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Research Article

The Effect of Problem-Solving Strategies Education on Developing Mathematical Literacy*

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Abstract – One of the most significant areas of mathematics education today is how to improve students' mathematical literacy success and level. In this context, the study aimed to examine the effect of problem-solving strategies education on mathematical literacy. The study included 42 students in the eighth grade of secondary school, and the experimental design was preferred in quantitative research methods. Five-week problem-solving strategies education was conducted with 21 students in the experimental group. The study data were obtained with the mathematical literacy test (MLT), which was developed to determine the mathematical literacy achievement and levels of the experimental and control groups before and after education. As a result of the findings, it was determined that problem-solving strategies in education had a significant effect on students' mathematical literacy achievement. Concordantly, suggestions have been made regarding the need to use problem-solving strategies to improve mathematical literacy.

Key words: mathematical literacy, mathematics education, PISA, problem-solving, problem-solving strategies.

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Introduction

The Program for International Student Assessment [PISA], which is carried out every three years, was last carried out in 2018. Close to 3,5 million students from over 90 different

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countries have encountered reading, science, and mathematical literacy problems in PISA since 2000. More than 600,000 students participated in PISA 2018, representing nearly 32 million students aged 15 from 79 countries (Organisation for Economic Co-operation and Development [OECD], 2019). PISA focuses on how much of the knowledge and skills students can use in real life (Reinikainen, 2012; Stacey & Turner, 2015). In this context, the education given at school affects the success of countries in PISA.

If the education given at school is used in life outside school, it will be successful (Jacobs, 1989). One of the main aims of the curriculum should be to equip students with the knowledge, skills, and abilities to overcome real-life problems. According to some studies, however, the teaching contents are disconnected from real life (Mudaly, 2011; Syeda, 2015; Yıldırım, 1996; Yılmaz & Altınkurt, 2011). To overcome this problem, curricula should be related to real life (Altun & Akkya, 2014).

Understanding mathematics, which includes abstract structures, can also be achieved by associating it with real life. Learning mathematics "in addition to acquiring basic concepts and skills also includes thinking about mathematics, comprehending problem-solving strategies, and realizing that mathematics is an effective tool in real life" (Ministry of National Education [MoNE], 2013, p. 1). Among the school's main objectives, mathematics is raising individuals who can understand mathematical concepts, use them in real life, develop mathematical literacy skills, explain their thoughts in problem-solving, and explain the relationship between objects using the meaning and language of mathematics (MoNE, 2018). Considering this information, we face the need to plan training that will ensure the consolidation of connections. This will be done by focusing on the connection between school mathematics and real life in mathematics education. In order to meet this need, individuals require to gain skills such as making connections between thoughts, reasoning, estimation, and problem-solving as well as developing calculation skills (Colwell & Enderson, 2016). Because students need to encounter events that require using the knowledge they learned in the lessons and to provide opportunities to defend their suggestions by offering solutions to these events in terms of the use of mathematical knowledge in real life (Altun & Bozkurt, 2017).

Mathematical literacy (ML), which is seen as the level of use of mathematical knowledge in real-life, is an influential criterion for revealing the relationship between school mathematics and real-life situations. PISA, which offer a perspective on reading skills and science literacy as well as ML, are an application that evaluates to what extent 15-year-old students who are at the end or middle of compulsory schooling have acquired the knowledge and skills necessary for participation in modern society (OECD, 2016). PISA focuses not only on the evaluation of the knowledge that students have produced but also on how they can transfer what they have learned to new situations they may encounter inside and outside the school. In this context, PISA provides a way for the participating countries to review their education policies and practices. By keeping a mirror to the education systems of the countries, PISA reports have the opportunity to accurately describe the strengths and weaknesses of the current education systems of the countries, increase public awareness, evaluate education policies, curricula, and teacher competencies (Breakspear, 2012; Carvalho et al., 2017).

Türkiye took part in PISA, which was originally conducted in 2000, for the first time in 2003. It is seen that the scores at each basic area level are below the OECD average. In a way, this situation has opened Türkiye's education programs to discussion. Discussions took place not only in Turkey, but also in many countries such as Australia, Israel, South Africa and Finland. It can be said that the results of mathematics literacy within the framework of PISA are effective in the revision of the education programs of many countries (Breakspear, 2012). In this framework, the Ministry of National Education has accelerated its program development studies by determining the weaknesses in education in line with the PISA results and considering the results of international practices such as PISA in order to strengthen these aspects (Uyangör & Övez, 2012). In 2005, the mathematics curriculum in Turkey was changed and it was emphasized that the updated curriculum should teach mathematical concepts and expressions by relating them to real life and that students should gain skills such as problem-solving (Şefik & Dost, 2016). The effect of this change continued in the 2013 and 2018 curricula, and it was among the aims of real-life and ML curricula in mathematics curricula.

