

# **The effect of metacognitive strategy training on mathematical problem solving achievement**

**Gökhan ÖZSOY<sup>a</sup>**

*Aksaray University, Aksaray, Turkey*

**Ayşegül ATAMAN**

*Gazi University, Ankara, Turkey*

## **ABSTRACT**

*The purpose of this study was to investigate the effect of using metacognitive strategy training on mathematical problem solving achievement. The study took place over a nine-week period with 47 fifth grade students. The experimental group (n = 24) instructed to improve their metacognitive skills. At the same time the students in the control group (n = 23) received no additional activities and continued their normal lessons. Students were pre- and post-tested with the Mathematical Problem Solving Achievement Test and Turkish version of Metacognitive Skills and Knowledge Assessment (MSA-TR). The results indicated that students in the metacognitive treatment group significantly improved in both mathematical problem solving achievement and metacognitive skills.*

**Keywords:** *Metacognition, metacognitive strategy training, metacognitive skills, problem solving, problem solving achievement.*

## **Introduction**

Whatever its source is, a real-life problem or a scientific one, a problem is a phenomenon requiring an individual to choose a strategy and make a decision for a solution in any encountered situation (Van De Walle, 1989). Since 1980s, many instructional programs regarding the mathematics have been reformulated as being problem solving oriented (NCTM, 1989). Mathematical problem solving is generally discussed together with heuristics designed by Polya (1988). However, another equally effective element, key to success in problem solving, is metacognition (Lester, 1994).

---

<sup>a</sup> Corresponding author. E-mail: gokhan.ozsoy@aksaray.edu.tr

Research on problem solving shows that it is not sufficient to learn procedures and problem solving heuristics (cognitive content) such as defining the problem, planning, carrying out a plan, testing and checking a solution (Lester, 1994). It is not enough to know what to do, but also when to apply such strategies (McLoughlin & Hollingworth, 2001). An effective use of cognitive content is possible only through metacognitive skills.

Metacognition means an individual's awareness of his own thinking processes and his ability to control these processes (Flavell, 1979; 1999; Huit, 1997; Hacker & Dunlosky, 2003; Jager, Jensen & Reezigt, 2005). It is observed that modern studies discuss the metacognition under two main headings: Metacognitive knowledge and metacognitive control (Flavell, 1979, 1999; Nelson & Narens, 1990; Otani & Widner, 2005; Sungur, 2007). Metacognitive knowledge, in one case, refers to one's knowledge and beliefs in his mental resources and his awareness about what to do. It also mathematically refers to the mathematical processes and techniques students have and their ideas about the nature of mathematics. Metacognitive knowledge means one's own cognitive skills; own cognitive strategies and knowledge about what to do under which circumstances (Flavell, 1979). Metacognitive knowledge requires one to accurately and exactly define his/her thought or knowledge. An individual's ability in problem solving depends on effective use of his/her knowledge. If an individual does not have a decent perception about his/her knowledge, he/she can consider, for example, being a successful student in problem solving as a hard work. In other words, approaches to the problem and insights into how to solve a problem is related to how accurately an individual assesses his/her knowledge (Flavell & Wellman, 1977). However, metacognition requires one, besides the knowledge mentioned above, to use this knowledge effectively. The ability to use metacognitive knowledge, on the other hand, is called metacognitive control (Özsoy, 2007). Also called metacognitive strategy, the metacognitive control skills consists of leading mental operations in metacognitive processes and can be defined as the ability to use the metacognitive knowledge strategically in order to attain cognitive objectives (Desoete, 2008; Schraw & Moshman, 1995). The literature focuses on four metacognitive skills; prediction, planning, monitoring and evaluation (Brown, 1980, Desoete, Roeyers & Buyse, 2001; Desoete & Roeyers, 2002; Lucangeli & Cornoldi, 1997).

Metacognitive control/regulation is considered as the ability to use knowledge to regulate and control cognitive processes. Metacognitive control is related with metacognitive activities that help to control one's thinking or learning (Özsoy, 2008). Students having the prediction skill think about the learning objectives, proper learning characteristics, and the available time. Prediction skill enables students to predict the difficulty of a task, by this way they use that prediction to regulate their engagement related to outcome. The selection of appropriate strategies and allocation of resources closely related with the prediction skill (Desoete, 2008). Monitoring refers to one's on-line awareness of comprehension and task performance. The ability to engage in periodic self-testing while learning is a good example (Winnie, 1997). Planning is a deliberate activity that establishes sub-goals for monitoring engagement with a task (Winnie, 1997). Students having the evaluation skill appraise the products and

regulatory processes of their learning. Students can re-evaluate their goals and conclusions. Evaluation enables students to evaluate their performance on the task, students can compare their performances with each other and they can use the result of comparison to locate the error in the solution process (Lucangeli, Cornoldi, & Tellarini, 1998).

