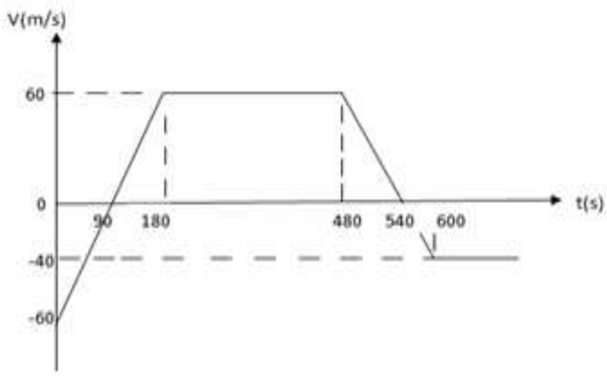
The research was conducted in a country in The Black Sea region. The determination of the participants of the study was based on volunteerism. Considering the difficulty of collecting data during the pandemic process, the data collection process has started in many schools. However, the answers of many students were not taken into consideration due to the reluctance of the students and the invalid filling of the data collection tools. 119 students who were in the 11th grade and completed learning of motion subject from two different schools constituted the participants of this research. 75 of these students study at Science High School and 44 of them study at Anatolian High School. In order to receive education in these schools, students must get a high score from the high school entrance exam. Considering this situation, it can be said that the students are generally more successful than the students receiving education in other schools**.**

Data Collection Tools

Quantitative Data Collection Tool

Examples of problems presented in the form of text and graphic related to constant speed and constant acceleration motion, which are the subjects of 11th grade physics course, are presented. In the examples developed by the researcher, the numerical values required to solve the problems were taken as the same by considering the effect of algorithmic information. In graphic representations, x-t (position-time), V-t (velocity-time) and a-t (acceleration-time) graphs containing movements in two different directions were used. For the tests created, opinions were received from two physics teachers and two academicians about the accuracy, clarity, and suitability of the problems for the students' level. According to suggestions from physics teachers, changes were made, such as writing "acceleration-time graph" instead of "a-t graph". They stated that they found the problems in both tests to be appropriate, accurate and understandable to the student level.

One of the pairs of problems presented in the form of graphic and text is as follows.



The V-t (velocity-time) graph of the car passing through the starting point at the moment of t=0 on a straight road is as follows on the side. According to the data in the graph, how far does the car stand at the end of the 660 secs to the starting point?

When driving on a straight road, someone notices that his car is going in the opposite direction as it passes by the stop with 60 m/s, and he stops by putting on the *brakes, slowing down properly within 90 s. He/she changes direction and accelerates properly, reaching a speed of 60 m/s within 90 s. After 300 seconds at a constant speed of 60 m/s, he realizes that he has passed the pharmacy and puts on the brake, slows down properly and stops within 60 seconds. It turns back and accelerates properly, reaching a speed of 40 m/s within 60 secs. At a constant speed of 40 m / s, he reaches the pharmacy in the 60s. According to this, how far is the distance between the pharmacy and the stop?*

At the end of the sample problems presented, three open-ended questions were included for students to explain their solution processes. In these questions, it was aimed to determine the way students follow in solving problems presented in the form of text or graphic, how presenting the problem in the form of text or graphics affects the problem solving process, and other opinions of students about the problem solving process. Before starting the research, five students' opinions were asked related to problems (in text and graphic form) and open-ended questions. Students expressed that they are clear and there is nothing incomprehensible.

Qualitative Data Collection Tool

The Likert-type high school level physics problem solving strategies scale (HSL-PPSS), adapted by Eryılmaz-Toksoy and Çalışkan (2015), was used to determine the strategies that students use to solve physics problems presented in text and graphical form. The Cronbach Alpha reliability coefficient of .885 scale consists of 25 items collected under four factors (understanding the problem, organizing the problem, gathering attenion, control, and evaluation) for original of scale. For this study the Cronbach Alpha reliability coefficient is calculated .833. Students were asked to indicate the strategies they used to solve problems presented in the form of text and graphics, marking the most appropriate option for items on the scale. Options for scale items are as follows: "Always", "Often", "Sometimes", "Rarely", "Never". It is scored as from 5 to 0 between the "Always" option and the "Never" option.