According to the PISA 2015 results, it is seen that Singapore ranks first in the field of ML (OECD, 2016) and ranks second according to the 2018 PISA results (OECD, 2019). When we examine Singapore's achievements in ML in other years, it ranked second similarly in PISA 2012 and 2009 applications. A look at the mathematics curricula for the secret of Singapore's success shows that, in 1992, the main goal of the Singapore mathematics program was mathematical problem-solving. In the curriculum, which was overhauled twice in 2001 and 2007, mathematical problem-solving remained the main purpose of the curriculum (Kaur & Yeap, 2009). Since the 1990s, mathematical problem-solving has been seen as the heart of the Singapore mathematics curriculum. It aims to develop student’s skills such as problem-solving and process skills based on problem-solving (Toh, 2021). In countries such as Hong Kong and the Netherlands, which are at the top level in PISA and TIMSS, it is seen that problem-solving is given a significant place in the mathematics curriculum (Anderson, 2009). Considering that problem-solving is at the core of the mathematics curriculum of countries that are at the top in ML, it is thought that there is a relationship between problem-solving and ML. In this context, it is thought that examining the effect of problem-solving strategy education aimed at increasing the level of ML will offer a solution to improve the ML levels of countries that cannot achieve the desired success in the field of ML.

ML is closely connected with many concepts discussed in mathematics education (Stacey, 2015). One of these concepts is problem-solving. Because ML is generally determined by the solution processes for the problems presented in the context (Stacey & Turner, 2015). ML is based on developing problem-solving skills rather than developing basic mathematical skills (Ülger, et al., 2020). Problem-solving is the primary goal of being mathematically literate (Pugalee, 1999). In this direction, planning which strategies will be used in the problems encountered, in other words, the effective use of problem-solving strategies can be seen as an significant criterion for success in ML. Because problem-solving strategies are also used in the processes of transferring the problems given in the context of real life to the mathematical world, obtaining results from the problems in the mathematical world using mathematics, and interpreting, evaluating, and applying the obtained results to real-life situations. Therefore, the development of ML can be achieved with problem-solving strategies.

When the literature on ML is examined, studies examining the causes of failure in ML (Altun & Akkaya, 2014; Güler, 2013), and studies comparing the ML achievement levels of countries (Dossey et al., 2008; Kılıç et al., 2012), examining the ML achievements studies (Breen et al., 2009; Lin & Tai, 2015; Sáenz, 2009; Yenilmez & Uysal, 2011) and studies examining situations such as self-efficacy, attitude, and motivation towards mathematical literacy (Dinçer et al., 2014; Hopfenbeck & Kjærnsli, 2016) are encountered. Most of the studies conducted within the framework of ML are aimed at determining ML's situation (Ülger et al., 2020).

Purpose and Importance of the Study

When data from PISA examinations is presented on countries' ML levels, it is clear that many countries have not attained the intended results. This situation brings with it many discussions about education, and it is thought that innovations that will increase the ML level of students should be included in the curriculum. Therefore, determining the arguments that will increase the level of ML will be significant in terms of the effectiveness of the mathematics education given to the students. Therefore, this study aimed to examine the effect of problem-solving strategy education on ML achievement.

Recently, studies on ML in mathematics education have risen remarkably and have become the focus of educational research (Altun & Bozkurt, 2017; Rizki & Priatna, 2019; Wedege, 2010). When the studies on ML are analysed, it is seen that the majority of the studies are limited to descriptive definitions to reveal the existing situation, and there are not enough studies to increase the success levels of ML or to produce solutions to problems (Ülger et al., 2020). It is thought that this study will contribute to the literature in terms of presenting a teaching method and solution proposal to increase ML levels.

The research problems and sub-problems of this study, which aimed to determine the effect of problem-solving strategies on ML, were determined as follows:

1. What is the effect of problem-solving strategy education on students' mathematical literacy achievement level?"

Sub-Problems of the Research

1.1. Is there a significant difference between the mathematical literacy pre-tests of the experimental group and the control group?

1.2. Is there a significant difference between the mathematical literacy post-tests of the experimental group and the control group?

1.3. Is there a significant difference between the mathematical literacy permanency tests of the experimental group and the control group?

Method

In this study, a part of the thesis, the main topic of which is the classification of problem-solving strategies according to process skills, is reported. In this direction, the data obtained from the mathematical literacy test (MLT) used in the quantitative dimension of the research are included.

In order to examine the effect of problem-solving strategies education on ML, the quantitative research method, which is considered the preferred approach to test a theory or approach, was adopted (Creswell, 2013). Quantitative research is based on a systematic and pre-planned pattern. Since it is not possible to randomly assign individuals to groups in most educational research, it is seen that it is extremely difficult to use the real experimental design in educational research (Cohen et al., 2005). Therefore, since students cannot be randomly assigned to groups, quasi-experimental design is generally used in educational research (Evrekli et al., 2011). In addition, it is suggested that researchers use the quasi-experimental method when the sample cannot be determined randomly (Marczyk et al., 2005). The quasi-experimental design was preferred because the study was educational research, the groups were determined from the classes where teaching was carried out, and it was not possible to randomly assign the students participating in the study to the groups. The following table presents the research design:

Table 1. The research design of the experimental dimension

Groups	Pre-Test Data Collection Tool	Implementation	Post-Test Data Collection Tool	Persistence-Test Data Collection Tool
Experimental Group	MLT	Problem-Solving Strategies Education	MLT	MLT
Control Group	MLT	X	MLT	MLT

Study Group

The study group consists of 42 eighth-grade secondary school students. The research was carried out with students at eighth-grade level, since problem-solving strategies developed throughout the upper grades and required high-level skills (Işık & Kar, 2011) and because eighth-grade students were more successful at problem-solving than in the lower grades. In addition, the participation of students from the eighth-grade level at the secondary school level in PISA can be seen as another reason why the study was conducted at the eighth-grade level.

