An Investigation of Students' Performances in Solving Different Types of Problems

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Abstract

The purpose of this study was to analyze the performances of students in solving problems presented in different forms including equations, verbal equations, stories, and stories supported by diagrams in problem-solving. A descriptive survey model was employed in the study. The study group consisted of 14 fourth-grade students. Data were collected from the students by using four different types of worksheets (equation, verbal equation, story, and story + diagram). Each worksheet consisted of 10 similar problems that require the same mathematical operations but differ in presentation. To prevent the similarity in the problems by the students, the worksheets were applied to the students face-to-face by the classroom teachers during the course hours, at two-week intervals. The obtained data were analyzed through descriptive statistics. According to the findings of the study, the students solved the equation problems more accurately than the verbal and story problems. Furthermore, it was determined that students solved diagram-supported story problems more accurately than the other problem types.

Keywords: Problem-Solving, Problem Type, Equation Problems, Story Problems, Diagram Supported Problems

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INTRODUCTION

The effects of external representations on problem-solving and learning have been discussed by many researchers (Koedinger, Alibali, & Nathan, 2008). It was observed that when a problem was presented with different external representations, it caused different problem-solving performances (eg. The Tower of Hanoi problem). According to Logan and Ho (2013), students needed to understand the problem before starting to solve the problem. When students do not understand the problems, they have difficulty solving problems and they do not know how to represent the problem context. The use of diagrams to represent mathematical ideas is essential for elementary students to solve non-routine problems. Such operations allow students to create mental models (Pape, 2004) and organize their thoughts in connected and systematic ways (Ainsworth & Loizou, 2003). However, it is still a matter of debate how these representations or different problem presentations affect performance and learning. For example, it was observed in studies (Boonen, van Wesel, Jolles & van der Schoot, 2014) that the use of diagrams in problems increased the performance of upper-class and gifted students in problem-solving, while it did not affect the performance of younger age groups and low-talented students and even decreased their performance. However, Lowrie (2020) stated the opposite in his study. It was stated that adding diagrams to the problems also provided some variables (suitability of the diagram to the problem, student's skills, and prior knowledge, spatial chunking of information, familiarity, etc.) to increase the problem-solving performance (Koedinger, Alibali, & Nathan, 2008; Çilingir-Altıner, 2018). Current research on the effects of visual representations presents a complex picture (Cooper, Sydney, & Alibali, 2018). Some studies reported beneficial effects of visual representations (Hegarty & Kozhevnikov, 1999); while others reported harmful effects (Berends & van Lieshout, 2009), or others reported no effects (Dewolf et al., 2014) or mixed effects (Magner et al., 2014). When the studies were examined, it was seen that the visual representations had different effects on the abilities of the students in the younger age groups (Berends & van Lieshout, 2009; Booth & Koedinger, 2012; Özkubat, Karabulut & Akçayır, 2020). In addition, it was revealed that the performance of students who worked with diagrams even in science class was significantly better (Ainsworth & Loizou, 2003). Hembree (1992) revealed that students' success increased in problems presented with diagrams or figures. Despite all these dilemmas, NCTM (2000) advocated the use of diagrams in mathematics education. Because diagrams can support students' mathematical problem-solving performance by emphasizing relevant spatial information that was not easily accessible from the text or by making critical information more specific (Davenport et al., 2008). When diagrams were more interesting (eg, colouring), students would bring more information into the learning environment for active processing (Mayer, 1993). However, drawings containing no relevant mathematical information, such as a drawing of a person's face, may not support learning or problem-solving at all. So the type of diagrams was also important for problem-solving.

When other studies on problem types were examined, there were also studies, showing that students have more difficulty in verbal story problems than that in equation problems (Sloutsky, Kaminski, & Heckler, 2005). In these studies, it was stated that students should be directed to verbal story problems after gaining experience in equation problems. The inability to translate story problems into usable internal representations or to produce appropriate mathematical representations of the problem can hinder successful problem-solving. However, in some studies, it was stated that students should be directed to more abstract equation problems after gaining experience in story problems (Koedinger & Nathan, 2004). According to the researchers, there were no clues such as which operation to do and in what order due to the lack of words and syntax in equation problems.