Data Collection Process

First of all, an ethics committee permit was obtained, indicating the ethical suitability of the research. Later, a research permit was obtained from the Ministry of Education. First, the data was tried to be collected face-to-face. Students were asked to fill out data collection tools offered in printed form in schools during exam weeks one week apart. But given the pandemic process and the number of students available, the data collection process continued online. The students were informed about the confidentiality of the data obtained from the research, and the data collection process was completed in an average of two months (March - April 2021) with the volunteer participants of the research.

Data collection was carried out in two stages. Primarily, students were asked to answer open-ended questions about the processes of solving problems presented in graphical form. Students were then asked to fill out the HSL-PPSS scale, taking into account the problems presented in graphical form. After the first stage, students were given a 10-day break so that they did not remember the questions and did not get bored. In the second stage, the same operations in the first stage were applied to solve the problems presented in the text. During the data collection process, 119 students were reached. But when the data obtained from the scale was examined, it was found that some students did not have answers for both scales, while some scales were not filled out in a valid way. The answers of 72 students (42 Science High School students, 30 Anatolian High School students) who filled the scales validly for two types of problems were included in the analysis.

Data Analysis

The responses of 72 students to the scale were analyzed through the SPSS 25 program. Data on scales completed by the same students were examined, and it was found that the data on all scales were distributed normally, but the data on their sub dimensions were not distributed normally. For this reason, the dependent t test was used in the analysis of the data for the entire scale, and the Wilcoxon marked rows test was used in the analysis of the data for its sub-dimensions.

All answers to open-ended questions were subject to content analysis. During the data analysis process, students were coded as S1, S2, S3 for given answers for in graphical and text form. The data was encoded by another researcher who is an expert in physics education and the opinion on the generated codes was taken. Incompatible code names were decided as a result of interviews. It was discussed that the obtained codes to be themed according to the dimensions contained in the HSL-PPSS scale. It was found that not all of the first level codes reached were in scale items. Therefore, in addition to the dimensions in the scale, the “solving” dimension was added. The obtained codes are presented under the titles of understanding the problem, organizing the problem, gathering attention, solving, controlling and evaluating the problem.

Ethical Procedures

Application made to Recep Tayyip Erdogan University Social and Human Sciences Ethics Committee was found ethically appropriate with the decision numbered 22, at the meeting held in 02.02.2021. Data were collected by paying attention to the pandemic conditions, and no risk was created regarding the health status of the participants.

Results

Strategies Used in Solving Problems Presented in Text and Graphical Form

Under this title, descriptive statistics about the answers to the HSL-PPSS scale and the results obtained from the students’ answers to open-ended questions about solving problems presented in graphic and text are presented.

Average and standard deviation values for strategies used by students to solve problems presented in the form of text and graphical according to the HSL-PPSS scale are presented in Table 1.