#### *Metacognitive strategy instruction*

Metacognitive awareness may arise at the age of 4–6 years (Demetriou & Efklides, 1990). There is a substantial increase in metacognitive development during the primary school years as a function of age and experiences (Flavell, 1988). However, instruction has a more impact on the acquisition of metacognitive skills than growth has (as cited in Subaşı, 1999; Gage & Berliner, 1988; Veenman, Wilhelm & Beishuizen, 2004). Metacognitive instruction which plays such an important role in regulation of cognitive processes is based on the assumption that when an individual perceives how cognitive processes operate, he/she will be able to control these processes and use them in a more efficient way by arranging them for a more qualified learning (Ulgen, 2004). On the condition that instructional arrangements which will develop metacognitive skills contain characteristics such as active participation and learner's controlling the process, they can improve metacognitive skills through instruction (El-hindi, 1996). Instruction of metacognitive strategy enables the learners to reach a high-level cognitive process by allowing them to discover appropriate problem solving processes and use these processes under different conditions (Victor, 2004). On the other hand, it drives forward the internalization of knowledge through definition of the problem, asking questions to himself/herself, establishing connections between existing and new information, monitoring the learning process and associating learned information with current situations (Ashman & Conway, 1997).

It is seen that studies on the instruction of metacognitive strategy use methods such as developing supportive social environment (Schraw, 1998), giving feedback (Cardelle-Elawar & Corno, 1985) interactive problem-solving (Kramarski, Mevarech, Liebermann, 2001; Schraw, 1997), asking reflective questions (Mayer, 1998; Schoenfeld, 1985), conditional knowledge discussions (Schraw, 1998) and using control lists (Schraw, 1998). However, if we are to make a general classification, studies on this topic use two basic approaches as strategy instruction and supporting social environment.

One of the strategies which can be used for developing metacognition within the framework of constructivist learning is to encourage the students to ask questions themselves. In order to enable the students to ask questions themselves about what they are doing and establish an appropriate discussion environment, it is important to ask effective questions. Effective questions contribute to problem solving, trigger the thinking process and stimulate the imagination. Asking appropriate questions activates the metacognitive skills of students (Hacker & Dunlosky, 2003). While especially questions asked by teachers, such as '*What about next?*', '*What do you think?*', '*Why do you think so?*' and '*How can you prove this?*' trigger the thinking and contribute to the development of metacognitive abilities (Yurdakul, 2004).

It is observed that the method commonly used and proposed to be used theoretically in studies on metacognitive strategy instruction is instructing through

structured activities (Marge, 2001; Schoenfeld, 1985). This approach is based on the fact that metacognitive skills should be taught together with activity content. When the issue is instruction of metacognition, the most significant advantage of structured instruction is that it not only teaches the skills but also provides opportunities for teaching where, when and how to use these skills. Metacognitive strategy instruction using structured activities provides the learner with both knowledge of cognitive processes and strategies, and experience or practice in using both cognitive and metacognitive strategy and evaluating the outcomes of their efforts (Goldberg & Bush, 2003; Wilburne, 1997). Simply providing knowledge without experience or vice versa does not seem to be sufficient for the development of metacognitive control (Livingston, 1996).

#### *Metacognition and problem solving*

Failure in problem solving is generally resulted from failing to organize the mathematical operations, to choose the most effective method, to analyze, to understand the point of problem and to monitor and control operations carried out (Victor, 2004). It is a known fact that students with high metacognitive skills perform better in problem solving (Desoete, Roeyers & Buysse, 2001; Schoenfeld, 1985; Lester, 1994). It has been observed that during problem solving process they are more controlled; they try to break the complex problems into simple parts and they ask questions themselves for clarifying their thoughts. Schoenfeld (1985) states that when one encounter with failures in problem solving techniques, control skills (metacognition) will be helpful for applying strategies successfully.

Metacognition plays an important role during each level of mathematical problem solving. Goos, Galbraith and Reenshaw (2000) stated that a failure in metacognitive skills ensures the corresponding failure in mathematical thinking and problem solving. Problem solving process requires analyzing the given information about the problem, organizing the possessed information, preparing an action plan and assessing all the operations carried out. These operations of problem solving process require one to arrange each level and step and make decisions at the same time. And all these operations performed during the process are skills which constitute the character of metacognition (Yimer, 2004). For that reason, metacognition is a necessary skill for being successful in problem solving (Victor, 2004). McLoughlin and Hollingworth (2001) stated that studies on problem solving have suggested that problem solving operations such as definition of problem, practice, and controlling the outcome are not enough for learning. It is not sufficient to know what to do. It is necessary to know when to apply similar strategies, too (McLoughlin & Hollingworth, 2001). According to Montague (1992), three most commonly used metacognitive skills during problem solving are self-instruction, self-questioning and self-monitoring. Self-instruction helps children to determine and manage previously used problem solving strategies while working on a problem. Through the introduction of internal dialogues, self-questioning enables them to systematically analyze the given information about the problem and manage appropriate cognitive skills. Self-monitoring allows children to monitor their own general performances during problem solving operations and be sure about the

appropriateness of the strategies they use (Victor, 2004).