The students in the study group were divided into two groups, each comprise of 21 students, and these groups were randomly assigned as the experimental and control groups. Information about the experimental and control groups is presented in Table 2:

Table 2. Descriptive of study groups

Groups	Total (f)	Gender			
		Female		Male	
		f	%	f	%
Experimental	21	11	52.4	10	47.6
Control	21	9	42.9	12	57.1

Data Collection Tool

The "Mathematics Literacy Test (MLT)" was used to determine the ML achievement levels of the participants. MLT consists of ML problems used to determine students' ML levels in PISA 2000, 2003, and 2012. During the development of MLT, ML problems that were opened to access after declassification in PISA applications were examined, and the problems were examined according to mathematical content (Quantity, Space and Shape, Change and

Relationships, Uncertainty and Data) and ML levels. MLT consisting of 24 problems was created, four at each level for six mathematical literacy levels defined by PISA and six ML problems for each content area.

Content validity, sometimes expressed as logical or rational validity, was examined in order to determine to what extent MLT represents the situation to be measured (Shuttleworth, 2009). Content validity is an indicator of whether the items in the measurement tool adequately represent the situation to be measured (Büyüköztürk, 2013). Content validity is obtained within the framework of expert opinions (McMillan & Schumacher, 2010). In this context, expert opinion was sought to demonstrate the content validity of MLT. Opinions of three field experts (1 Prof. Dr., 1 Assoc. Prof. Dr., and 1 Assistant Prof. Dr.) were taken to evaluate the suitability of the study for the 24 problems in MLT. In line with the expert opinions, it was decided that the problems in the MLT were suitable for the purpose of the study and for the eighth-grade level.

MLT was also analysed for reliability, which is seen as the stability and consistency of test scores (Johnson & Christensen, 2014), obtaining similar results by using the same criteria, and the measurement being free of random errors (Karasar, 2008). In order to determine the internal consistency coefficient of the MLT, KR-20 reliability was calculated in line with the data obtained from 108 eighth-grade students outside the study group (KR-20 α=.88). In addition, analysis of the test-retest reliability criteria for MLT was also performed (Pearson Correlation Coefficient = .94). In this respect, it can be said that MLT is a reliable and stable measurement tool. MLT was applied to the experimental and control groups as a pre-test before the application, and as a post-test and permanency test after the application.

Implementation Process

In order to reveal the effect of problem-solving strategies education on the level of ML, five-week problem-solving strategies education was conducted with the experimental group. Separate lesson plans were created for each strategy for problem-solving strategies education. The lesson plans, which were created by considering the four stages of George Polya's problem-solving process (Polya, 1973), are designed to be carried out within one lesson hour for the training of each strategy. The opinions of five experts (1 Prof. Dr., 2 Assoc. Prof. Dr., 1 Assistant Prof. Dr., and 1 Ph.D. Student) were consulted on the relevance and intelligibility of the instructions in the designed plans and the compatibility of the related problems with the strategy to be implemented. Corrections were made to the lesson plans in line with expert evaluations. Apart from the study group (Fraenkel & Wallen, 2006), a pilot study was conducted with 18 students before the main implementation, in order to observe the surprise developments that were overlooked during the implementation, and to be aware of the changes that may occur in the operation of the application, and to observe the steps of the application (Fraenkel & Wallen, 2006). In line with the data obtained as a result of the pilot study, the lesson plans prepared for each problem-solving strategy were finalized and put into practice.

Before the implementation phase, studies in the literature on problem-solving strategies were examined (Alibali et al., 2009; Altun & Arslan, 2006; Altun et al., 2007; Eisenmann et al., 2015; Ramnarain, 2014; Verschaffel et al., 1999; Yazgan, 2007; Yazgan & Bintaş, 2005). In most studies where problem-solving strategy education was given, it was seen that the training was carried out by dividing the students into groups of two or three. Based on such groupings in the studies on problem-solving strategies education and the results of Nahornick's (2014) study of the effect of group and individual activities on solving open-ended non-routine mathematical problems, the results of group activities are more effective. It was decided to divide the training into groups. The students in the study group were divided into groups of three, with high, medium, and low-level students in each group, classified as high, medium, and low level according to the Transition from Primary to Secondary Education Exam [TPSE] results. With the experimental group, the strategies of "Make a Systematic List", "Guess and check", "Draw a Diagram", "Look for a Pattern", "Use Variable", "Simplify the Problem", "Work Backwards", "Make a Table" and "Logical Reasoning" In line with the lesson plans consisting of four problems for each strategy, problem-solving strategies training was carried out for five weeks (10 lesson hours). An example of the lesson plans created for problem-solving strategy education is given in the appendix.

Determined by Yıkmış (1999) and used by Pilten (2008) in calculating the reliability of problem-solving strategies education; the formula for Application Reliability=Number of Behaviours Displayed/Number of Total Behaviours x100 was used. The mean reliability of problem-solving strategies education was calculated as 94.1.