Table 1

Descriptive Statistics for Substances on the HSL-PPSS Scale

Item no	Statements	When presented in text form		When presented in graphical form	
		$\bar{X}$	*SD*	$\bar{X}$	*SD*
1	If there is a given shape for the problem, I associate the problem sentence with the shape.	4.33	.769	4.22	.826
2	I visualize the problem in my mind.	4.28	.791	4.10	.937
3	I write down what's given and what's wanted in the problem.	3.93	.954	3.58	1.135
4	I create physics formulas that will provide the solution to the problem.	3.71	.941	3.57	1.019
5	I think about the relation between what's given in the problem.	3.96	.911	3.99	.796
6	I think about which law or laws of physics the problem is related to.	3.74	1.151	3.57	1.220
7	I identify important concepts related to the problem.	3.82	.954	3.65	1.023
8	I write the data with its units instead of the formulas.	3.33	1.256	3.40	1.195
9	I can guess the solution to the problem.	3.61	1.056	3.76	.986
10	I create a solution with more than one.	2.83	1.289	2.85	1.083
11	If there is no given shape for the problem, I visualize the problem by drawing.	3.54	1.174	3.40	1.057
12	When solving the problem, I wonder whether I'm doing right.	3.96	1.067	4.10	.995
13	I check the units of what is given in the problem, what is requested, and the result I get.	3.63	1.093	3.67	1.075
14	I rewrite the problem in my own sentences.	2.36	1.248	2.46	1.352
15	I determine the properties of the quantities in the problem (such as, scalar-vector).	2.92	1.381	3.03	1.126
16	I divide the problem into its sub-problems.	2.58	1.219	2.72	1.165
17	I wonder whether my conclusion to the problem makes sense.	4.01	1.055	4.17	.805
18	I check the mathematical operation steps that I use solving the problem.	3.85	1.122	3.93	1.012
19	I wonder whether the formulas I use in the solution make sense.	3.96	1.027	4.22	.938
20	At the end of the problem, I assess whether there is information that I need to learn in more detail on the relevant topic.	3.61	1.015	3.57	1.185
21	When I can’t solve the problem, I think about the reasons.	3.85	1.002	3.71	1.067
22	At the end of the problem, I think about what information I'm using.	3.28	1.116	3.40	1.109
23	I assess whether I can fully solve the problem.	3.76	1.014	3.89	.912
24	I evaluate whether I can completely solve the problem.	3.78	1.010	3.79	1.020
25	When I can’t solve the problem, I think about my lack of knowledge.	3.72	.953	3.60	1.070

According to their average value seen in Table 1, students often use the following strategies when the problem is presented in text form:‘If there is a given shape for the problem, I associate the problem sentence with the shape.’ ($\bar{X}$=4.33; *SD*=.769), ‘I visualize the problem in my mind.’ ($\bar{X}$=4.28; *SD*=.791), ‘I wonder whether my conclusion to the problem makes sense.’($\bar{X}$=4.01; *SD*=1.055).And they use ‘I rewrite the problem in my own sentences.’ ($\bar{X}$=2.36; *SD*=1.248) strategy less often.

When the problem is presented in graphical form, they often use the following strategies:‘If there is a given shape for the problem, I associate the problem sentence with the shape.’ ($\bar{X}$=4.22; *SD*=8.26), ‘I wonder whether the formulas I use in the solution make sense.’ ($\bar{X}$=4.22, *SD*=.938), ‘I wonder whether my conclusion to the problem makes sense.’ ($\bar{X}$=4.17; *SD*=.805). And they use ‘I rewrite the problem in my own sentences.’ ($\bar{X}$=2.46; *SD*=1.352) strategy less often.

Descriptive statistics on the sub-dimensions of the HSL-PPSS scale, which reflect the stages of problem solving, are presented in Table 2.

Table 2

Descriptive Statistics on the Sub-Dimensions of the HSL-PPSS Scale

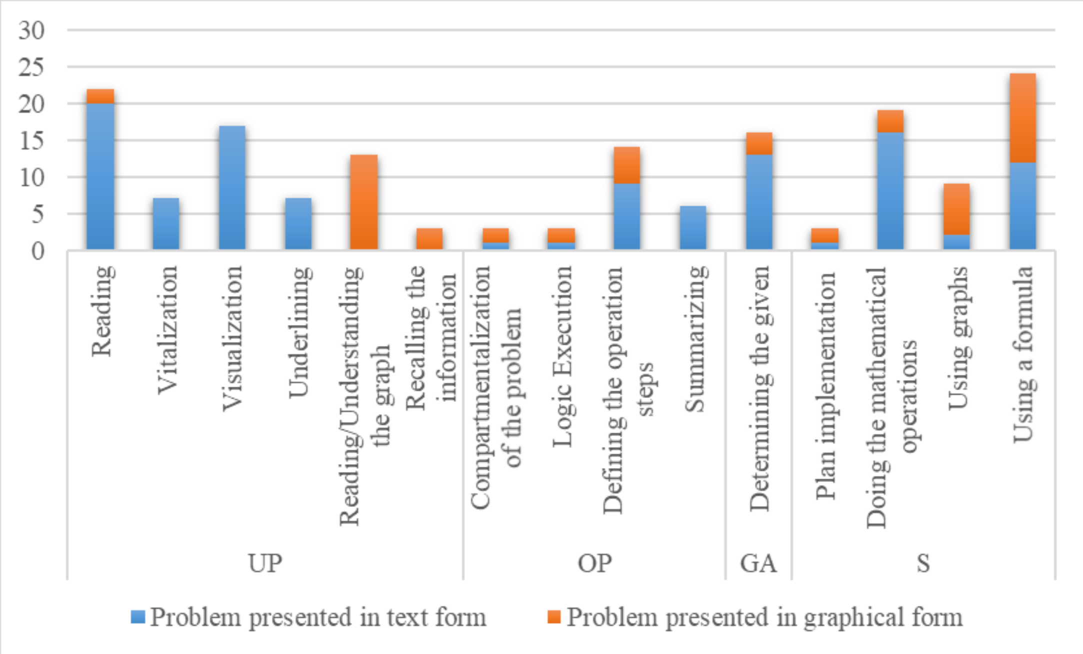
	Text form		Graphical form	
Dimensions	$\bar{X}$	*SD*	$\bar{X}$	*SD*
Understanding the problem	3.9246	.54410	3.8869	.56989
Organizing the problem	2.6736	1.00670	2.7639	.86388
Attention gathering	3.6833	.79275	3.5750	.69925
Checking and evaluating	3.7515	.74838	3.8009	.73866