The preferred strategy to enable students to learn in the elementary school period was to make a smooth transition to soft information by using concrete information. In addition to gaining concrete experience, students were provided gain experience with real-life examples (stories), so that they can use more abstract representations by using these connections and transfer their knowledge to different environments more easily. Foong and Koay (1997), in a study on the types of problems teachers use, stated that when determining mathematical problem types, teachers generally used word problems found in textbooks. The content of the textbooks taught in Turkey and the types of problems used are very important. Because teachers give priority to the use of sample problem types in textbooks. For this reason, the types of problems that teachers use constitute the types of problems that students will encounter more. In this direction, when the Ministry of National Education Mathematics Teaching Program (2018) was examined, one of the aims of the program was to establish a connection in mathematics teaching; It enabled students to make sense of mathematical ideas by realizing the relationships between concrete experiences, mathematical language, visual elements (diagram, schema, graph, number line, etc.) and mathematical symbols (0, 1, 2, +, =, etc.). In the program, it was emphasized that the relationship established between different mathematical ideas, concepts, and skills were very important in the development of students' conceptual understanding. In the first stage of the relationship-building process, students should be invited to make sense of what they were doing to solve mathematical problems. For these purposes, primary school books and lesson plans were arranged and primary school students received their education in this direction. It was also a matter of curiosity about what kind of problems primary school students solve better by using the newly adopted teaching approach. However, it was determined that studies on different types of problems were limited in the primary school period, where many efforts were made to increase problem-solving performance (Lowrie, 2020). To fill this gap, the problem-solving performances of students in solving problems such as equations, verbal equations, stories, and stories supported by diagrams in problem-solving were tried to be determined.

METHOD

The descriptive survey design was used in the research. Descriptive studies allow us to describe a given situation as precisely and carefully as possible (Büyüköztürk et al., 2011). It aimed to describe, compare, classify and analyze the parts that make up the event to reveal what it is (Cohen, Manion & Morrison, 2000).

Participants Research Design

In the 2020-2021 academic year, 14 students (9 girls and 5 boys) in two different classes, studying in the fourth grade, participated in the research. The application of research was carried out in a public elementary school located in the inner region of Turkey. The participants of the research were selected through easily accessible sampling. The reason for choosing this method was to apply face-to-face with students who come to school during the epidemic period. For this reason, students who came to the school and whose parent consent forms were obtained were included in the study.

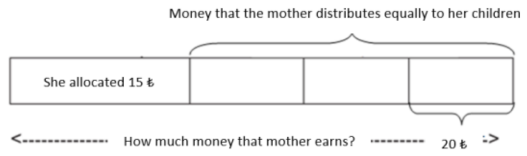
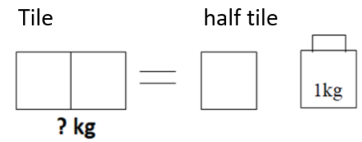
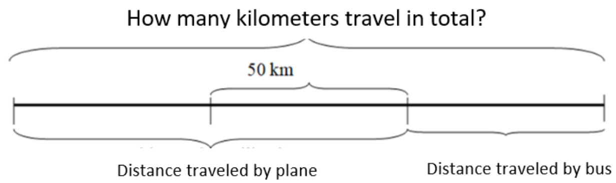
Before starting the study, the required permissions from the teacher and the school principal were obtained and the consent forms of the parents were collected from the parents. Data were collected in accordance with the necessary ethics.

Data Collection

Using the questions used by Booth and Koedinger (2012) and the Mathematical Operations Test of Suwarsono (1982) with visual solutions, worksheets belonging to 4 different problem types (equation, verbal equation, story, and story + diagram) were prepared. While preparing these worksheets and choosing the problems, compliance with the level of the students was taken into consideration. Expert opinions were obtained from 2 mathematics education specialists and 3 classroom teachers. The opinions collected from the teachers were evaluated with the Lawshe analysis. Content validity ratios (CVR) were determined by using the data obtained from the experts. The CVR values of these questions were 0.6 and above. Arrangements have been made regarding the questions and procedures that are required to be corrected. After these questions were corrected, the score was accepted as 1.