Data Analysis

The data obtained from the MLT for answering the research problems were transferred to the Statistical Package for the Social Sciences (SPSS) program, and statistical analyses were carried out to determine the significant difference between the scores of the experimental and control groups from the pre-test, post-test, and permanency tests. In order to determine the significant difference between the ML pre-tests, post-tests, and permanency tests of the experimental group, which was given problem-solving strategies education, and the control group, where the traditional teaching method was applied, first of all, the normality of the data was examined. The reason for examining the normality of the data groups is to decide which of the parametric or non-parametric analysis methods will be applied for the analyses to be applied to detect the significant difference (Büyüköztürk, 2013, Can, 2014; Karasar, 2008). As a result of normality tests, the parametric analysis method was used for normally distributed data groups, and the non-parametric analysis method was used for data groups that did not show normal distribution.

The summary table regarding the analyses conducted to determine whether there is a significant difference between the pre-tests, post-tests, and permanency tests of the experimental and control groups in line with the data obtained from the MLT is presented in table 3:

Table 3. Data analysis table

	MLT	MLT Content Areas			
		Quantity	Space and Shape	Change and Relationships	Uncertainty and Data
Pre-Test	Independent Sample T-Test	Mann-Whitney U	Mann-Whitney U	Mann-Whitney U	Mann-Whitney U
Post-test	Independent Sample T-Test	Mann-Whitney U	Mann-Whitney U	Independent Sample T-Test	Mann-Whitney U
Permanency Test	Independent Sample T-Test	Mann-Whitney U	Independent Sample T-Test	Mann-Whitney U	Mann-Whitney U

Findings and Discussions

Findings related to the first sub-problem

Prior to problem-solving strategies education, MLT was used as a pre-test for both experimental and control groups. In this direction, the independent sample t-test, which is one of the parametric analysis methods, was used to determine whether there is a significant difference between the pre-test scores of the experimental and control groups. The findings of the t-test analysis are presented in table 4:

Table 4. T-test analysis results regarding MLT pre-tests of experimental and control groups

MLT Pre-test	N	M	SD	df	t	p
Experimental	21	9.76	4.49	40	.03	.97
Control	21	9.71	3.87			

p>.05

When the t-test analysis table is examined, it is seen that the significance value (p=.97) is greater than the significance level of .05. Therefore, it can be stated that there is no significant difference between the mathematics literacy scale pre-test scores of the experimental group students who were given problem-solving strategies education and the control group students to whom the traditional teaching method was applied ($t_{(40)}$=.03, p>.05). In line with this finding, it can be said that there is no significant difference between the ML levels of the experimental and control groups. In addition, the groups are equivalent in terms of ML levels. In addition, as seen in the t-test analysis results, it is clear that the MLT pre-test average of the experimental group students ($M_{Experimental}$=9.76) and the MLT pre-test average of the control group students ($M_{Control}$=9.71) are remarkably close to each other.

Mann-Whitney U test analysis, which is one of the non-parametric analysis methods, was used to determine whether there was a significant difference between the MLT pre-tests of the experimental and control groups in terms of content areas. The results of the Mann-Whitney U analysis are presented in table 5:

Table 5. Results of Mann-Whitney U tests in terms of content areas of problems according to MLT pre-tests of experimental and control groups

Content Areas	MLT Pre-Test	N	Mean of ranks	Sum of ranks	U	p
Quantity	Experiment	21	22.62	475.00	197.00	.54
	Control	21	20.38	428.00		
Space and Shape	Experiment	21	22.88	480.50	191.50	.45
	Control	21	20.12	422.50		
Change and Relationships	Experiment	21	20.86	438.00	207.00	.72
	Control	21	22.14	465.00		
Uncertainty and Data	Experiment	21	19.74	414.50	183.50	.34
	Control	21	23.26	488.50		

p>.05

When the Mann-Whitney U analysis results are examined, it can be said that there is no significant difference between the MLT pre-tests of the experimental and control groups in terms of each content area (p>.05).

The correct response rates of the experimental and control groups to the problems in MLT according to the content area are presented in table 6:

Table 6. Results for the correct answer rates of the experimental and control groups according to the content areas for the MLT pre-tests

MLT Pre-Test	Quantity	Space and Shape	Change and Relationships	Uncertainty and Data
Experimental	66%	35%	33%	37%
Control	64%	29%	36%	43%

According to the content areas of the MLT pre-test problems of the experimental and control groups, it is seen that the highest rate of correct answers in both the experimental and control groups is in the "Quantity" content area. The lowest correct answer rate in terms of content in the experimental group was in the "Change and Relationships" ($Experimental_{Change\ and\ Relationships}$=33%) and the "Space and Shape" ($Control_{Space\ and\ Shape}$=29%) content area in the control group.

Findings related to the second sub-problem

The MLT post-test was administered to the experimental and control groups after problem-solving strategies education. Within the framework of the data obtained, it was concluded that the data groups showed a normal distribution. In this direction, an independent sample t-test was used to determine whether there was a significant difference between the MLT post-test scores of the experimental group and the control group. The independent sample t-test is presented in table 7:

Table 7. T-test analysis results regarding MLT post-tests of experimental and control groups

MLT Post-Test	N	M	SD	df	t	p
Experimental	21	13.04	4.66	40	2.06	.04*
Control	21	10.14	4.46			

*p<.05

According to table 7, it was concluded that there was a significant difference between the MLT post-tests of the experimental group who received problem-solving strategies education and the control group who continued their normal education ($t_{(40)}$=2.06, p<.05). When the MLT post-test mean scores are examined, it is seen that the post-test mean scores of the experimental group ($M_{Experimental}$=13.04) are higher than the mean scores of the control group ($M_{Control}$=10.14) ($M_{Experimental} > M_{Control}$). In line with these findings, it can be said that there is a significant difference in favor of the experimental group between the ML achievement levels of the experimental group students who were given problem-solving strategy education and the control group students to whom the traditional teaching method was applied.