According to the descriptive statistics seen in Table 2, students use respectively the following strategies below when the problem is presented in text and graphical form: understanding the problem ($\bar{X}$=3.9246; $\bar{X}$=3.8869), checking and evaluating ($\bar{X}$=3.7515; X=3.8009), gathering attention ($\bar{X}$=3.6833; $\bar{X}$=3.750), organizing the problem ($\bar{X}$=2.6736; $\bar{X}$=2.7639).

Frequencies related to the strategies that students stated that they use in the stages of understanding the problem (UP), organizing the problem (OP), gathering attention (GA) and solving it (S) when solving problems presented in the form of text and graphic are presented in Figure 1.

Figure 1

Change of Strategies Used in Solving Problems Presented in the Form of Text and Graphic According to Stages



As seen in figure 1, students stated that when the problem is presented in text, they use reading (20), visualization (17), animation (7) and underlining (7) strategies for understanding the problem. A student (S34) stated that he used the reading strategy with the sentence below: *"I try to understand what I read first. I read it over and over again."*. A student (S39) stated that he used the visualization strategy with the sentence below: *"I usually visualize the question. If it's easy, I visualize it in my head. If it's complicated, I draw it simple."*. Another student (S28) stated that he used the revitalization strategy with the sentence below: *"I try to understand what the text says. Then I start visualizing it."*. Another student (S50) stated that he used the underlining strategy with the sentence below: *"I start by highlighting things that can be overlooked."*.

Students stated that they used the strategies of reading/understanding the graph (13), information recall (3), and reading (2) when the problem was presented in graphic form. A student (S15) stated that he used the graph reading/understanding strategy with the sentence below: *"First I examined the graph. I thought about the features of the graph and what I had to do."*. Another student (S49) stated that he used the information recall strategy with the sentence below: *"I tried to recall the information I learned in class."*. Another student (S5) stated that he used the reading strategy with the sentence below: *"I read it again and again and try to understand."*.