Each worksheet consisted of 10 similar questions that require the same mathematical operations but have a different presentation. For the students not to notice the similarity in these problems, the worksheets were applied to the students face-to-face by the classroom teachers during the course hours, with an interval of 2 weeks. Table 1 shows examples of different types of problems.

Table 1. Problem Types

Equation	Verbal Equation	Story	Story + Diagram
(□ -15) / 3 = 20 so □ = ?	If we subtract 10 from which number and divide by 4, the result is 10?	My aunt set aside 150 ₺ from her salary and distributed the rest equally to each of her 3 daughters. If each girl received 30 ₺, how much is my aunt's salary?	My mom won some money in the lottery. She allocated 15 ₺ to herself and distributed the remainder equally to each of her 3 sons. If each son received 20 ₺, how much did my mother earn? (You can use the image below to help you solve the problem.) 
□ x 2 = □ + 1 so □ = ?	Which number is equal to the sum of one half of itself?	There is 1kg weight and half a watermelon on one pan of the scale. In the other pan, there is a whole watermelon. If the scales are in balance, how many kilograms does a watermelon weigh?	There is 1kg weight and half tile on one pan of the scale. On the other side, there is a whole tile. If the scales are in balance, how many kilograms does a tile weigh? 
50 x 3 = ?	What is 4 times the number 60?	Ali completes part of his journey by plane and the rest by bus. The distance travelled by bus is half the distance travelled by plane. If the distance travelled by plane is 50 km longer than the distance travelled by bus, how many kilometres did Ali travel in total?	A tourist completes part of his trip by plane and the rest by bus. The distance travelled by bus is half the distance travelled by plane. If the distance travelled by plane is 50 km longer than the distance travelled by bus, how many kilometres did the tourist travel in total? 

Analysis Of Data

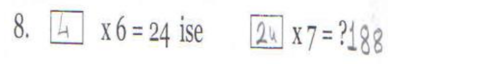
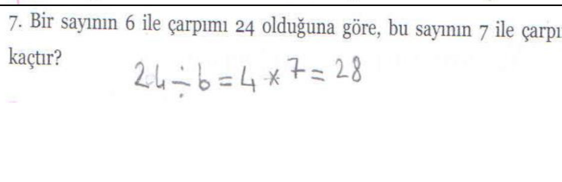
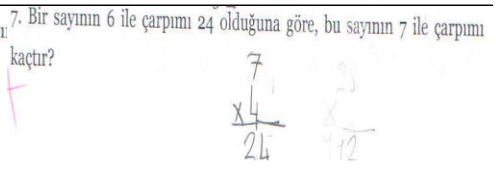
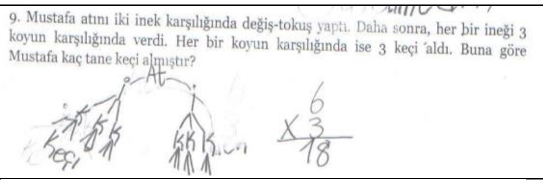
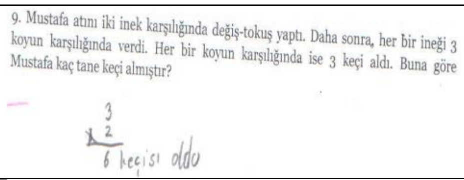
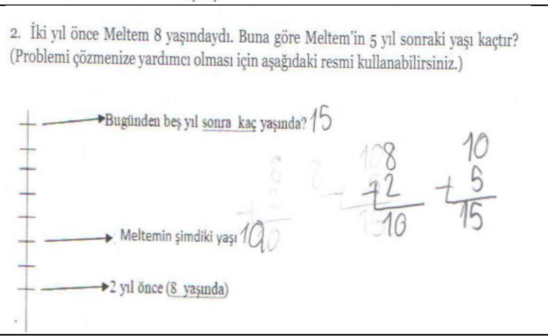
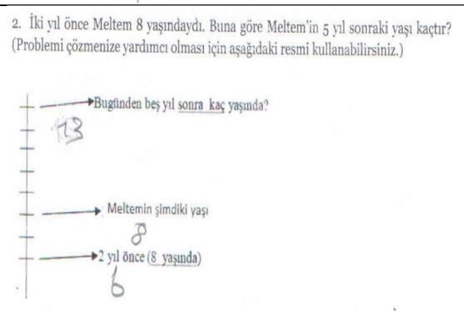
The data obtained were then analyzed using descriptive statistics. The following questions were examined: (1) How were the students' answers according to the types of problems? (2) Which type of problem has more truth? (3) Which types of problems were answered correctly when being asked?