In the analysis of the significant difference in terms of the content area of the problems according to the MLT post-tests, it was concluded that the "Change and Relationships" content area data showed a normal distribution, while the data groups related to the other content areas did not show a normal distribution. Therefore, an independent sample t-test was used to determine the significant difference between the MLT post-tests of the experimental and control groups according to the "Change and Relationships" content area, and the Mann-Whitney U test analysis was used to determine the significant difference according to the other content areas. In this direction, the results of the t-test and Mann-Whitney U analysis are included.

Table 8. T-test results in terms of the content area of changes and relationships according to MLT post-tests of experiment and control groups

Content Area	MLT Post-test	N	M	SD	df	t	p
Change and Relationships	Experimental	21	3,19	1.32	40	2.29	.02*
	Control	21	2,28	1.23			

*p<.05

Table 9. Results of Mann-Whitney U tests in terms of content areas of ML problems according to MLT post-tests of experiment and control groups

Content Areas	MLT Post-Test	N	Mean of ranks	Sum of ranks	U	P
Quantity	Experimental	21	21.31	447.50	216.50	.91
	Control	21	21.69	455.50		
Space and Shape	Experimental	21	25.95	545.00	127.00	.01*
	Control	21	17.05	358.00		
Uncertainty and Data	Experimental	21	26.62	559.00	113.00	.00*
	Control	21	16.38	344.00		

*p<.05

When the findings are examined in table 8 and table 9, it is seen that the significance value is less than .05, which is the significance level, compared to the other content areas except for the "Quantity" content area (p<.05). Therefore, it was determined that there was no difference between the MLT post-tests of the experimental and control groups according to the "Quantity" content area. In the areas of “Change and Relationships”, “Space and Shape”, and “Uncertainty and Data” content, it was concluded that there was a statistically significant difference in favor of the experimental group between the MLT post-tests of the experimental and control groups.

Table 10. Results for the correct answer rates of the experimental and control groups according to the content areas for the MLT post-tests

MLT Post-Test	Quantity	Space and Shape	Change and Relationships	Uncertainty and Data
Experimental	73%	44%	53%	60%
Control	69%	29%	38%	40%

When the correct answer rates of the students in the MLT post-test according to the content area are examined, it is seen that the highest rate of correct answers for both the experimental and control groups, as in the pre-test, is in the problems related to the "Quantity" content area. According to the MLT post-tests, while the correct answer rate of the problems in terms of the "Quantity" content area was close to each other in the experimental and control groups, it was observed that there were significant differences in the other content areas.

Findings related to the third sub-problem

The permanency test of the MLT was applied to both experimental and control groups in order to determine whether the problem-solving strategies education conducted with the experimental group continued to have an effect after it had ended. MLT permanency tests were conducted six weeks after the post-tests were applied to the experimental and control groups. Independent sample t-test was used to determine whether there was a significant difference between the MLT permanency test scores of the experimental and control group students.

Table 11. T-test results in terms of the content area of changes and relationships according to MLT permanency-tests of experiment and control groups

MLT Permanency Test	N	M	SD	df	t	p
Experimental	21	13.00	4.64	40	2.05	.04*
Control	21	10.23	4.04			

*p<.05

In line with the results obtained in table 11, it is seen that there is a significant difference between the MLT permanency tests of the experimental and the control group ($t_{(40)}=2.05$, $p<0.05$). According to the MLT permanency test mean scores of the experimental and control groups, the mean score of the experimental group ($M_{Experimental}=13.00$) is higher than the mean score of the control group ($M_{Control}=10.23$) ($M_{Experimental} > M_{Control}$). Therefore, it can be said that there is a significant difference in favor of the experimental group between the ML levels of the experimental and the control group according to the permanency tests.

When we analysed the MLT permanency tests of the experimental and control groups in terms of content areas, it was seen that the data groups showed a normal distribution according to the "Space and Shape" content area, but the data groups did not show a normal distribution according to the other content areas. In this regard, independent sample t-tests were used for normally distributed data groups, while the Mann-Whitney U test was used for groups that did not show a normal distribution.

Table 12. Results of t-test in terms of space and shape content area of ML problems according to MLT permanency tests of experimental and control groups

Content Area	MLT Permanency - Test	N	M	SD	df	t	p
Space and Shape	Experimental	21	2.42	1.16	40	2.34	.02*
	Control	21	1.61	1.07			

*p<.05

Table 13. Results of Mann-Whitney U tests in terms of content areas of ML problems according to MLT permanency tests of experiment and control groups

Content Areas	MLT Post-Test	N	Mean of ranks	Sum of ranks	U	P
Quantity	Experimental	21	21.79	457.50	214.50	.87
	Control	21	21.21	445.50		
Change and Relationships	Experimental	21	24.29	510.00	162.00	.12
	Control	21	18.71	393.00		
Uncertainty and Data	Experimental	21	26.26	551.50	120.50	.00*
	Control	21	16.74	351.50		

*p<.05

According to table 12 and table 13, it is seen that while there is no significant difference in the content areas of "Space and Shape" and "Uncertainty and Data" (p>0.05), there is a significant difference in the content areas of "Quantity" and "Change and Relations" (*p<0.05).