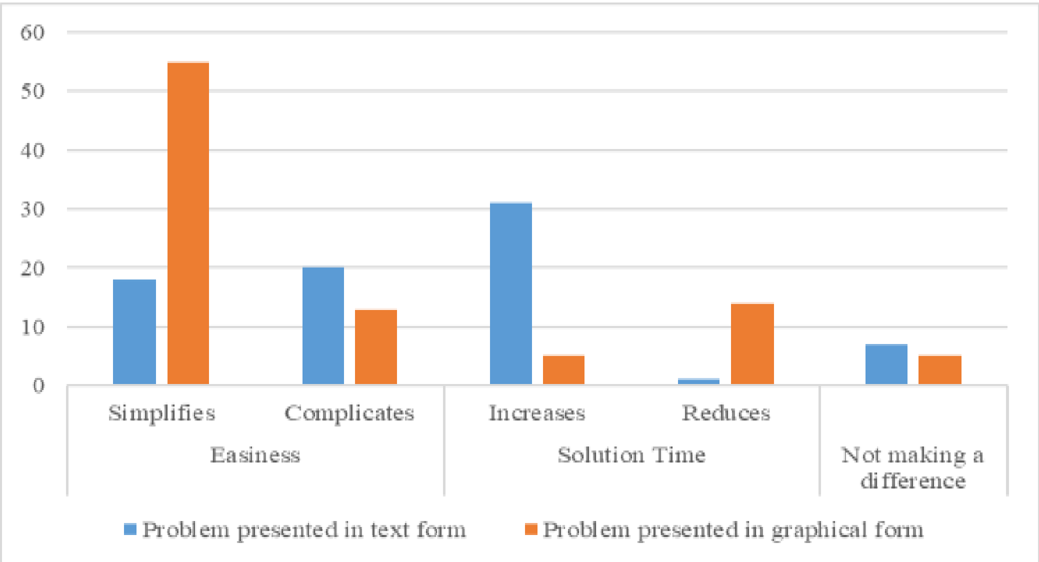
Students stated that when the problem is presented in text form, they use the strategies of defining the operation steps for the stage of organizing the problem (9), summarizing (6), logic execution(1) and compartmentalizing the problem (1). One of the students (S22) who uses the strategy of determining the operation steps stated the sentence below: *"... then I determine the order of operation"*. One of the students (S44) who uses summarizing strategy stated the sentence below: *"I don't get too stuck in sentences that storify the event, I get the numbers or details I need to get, and I write* *them in the corner of the paper.".* A student (S5) who uses logic execution strategy stated the sentence below: *"I reason, and then I solve it.".* A student (S60) who uses the strategy of compartmentalizing the problem stated the sentence below: *"I spare the text into step-by-step to-dos.".*

When the problem is presented in graphical form, students stated that they used strategies such as determining the operation steps (5), executing logic (2), and compartmentalizing the problem (2). One of the students (S15) who used the strategy of determining the steps of the operation said: *"First I examined the graph. I thought about the features of the graph and what I had to do. I determined the operations.".* One of the students (S2) who used the logic execution strategy said: *"I proceeded with the information in my mind, made reasoning, and interpreted the graph.".* One of the students (S8) who used the strategy of compartmentalizing the problem said: *"I compartmentalized the problem."*Students stated that they used determining strategy when the problem was presented in the form of text and graphical for the gathering attention phase. When the problem was presented in the form of text 13 students, and when the problem was presented in the form of graphical, three students stated that they used this strategy. Some of the students' statements are as follows: *"I write down the information provided." (S24 for solving problem in text form), "...then I write down the given values." (S43 for solving problem in text form), "I read the information in the text and write down what was given." (S47 for solving problem in graphical form).*

In the data about the strategies that students use to solve problems presented in text and graphics, there is no strategy for the control and evaluation stage. According to the students, the findings on how presenting the problem in text or graphics affects the solution processes are presented in Figure 2.

Figure 2

Effects of the Presentation Way of Problem on Solution Process



As can be seen in figüre 2, 20 students stated that presenting the problem in text form made the solution process complicated, while 18 students stated that it made it more simple. Students who think that it complicates the solution process stated that they find it complex that the problem situation is presented in text form. And they expressed their views with the following sentences: *"It can be confusing to present it in a storified text, rather than asking the question directly. (S24)", "The texts are confusing because they are longer. (S29)", "It's a little harder to analyze long texts. (S50)".* Some of the students who think it facilitates the solution process expressed their views as follows: *"It's actually a little easier because more information is given. (S14)", "It's good for me because the problem becomes more clear in my head. (S41)".*

31 students stated that presenting the problem in text form increased the time needed to solve it, and 1 student stated that it reduced it. Students expressed their opinion that presenting the problem in the form of text increases the time needed to understand the problem in the following sentences: *"It makes it difficult for me to understand the question and lengthens the time. (S58)", "It increases my solution process because to understand the text, I have to visualize it, at least in my head, imagine it, the fact that the problem is in the text requires me to do all these steps. (S73)".*