Since the number of male and female students was not close to each other, the number of correct answers according to the problem types of male and female students was not considered.

FINDINGS/RESULTS

It was tried to determine the problem-solving performances of the students in the solution of the typical problems like equations, verbal equations, stories, and stories supported by diagrams, and first of all, the answers given by the students to different types of problems were examined. Table 2 lists examples of the answers given by the students.

Table 2. Correct and Incorrect Answers to Different Types of Problems

Problem Types	Correct Answer	Incorrect Answer
Equation		
Verbal Equation		
Story		
Story + Diagram		

When the correct and incorrect answers given by the students to different types of problems were examined in Table 2, it was thought that the reason for the wrong answer in the equation problem was due to the lack of explanation in the problem. In the verbal equation problem, the student both made a calculation error and could not engage the reasoning process. For example, a number multiplied by 6 is 24, and she/he cannot reason about whether this number will give the same result when multiplied by 7. It was noteworthy that the correct answer to the story problem was shown with a diagram. It was seen that the wrong answer was given incorrectly due to not fully understanding the question or not reading the question completely. In the story problem supported with a diagram, although the student used the diagram presented to her/him in the correct answer, it was observed that the student who answered incorrectly used the diagram incorrectly and put the numbers in the wrong place. Table 3 lists the scores that the students got from the worksheets in different problem types and also the number of correct answers.

Table 3. The Scores Students Obtained from Different Types of Worksheets

Student	Gender	Equation	Verbal Equation	Story	Story + Diagram
S1	Female	5	5	6	8
S2	Female	10	8	9	9
S3	Female	7	6	9	9
S4	Male	9	7	6	8
S5	Female	7	6	7	7
S6	Female	8	8	8	9
S7	Male	7	5	3	9
S8	Female	9	9	8	9
S9	Male	8	10	9	9
S10	Male	8	7	9	9
1	Female	3	7	8	9
S12	Female	6	8	8	8
S13	Female	9	10	8	9
S14	Male	8	2	0	3

When Table 3 was examined, it was seen that students obtained different scores according to different types of problems. While some students (for example, S14) got high scores (N=8) from equation problems, they had no correct answers to story problems. While S7 got high points (N=9) for story problems supported with diagrams, he got lower points (N=3) for story problems compared to other problem types. S5, S8, S12 got similar scores in almost all problem types (for example, student coded S8: Nequation = 9, Nverbal equation = 9, NStory = 8, NStory+diagram = 9). The number of correct answers given by the students to different types of each problem is given in Table 4.

Table 4. Correct Answers to Different Kinds of Problems

Problems	Equation	Verbal Equation	Story	Story + Diagram
1	12	10	11	14
2	14	13	13	13
3	14	13	11	13
4	12	8	5	14
5	8	3	4	9
6	9	10	12	13
7	12	13	12	9
8	4	6	6	6
9	5	9	12	12
10	14	13	12	12
Total	104	98	98	115

According to Table 4, it were 104 in the equation type, 98 in the verbal equation type, 98 in the story type, and 115 in the diagram-supported story type answered the question correctly. Students solved equation problems more accurately than that verbal and story problems. At the same time, it was seen that students solved diagram-supported story problems more accurately than other problem types.