Table 14. Results for the correct answer rates of the experimental and control groups according to the content areas for the MLT permanency tests

MLT Permanency Test	Quantity	Space and Shape	Change and Relations	Uncertainty and Data
Experimental	%72	%40	%50	%62
Control	%66	%27	%40	%45

When we examined table 14, it was concluded that the content area with the highest correct answer rate in both the experimental and control groups was "Quantity", and the least correct response rate was in the "Space and Shape" content area.

Discussion and Conclusions

It is seen that efforts to make students realize the importance of mathematics in real life are increasing around the world (Bolstad, 2021). In this context, one of the main purposes of the education given at school should be to enable students to realize mathematics in real life and to use the knowledge and skills they learned at school for the solution of real-life problems. Mathematical literacy, which can be defined as the transfer of mathematical knowledge and skills to real life and the mathematical interpretation of real-life situations, is significant in solving real-life problems (Kabael & Ata Baran, 2019). When the studies conducted within the framework of mathematical literacy are examined, it is stated that these studies are generally aimed at determining the situation and there are not enough studies on how to increase the success of mathematical literacy (Ülger et al, 2020). Based on this situation, the aim of this study was to see if problem-solving strategies education had a significant influence on mathematical literacy achievement. Participants in the experimental group received problem-solving strategies training, and the mathematical literacy levels of the experimental and control groups were assessed before and after the training.

According to the MLT pre-tests, when the correct response rates of the problems in terms of the content area were examined, it was concluded that the area with the highest correct response rate in both the experimental and control groups was "Quantity". While the content area with the highest success rate in PISA 2003, 2006, and 2009 is uncertainty (İlbağı, 2012), it is seen that the content area with the highest success rate in PISA 2012 is “Quantity” (Anıl et al., 2015). While this finding of the study differs according to PISA 2003, 2006, and 2009, it is parallel to PISA 2012. It was concluded that the content area with the lowest correct answer rate was "Space and Shape". This finding of the study is similar to the PISA 2003, 2006, 2009, and 2012, and it is seen that it overlaps with Köse's (2012) findings. As in the general PISA exams, in terms of Türkiye, the subject area where students fail the most is “Space and Shape”. Similarly, it is stated that the most unsuccessful field in TIMSS exams is geometry. (Fidan & Türnüklü, 2010). The reason for the low success in the "Space and Shape" content area, which brings the field of geometry to mind (Altun, 2014), may be due to the fact that geometry, which is identified with nature and daily life, cannot be thought of in real life (Delice & Sevimli, 2010). In addition, the abstract perception of geometry in general causes students to move away from geometry (Baki & Özpınar, 2007) and reduces the success of these students in the "Space and Shape" content area. This situation can be shown as another reason for the low success of students in the "Space and Shape" content area.

Based on the results gained from the MLT post-tests of the experimental and control groups, it is thought that problem-solving strategies education has an important effect on improving students' ML success level. Because problem-solving activities improve students' questioning and thinking skills (Novita et al., 2012), problem-based instruction will increase students' ML success levels (Wardono, et al., 2016). In this direction, it was concluded that the problems used in the problem-solving strategies education increased the ML levels of the students. It can be said that this finding of the study supports the findings of Wardono et al. (2016). In addition, the findings obtained from the study differ from the finding that Muyo's (2015) activity-based mathematics education program did not experience a significant change in terms of ML. The effect of the problem-solving strategy education revealed in the study on the level of ML achievement is thought to be a guide for how countries can improve students' ML skills. In this context, it can be said that the results of this study are a guide for future studies within the framework of the idea (Ülger et al., 2020) that studies should be carried out to increase ML achievement levels or to produce solutions to problems in studies carried out within the framework of ML.

In terms of the content area of the experimental and control groups, it was seen that the most significant difference between the two groups in the MLT post-tests was in the content area of "Uncertainty and Data". Based on this finding, it is thought that the problem-solving strategies education carried out with the experimental group has an important effect on solving the problems related to the "Uncertainty and Data" content area. When the scores of the countries that are at the top of PISA 2012 are examined in terms of content, it is seen that they have achieved quite high scores in the content area of "Uncertainty and Data" (OECD, 2014). This situation is also expressed in the studies of Wheater et al. (2014). In addition, it is striking that the Netherlands, Vietnam, and Australia, which achieved significant success in ML, achieved high scores in the "Uncertainty and Data" content area. In this context, it is thought that the applications and training for the "Uncertainty and Data" problems within the framework of mathematical literacy will contribute significantly to the success of the countries.

As a result of the analysis of the MLT permanency tests, it was concluded that there was a significant difference in favor of the experimental group between the MLT permanency tests of the experimental and the control groups. This is an indication that education on problem-solving strategies has a permanent effect. It is thought that the permanent effect of problem-solving strategies education also affects the level of ML achievement. ML is associated with students' capacity to solve problems, reason, and produce effective solutions in different situations in daily life (Özgen & Bindak, 2008). In this context, it can be said that problem-solving strategies have an undeniable effect on creating solutions to ML problems. The findings obtained from the MLT pre-test, post-test, and permanency tests support these thoughts.