The student (S61), who thinks that it reduces the time needed for the solution, said*: "Because there is more information, it becomes difficult for me to read and understand, but the solution time becomes shorter."* 7 of the students stated in the following sentences that presenting the problem in the form of text does not make a difference in the solution process: *"It doesn't affect much. (S59)"*, *"They're thought to be more difficult, but it doesn't really matter (S3)".*

Most of the students (*f*=55) stated that presenting the problem in graphical form made the solution process easier, while 13 students stated that it made the solution process difficult. Students who think that presenting the problem in graphical form facilitates the solution process stated that graphs make it easier to understand in the following sentences: *"It allows us to see more clearly and create it in our head. (S6)", "It affects us to see the situation more clearly. (S30)"*, *"It is better. It is seen more clearly. It can be solved on paper. (S31)", "Seeing all the data in a graph, rather than being described in text, makes it easier in the solution process. (S73)".*

Students who think that presenting the problem in graphical form complicates the solution process stated that graphs make it easier to understand in the following sentences: *"Extra graph interpretation is added in the solution process. (S91)" , "I find it very difficult to solve problems in the form of graphics. (S46)".*

Some students (*f*=14) stated that presenting the problem in graphical form shortened the time required for the solution, while five students stated that it increased the time. Those who think it reduces the time said the following sentences: *"I think it works well because we can think like this, as a result of presenting a problem as a paragraph, we can reach a solution by graphing the elements in it, and giving it in graph form saves us time. .(S74)", "It allows us to solve it easier and faster. (S53)"* Those who think that it increases the time stated that understanding the graph requires effort in the following sentences: *"Graph questions take longer than normal ones because reading the graph wastes time. (S18)"*, *"I take more time because I have to interpret it first. (S76)"*. 5 of the students explained in the following sentences that presenting the problem in graphical form does not make a difference in the solution process: *"It is not very different from the solution process in non-graphic questions. (S80)"*, *"It doesn't affect the one who has a high level of chart information (S57)".*

Differentiation of PPSS according to the Presentation of the Problem

The result of the dependent t test to determine the differentiation state of the problem solving strategies that participants use according to the presentation of the problem is presented in Table 3.

Table 3

Analysis Results Regarding the Differentiation State of the Problem Solving Strategies Used According to the Presentation of the Problem

Presentation of the problem	*N*	$\bar{X}$	*SD*	*t*	*df*	*p*
Graphical	72	3.6139	.58685	.000	71	1.000
Text	72	3.6139	.62490			

As can be seen in Table 3, there is no significant difference between the problem solving strategies that students use to solve problems presented in the form of text and graphic ($t(71)=.000$, $p=1.000$).

The Wilcoxon signed-rank test results are presented in Table 4 to determine the state of differentiation of the use of strategies in the dimensions of the scales according to the presentation of the problem.

Table 4

Results of the Analysis on the Differentiation State of Scores Taken From the Dimensions of the HSL-PPSS Scale According to the Problem Presentation

Dimension	Sequence	*N*	Sequence average	Sequence sum	*z*	*p*
Understanding the problem	Negative Sequence	39	33.97	1325.00	-.270	.787
	Positive Sequence	32	38.47	1231.00		
	Equal	1				
Organizing the problem	Negative Sequence	36	32.85	1182.50	-.720	.421
	Positive Sequence	29	33.19	962.50		
	Equal	7				
Gathering Attention	Negative Sequence	36	37.44	1348.00	-.842	.400
	Positive Sequence	33	32.33	1067.00		
	Equal	3				
Checking and evaluating	Negative Sequence	37	32.88	1216.50	-.266	.790
	Positive Sequence	31	36.44	1129.50		
	Equal	4				

* *Based on Positive Sequences*

As can be seen from Table 4, there is no significant difference among the problem solving strategies used by students in the terms of understanding the problem z=-.270 (p>.005), organizing the problem z=-.720 (p>.005), gathering attention z=.-842 (p>.005), controlling and evaluating the problem z=-.266 (p>.005).