DISCUSSION, CONCLUSION AND IMPLICATIONS

When the answers given by the students were examined, it was thought that the reason for giving the incorrect answer to the problem was that the student did not understand the problem in general. According to Logan and Ho (2013), students tended to assign arithmetic operations to embedded quantities while solving problems in an incomprehensible problems. This situation can be understood from the fact that the student should not use a number in the equation problem, but use the given all numbers or pieces of information, for the solution of the problem. Similarly, as a result of not fully understanding the verbal equation problem, it was seen that the students make conceptual errors as well as procedural errors. In the story problem, although the problem was based on the knowledge of concrete quantitative relations and what to do in the problem was explained in detail, it was thought that the student may have solved the problem incorrectly as she/he wanted to solve the problem quickly, read the problem quickly and take action immediately. As such, it can be said that the student did not understand the problem. Booth and Koedinger (2012) stated in their study that diagrams were useful additions to story problems for more successful students and that their use as a transition to abstract, symbolic representations can be constructive for these students. In their study, they examined the performances of 6th, 7th and 8th-grade students in diagram-supported story problems. They found that students with low math skills did not benefit from diagrams. As students' capacity increases, they can better coordinate the diagrams and information in the problem sentence and make more accurate decisions about where to focus on the problem. There are also studies, which indicate that success in diagram problems was associated with increased working memory capacity (Lee, Ng & Ng, 2009). It should be noted that a representation can only be useful to the extent that it was "understood" by the child (Dufour-Janvier, Bednarz & Belanger1987). The reason for the differences in the performance of the students in this study may be due to the fact that the students have different mathematical skills.

In the study, it was seen that equation problems using procedural information were solved more accurately than that the verbal equations and story problems using conceptual information. When the studies comparing the solutions of equation problems and story problems were examined, it was obvious that although middle school students (6, 7 and 8th grades) solve story problems better than equation problems (Booth & Koedinger, 2012), the opposite was true for university students (Koedinger, Alibali, & Nathan, 2008), university students solved equation problems more easily. This may be due to the fact that elementary school students' procedural knowledge skills develop earlier than conceptual knowledge. Students were more familiar with calculation. Reading comprehension in verbal problems was a skill that can be developed in the elementary school period (Akay, 2004). It was thought that students' performance in verbal equation problems will also increase with the interdisciplinary teachings related to reading comprehension and the diversity of problem types preferred by the teacher.

Another finding was that students were more successful in equation problems than in verbal equation problems. However, in some studies, on the contrary, it was stated that students who started elementary school were more successful in verbal problems rather than symbolic equation problems (Carpenter & Moser, 1984; De Corte & Verschaffel, 1981). Therefore, the result obtained was not supported by previous studies. It can be said that current mathematics education programs in elementary school affected the student's performance in problem-solving according to the types of problems.

In this study, fourth-grade students solved story problems by using diagrams more accurately. Thanks to diagrams, students were guided to visually distinguish the components of the problem rather than distinguishing them from words. This suggested that the problem can be solved more easily because it makes it more concrete. Unlike Booth and Koedinger's (2012) study, sixth grade students tended to solve more problems in the story type correctly, while seventh and eighth grade students solved more problems correctly when a diagram accompanied the story. They argued that factors such as mathematical skills, familiarity with problems, and experience are effective in this. However, by changing the understanding of the mathematics curriculum and textbooks in Turkey (see 2005 curriculum, 2015 curriculum and 2018 curriculum), including more visual elements in these materials and supporting the problems with visual elements have increased the familiarity, skills and experience of elementary school students with diagram-supported story problems. For this reason, it was ensured that the skill of using the diagram was reduced to the lower classes. Because the special aims of the Ministry of National Education Mathematics Curriculum (2018) include developing mathematical literacy skills, understanding mathematical concepts, using mathematical terminology correctly, expressing one's own and others' reasoning, developing metacognitive knowledge and skills, being able to use the skills of estimation and mental processing effectively, expressing concepts with different forms of representation, and making sense of the relationship between people and objects. This explains why and how elementary school students acquire the ability to use diagrams.

In this study, unlike other studies, both elementary school students were studied and in terms of the diversity of different problem types, some more extensive information was provided about the diagrammatic, symbolic, verbal and story problem types of the students. In addition, when previous studies were examined, it was seen that considering individual differences in ability and attitude was important for understanding the effects of different types of representations on problem-solving (Cooper, Sidney & Alibali, 2017). Future studies could benefit from further investigation of the effectiveness of these different types of problems in a larger sample. In addition, the fact that the study was only descriptive prevented generalizations from being made. It is considered important that future studies can generalize the results by using different analysis methods.

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