Therefore, we can infer that problem-solving strategies education accounts for the significant difference between the experimental and control groups in terms of ML. Because problems are at the centre of mathematics education and teaching in the realization of mental activities in the classroom (Lampert, 2001). Teaching problem-solving strategies contributes to the development of non-routine problem-solving skills (Altun & Arslan, 2006; Altun & Memnun, 2008; Artut & Tarım, 2006; Çelebioğlu & Yazgan, 2009; Elia et al., 2009). Considering that ML problems can also be viewed as non-routine problems (Altun, 2014), it is a significant finding of this study that problem-solving strategies education increases students' ML success levels. In this context, training can be carried out by making use of problem-solving strategies to improve students' ML skills and levels.

Limitations and Suggestions

In this study, nine problem-solving strategies were studied, and the effect of these strategies on ML was examined. In future studies, studies on the effects of different problem-solving strategies other than the nine strategies on ML can be conducted, and studies on which strategy contributes more to ML can be put forward.

In the study, problem-solving strategies education was limited to eighth-grade students. The effect of problem-solving strategies education on the level of ML can be determined by conducting training at different grade levels, with larger samples and longer durations. The fact that the participant group consisted of eighth-grade students and that these students were preparing for high school entrance exams did not us allow to support the findings obtained through observations and interviews with the students. In the study, the determination of the effect on ML was limited to MLT. In future studies, to reveal the effect of problem-solving strategies education in more detail, interviews and observations with students can be carried out and a holistic result can be revealed by supporting the quantitative findings with qualitative analyses.

No study in the literature examines the effect of problem-solving strategies education on students' ML success. In this respect, the findings of the research are seen as significant in terms of revealing the effect of problem-solving strategies on ML. In this direction, it is thought that studies examining the effect of problem-solving strategies on ML should be increased. It has been concluded that problem-solving strategies have a permanent effect on achievements in areas such as "Space and Shape" and "Uncertainty and Data", which are expressed within the framework of ML. Research can be conducted to determine the causes of the permanent effect in these areas and the permanent effects in the other two areas.

In this study, problem-solving strategies education was carried out with group studies, and it is thought that group studies have a significant effect on problem-solving strategies education. In this context, the effect of individual problem-solving strategy education on students' ML success can also be examined. In addition, considering the effect of group work, program developers can design programs and develop activities suitable for group work.

Matematik Okuryazarlığını Geliştirmede Problem Çözme Stratejileri Eğitiminin Etkisi

Özet:

Günümüzde matematik eğitiminin en önemli uğraşı alanlarının başında öğrencilerin matematik okuryazarlık başarı ve düzeyinin nasıl arttırılacağı gelmektedir. Bu bağlamda gerçekleştirilen çalışmada problem çözme strateji eğitiminin matematik okuryazarlığına etkisinin incelenmesi amaçlanmıştır. Araştırmaya ortaokul sekizinci sınıfta öğrenim gören 42 öğrenci katılmış ve nicel araştırma yöntemlerinden deneysel desen tercih edilmiştir. Deney grubunda bulunan 21 öğrenci ile beş haftalık problem çözme stratejileri eğitimi gerçekleştirilmiştir. Çalışmanın verileri, eğitim öncesi ve sonrasında deney ve kontrol grubunun matematik okuryazarlık başarı ve düzeylerini belirlemek amacıyla geliştirilen matematik okuryazarlık testi (MOT) ile elde edilmiştir. Elde edilen bulgular sonucunda, problem çözme stratejileri eğitiminin öğrencilerin matematik okuryazarlık başarı düzeylerine anlamlı bir etkisinin olduğu belirlenmiştir. Bu bağlamda matematik okuryazarlığını geliştirmede problem çözme stratejilerinden faydalanılması gerektiğine yönelik önerilerde bulunulmuştur.

Anahtar kelimeler: matematik okuryazarlığı, matematik eğitimi, PISA, problem çözme, problem çözme stratejileri

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Appendix

Lesson plan : Lesson 1
Subject : Make a Systematic List Strategy
Duration : 40 min
Group : 3-4 student
Tools : Paper, pencil, Worksheets, Projector
Behaviours : 1- Understanding the Problem
2- Ability to Think About the Problem
3- Exploring the Make a Systematic List Strategy
4- Implementing the Make a Systematic List Strategy
5- Naming Problems Related to the Make a Systematic List Strategy

	Learning Activities	**Behaviours Expected from Students**	**Guiding Behaviours**
Understand the problem	If two coins are tossed at the same time, what is the number of possible pairs?	Determining what is given and desired within groups	Students are given 5 minutes to discuss the problem. What is given in the problem? What is required? How are the front and back of a coin named?
Devise a plan	First coin: Heads Second coin: Heads or Tails First coin: Text Second coin: Heads or tails HH, HT, TH, TT	Students are expected to argue among themselves for a solution. Students are expected to decide to make a systematic list as a result of their discussion.	What can be the values of the first coin tossed on the upper surface? What can be the values on the upper surface of the second coin?
Carry out the plan		The determining strategy is implemented. Students are expected to write down what values the second coin can get when the first coin systematically comes "heads". When the first coin comes "Tails", they are expected to write down what values the second coin can take.	Meanwhile, the teacher goes around the groups and checks the students' practices.
Look back	Four pairs	Students are expected to discuss their results among themselves and evaluate the result.	Groups are asked to describe their results on the board.