Discussion and Conclusion

In this research, which aims to examine the strategies that students use to solve problems presented in text and graphics, it was found that strategies aimed at understanding the problems were most often used (Table 2). Given the importance of understanding the problem in the process of solving the problem, this is an expected result. Mansyur (2015) determined through interviews what high school students and physics teachers do in the first stage of problem solving and how they successfully reach a solution. They determined that those who achieved successful solutions followed steps such as reading the problem, interpreting it, creating a diagram/visualizing it, and editing the equality/formula. They determined that they used the steps to determine what was given and what was wanted and organize the information to create the diagram. In this case, it can be said that understanding the problem covers most of the solution process.

At the stage of understanding the problem, it was found that students usually use strategies of animation, visualization, reading, underlining, reading/understanding the graph (Figure 1). These strategies correspond with the opinions of researchers who describe physics problem-solving strategies in the literature. These strategies are similar to the visualization and physical depiction of the problem in the Minnesota problem solving strategy (Heller et al., 1992), gathering information in the GOAL (gather, organize, analyze, learn) strategy (Beichner, 2002), "What's going on" in the WISE strategy (Wright & Williams, 1986); the stages of understanding the problem in the ANAPUK+KD strategy (Çalışkan, 2007).

According to the results obtained from the scale, one of the strategies that students most often use is understanding the problem (If there is a given shape for the problem, I associate the problem sentence with the shape.), and the others are related to controlling and evaluating the solution (When solving the problem, I wonder whether I'm doing right.) (Table 1). In the answers to open-ended questions, it is noteworthy that there is no expression related to checking and evaluating the solution, which is the last step of problem solving (Figure 1). This indicates that students do not consider the control and evaluation stage when explaining the process related to problem solving. Students may be taking this final stage out of the problem-solving process. In other words, they may see checking and evaluating as a process after problem solving. Or it may be an indication that they do not check their solutions, they do not evaluate the solution process. Researches in the literature have shown that students often have deficiencies in the use of control and evaluation strategies (Jua, 2018; Kelly et al., 2016). Another situation that is not mentioned in the explanations of the processes of solving students' problems is related to units. Students never made a statement about the units, but if the units are received incorrectly, the unit conversion is performed incorrectly the calculations will also be incorrect (Jua, 2018). The use of these strategies by students should be increased.

It was found that students often use the strategies of reading the problem, listing what is given, underlining, and visualizing it (Figure 1). Similarly, Çalışkan et al. (2006) determined that physics teachers candidates use “re-reading the problem” strategies while solving physics problems, Mansyur (2015) found that one of the strategies used by those who successfully solve physics problems is reading the problem. The problem reading strategy is done by each student but may not be expressed. It is important to determine what students pay attention to while reading the problem, and the factors that are effective in reading numbers. This situation can be examined in more detail in subsequent research. The findings that the visualization strategy is often used to list what is given when solving physics problems are also consistent with research in the literature (Çalışkan et al., 2006; Mansyur, 2015). Visualization is a strategy that makes drawing a diagram easier to solve by turning the problem into another form of presentation (Maries & Singh, 2018). Maries and Singh (2018) examined problem solutions in which a group of students presented diagram drawings, problem solutions that a group of students made by drawing the diagrams themselves, and problem solutions that a group of students made without interference. It was found that when solving the problems presented in the diagram, students skipped the stage of understanding the problem, made mistakes in the solution process because they moved directly to the stage of implementation, and were more unsuccessful than other groups. Arsal (2009) determined that those who used strategies for reading and understanding the problem and expressing the problem differently were more successful in solving the problem.

Findings from responses to the scale show that students generally use similar/problem-solving strategies when solving problems presented in the form of graphics and text (Table 3, 4). The results obtained from open-ended questions show that there are differences in some stages of problem solving according to the way the problem is presented. At the stage of understanding the problem, they use strategies of animation, visualization, underlining when the problem is presented in the form of text; when the problem is presented in the form of a graph, they use the strategies of reading/understanding the graph, remembering information. At the stage of organizing the problem, they use the strategy of summarizing important places in the solution of problems presented in the form of text, unlike the solution of problems presented in the form of graphs (Figure 1). This shows that, as De Cock (2012) states, students’ strategies depend on the presentation of the problem. Hung and Wu (2018) found that there were differences in the implementation and evaluation stages of the plan in their study in which they compared the solution of problems involving numbers and symbols. Different types of problems require different processes to be used in the solution (Kelly et al., 2016).