	Learning Activities	**Behaviours Expected from Students**	**Guiding Behaviours**
Understand the problem	Below is a restaurant's menu. <u>Pre Meals</u>: Tomato soup; Stuffed with Olive Oil <u>Main Meals</u>: Steak; Meaty Chickpeas; Mushroom Sauteed	Determining what is given and desired within groups	What is given and what is required in the problem? How many of the pre-meal and main meals should be chosen? Can more than one be chosen from the pre-meal?

	How many different ways can you eat with this menu, provided that you choose one each from the pre-course and main course sections?		Can more than one be chosen from the main meal?
Devise a plan	Pre-Meal Tomato soup Main Meal Steak Meaty Chickpeas Mushroom Sauteed	Students are expected to argue among themselves for a solution. Students are expected to decide to make a systematic list as a result of their discussion.	What can be chosen as a pre-meal? What can be chosen as the main meal?
Carry out the plan	Three situations Pre-meal: Stuffed with Olive Oil Main Meal Steak Meaty Chickpeas Mushroom Sauteed Three situations	Students are expected to write down the pre-meal and main meals systematically.	Meanwhile, the teacher goes around the groups and checks the students' practices. For struggling groups, what can be the main course when pre-meal tomato soup is chosen? What can be the main course when the pre-meal is "stuffed with olive oil"? leading questions can be asked.
Look back	Six different situations	Students are expected to discuss their results among themselves and evaluate the result.	Group spokespersons are invited to the board and asked to share the solutions they found. Ask students if they have different ideas.

	Learning Activities	**Behaviours Expected from Students**	**Guiding Behaviours**
Understand the problem	How many different two-digit numbers with different numerical values can be written using the numbers 2, 5, and 8?	Writing down what is given and what is wanted, The numbers 2, 5, and 8 are given. A two-digit number is required.	
Devise a plan	numbers starting with 2: 25, 28	Making a systematic list	It is asked whether there are similarities with other solved questions.
Carry out the plan	numbers starting with 5: 52, 58 numbers starting with 8: 82, 85	The smallest number that can be written is 25, The largest number is 85. All possible cases should be listed. Two-digit numbers starting with 2, 5, and 8 are determined.	The teacher checks the students by walking around the groups and poses guiding questions to the groups that cannot find the solution.
Look back	6 different numbers	The question is reviewed within the group. It is debatable why numbers such as 22, 55, and 88 are not written.	It is emphasized that the critical point in such problems is to determine where to start the sequence and to act systematically. It may be asked why 22 was not written.

	Learning Activities	Behaviours Expected from Students	Guiding Behaviours
Understand the problem	How many kinds of 25 liras can you get with the 1, 5, 10 liras you have?	There are 1, 5, and 10 liras. It is requested to obtain 25 liras. By using 1, 5, and 10 liras, 25 liras will be obtained.	What are the givens? What is desired?
Devise a plan	25 = 10 + 10 + 5 10 + 10 + 1 + 1 + 1 + 1 +1 10 + 5 + 5 + 1 + 1 + 1 + 1 +1 10 + 5 + 1 + 1 + 1 + 1 +1 + 1 + 1 + 1 + 1 +1 10 + 1 + 1 + 1 + 1 +1 + 1 + 1 + 1 + 1 +1 + 1 + 1 + 1 +1+ 1 10 + 5 + 5 + 5 5 + 5 + 5 + 5 + 5 5 + 5 + 5 + 5 + 1 + 1 + 1 + 1 +1 5 + 5 + 5 + 1 + 1 + 1 + 1 +1+ 1 + 1 + 1 + 1 +1 5 + 5 + 1 + 1 + 1 + 1 +1+ 1 + 1 + 1 + 1 +1+ 1+ 1+ 1 + 1 +1 5 + 1 + 1 + 1 + 1 +1+ 1 + 1 + 1 + 1 +1+ 1 + 1 + 1 + 1 +1 + 1 + 1 + 1 + 1 +1 1 + 1 + 1 + 1 +1+ 1 + 1 + 1 + 1 +1+ 1 + 1 + 1 + 1 +1 + 1 + 1 + 1 + 1 +1+ 1 + 1 + 1 + 1 +1	A list must be made. In the list to be made, the use of 1, 5, and 10 liras should be determined systematically. Making a Systematic List	Have you encountered such problems before?
Carry out the plan		Using 10, 5, and 1 lira, the production of 25 liras is written systematically. The cases where the 10 liras are used twice and the cases where they are used once are written. The cases where 5 liras are used 5 times, 4 times, 3 times, 2 times and 1 time are written. The situation in which 25 liras is obtained by using only 1 lira is determined.	The teacher checks the students by walking around the groups and poses guiding questions to the groups that cannot find the solution.
Look back	12 Situation	In such a case, the most important point is to determine where to start the ranking.	The lists created by the groups are written on the board. The list of each group is examined separately, and it is questioned how they created this list. The groups that make up the list are asked to explain according to which system they created the list. At the end of the lesson, the groups are asked to name the strategy used to solve the problems, and the strategy used throughout the lesson is named in line with the common decision of the class.