Some of the students stated that problem presentation in the form of text has effects such as facilitating and accelerating the solution process. Some students expressed the opposite. There were also different opinions that emerged regarding the presentation in the form of graphics (Figure 2). Similarly, Hung and Wu (2018) found that students had more difficulty solving problems involving symbols (such as m1, m2) in general than those containing numbers. Some students in the same study noted that symbols in symbolic problems help them remember formulas. Students stated that they are not accustomed to symbolic problems. This indicates the importance of previous schemas in problem solving. Those who recognize the type of problem apply the solution to the problem more easily (Shin et al., 2003). Özcan (2011) also found that most physics teacher candidates use an analogy approach to previously solved problems when solving problems related to special relativity. In this study, the problems presented in text form are longer than the problems that students often encounter. This can cause students to make more effort to understand the problem and have difficulty solving it.

Students who think that the process of solving problems presented in the form of graphs is more difficult see graphs as complex and require effort to understand them. The reason for this may be the students' lack of knowledge about graphics or lack of mathematical knowledge revealed by previous research. Eryılmaz-Toksoy (2020), in her study with 11th grade students, determined that students had deficiencies in their knowledge of which information to access and how to access this information from the graph. Sezen et al. (2012) determined that physics teacher candidates had low level of graphic reading, drawing and interpreting skills. Students are inadequate in interpreting the change in height or slope in the graph, in establishing relationships between different types of graphs that describe the same situation, and decisively in interpreting the area below the chart (Erceg & Aviani, 2014). Ivanjek et al. (2016) determined that graph interpretation strategies depend on the field and subject at the end of the study in which university students investigated physics, mathematics, and the interpretation of graphs in different contexts. In a study in which Planinic et al. (2013) presented students with questions about the slope of the graph and the area below the graph in mathematics, physics, and other contexts, they determined that the easiest substances for students were those related to mathematics that did not contain a context (physics or others). Ceuppens et al. (2019) at the conclusion of the study, in which they examined the solutions of physics and mathematical problems containing the same mathematical information, they determined that students were less successful in solving physics problems and that they had no difficulty in solving negative slope problems in mathematics. However, they had difficulty in solving negative speed problems in kinematics. Students have deficiencies in associating their mathematical knowledge with the concepts of physics (Handhika et al., 2019; Turşucu et al., 2020). As Erceg and Aviani (2014) noted, students have mathematical knowledge such as slope calculation, but they are inadequate in applying it to graphs in physics. Turşucu et al. (2020) found that reminding mathematical knowledge with cues increases the ability to solve physics problems in 10th grade students. Teachers can remind general information about graphics before problem solutions.

Mansyur (2015), in his study with physics teachers and their students working in 3 different schools, found that the teacher and the teaching process influence the steps that students follow when solving problems. The teacher stated that if he draws when he starts to solve problems, he asks his students to solve them in this way as well. The student also stated that he began the solution in the same way. When teachers teach students to solve traditional problems, they expect them to be able to apply this knowledge to other problems. In fact, this distracts them from the active learning process (Erceg & Aviani, 2014). Mansyur (2015) found that although they used the same strategies, there were those who failed to achieve a successful solution. This suggests that the problem-solving strategies that students use are not sufficient to reach a successful solution alone and that the order of strategies that they use in the process is also important. In subsequent research, the order of strategies used in solving problems presented differently can be determined. In this way, it can be revealed which stage of the problem solving process affects the way the problem is presented (understanding the problem, making plans, controlling, etc.).

Implications

More detailed data can be obtained by determining the strategies used by making clinical interviews with students while solving problems. However, this could not be fulfilled due to the pandemic conditions.

Conflicts of Interest

There no conflicts of interest in this study.

Author Bio

She is an assistant professor at the Department of Computer Education and Instructional Technology, Recep Tayyip Erdoğan University, Turkey. She completed her undergraduate education in physics teaching and her doctoral education in physics education at Karadeniz Technical University in Turkey. Her research interests include problem based learning, physics education, problem solving, science and technology.

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