Researches on problem solving revealed that the students cannot reach the intended success level (Özsoy, 2005; Polya, 1988; Schoenfeld, 1985; Tertemiz & Çakmak, 2003). In literature metacognition has been found essential to come to successful learning (Desoete, Roeyers, & Buysse, 2001; Pugalee, 2001; Teong, 2002). Studies on metacognition have proven that there is a strong correlation between problem solving and metacognition and that the students with a higher level of metacognitive skills become successful in problem solving (Mevarech & Kramarski, 1997; Schoenfeld, 1992). Artz and Armour-Thomas (1992) point out that the main reason underlying the failure of students in problem solving is that they cannot monitor their own mental processes during problem solving. Metacognition may affect how children learn or perform mathematics. Students must learn how to monitor and regulate the steps and procedures used to meet the goal of solving problems. Academically successful students acquire the self-understanding that supports effective strategies to solve problems (Garrett, Mazzocco & Baker, 2006). In addition, the study conducted by Desoete, Roeyers and Buysse (2001) indicated that metacognitive knowledge and skills account for 37 percent of the achievement in problem solving. Lucangeli, Galderisi and Cornoldi (1995) found that metacognitive training positively affects problem solving. Studies conducted with this purpose in mind suggested that there exist positive and meaningful increases in the achievement of children using instruction activities towards developing metacognitive skills (McDougall & Brady, 1998; Naglieri & Johnson, 2000; Özsoy, 2007; Teong, 2002; Victor, 2004).

### *Present study*

By taking into account the methods used in previous studies on an instruction towards developing metacognitive strategy, this study is based on the method 'structured activities' and uses problem-based learning activities. The method used has been named as 'metacognitive strategy instruction using problem solving activities'. This method also covers several methods and strategies which were used separately in previous studies and proved successful (giving feedback, interactive problem solving, asking reflective questions, etc.).

The present study was designed to examine the effect of metacognitive strategy instruction in mathematical problem solving achievement. In particular, the study was designed to seek answers to the following research questions: (a) Does the metacognitive strategy instruction in fifth grade primary school have an impact on mathematical problem solving achievement? (b) Does metacognitive strategy instruction using mathematical problem solving activities have an impact on metacognitive knowledge and skills?

## **Method**

### *Design*

A quasi-experimental design, with pre- and post-test measurements and two groups (experimental and control) was employed. The dependent variable was 'problem solving achievement' as measured by MPSAT (Mathematical Problem Solving Achievement Test). The independent variable of the study was metacognition as

measured by Metacognitive Knowledge and Skills Assessment- Turkish version. The inventory originally named as MSA by Desoete, Roeyers and Buysse (2001). Classes randomly assigned as treatment and control group. Only students in the treatment group received metacognitive strategy instruction. Students in the control group continued their normal lessons but they also solved the problems studied in treatment group.

*Participants*

The participants of the study consist of fifth-grade students (mean age 11.2) studying in one of the public primary schools in Ankara, in Turkey. The school selected conveniently. 47 students (23 girls and 24 boys) took part in the study. 24 of students were in experimental group, and 23 of them in control group. Both groups have been pre-tested and the results have been compared in order to study the equivalence of the groups. However, because the group size is small, Kolmogorov-Smirnov test has been used in analyzing whether the groups display a normal distribution or not. As a result of this test, it has been observed that the group displays a normal distribution ( $P = .729, p > .05$ ). *t* test has been conducted in order to find whether there is a considerable difference between the groups in terms of pre-test results. The results of this study have been presented in Table 1.

**Table 1** Comparison of pre-test results of groups

Test	Group	<i>n</i>	<i>M</i>	<i>SD</i>	<i>df</i>	<i>t</i>	<i>p</i>
MPSAT	Experimental	24	25.42	12.07	45	1.193	0.239
	Control	23	29.13	11.64			
MSA-TR	Experimental	24	118.33	47.73	45	0.203	0.840
	Control	23	115.52	47.35			

As can be seen in Table 1, there is no significant difference between pre-test mean scores achieved by experimental and control groups in both MPSAT and MSA-TR. These results are  $t(45) = 1.193 (p > .05)$  for MPSAT and  $t(45) = .203 (p > .05)$  for the MSA-TR. In accordance with these results, it has been concluded that there is no significant difference between the groups. For these reasons, it has been found appropriate to carry out the study on the groups. Upon evaluating the equivalence of the groups, one of them has been assigned as treatment group and the other as control group randomly. The teachers of treatment and control groups are equivalent of each other in terms of age, gender, fields of graduation and professional experience.

*Instruments*

*Mathematical Problem Solving Achievement Test (MPSAT)*. Used in the study with the aim of measuring the mathematical problem solving achievement, this test has been developed by the researcher. MPSAT consists of 20 items, each of which has four options. In order to minimize the effect of differences in mathematical knowledge among students taking the test, this test included only question which can be solved using four mathematical operations (addition, subtraction, multiplication, division).

Also, with the aim of ensuring the compatibility of the questions with student levels (fifth grade of primary school), questions prepared compatible with the Primary School Curriculum implemented by the Ministry of National Education (MEB, 2004). Also, during the preparation of MPSAT, we focused on testing the behaviours which are compatible with Polya's (1988) four stages (understanding the problem, planning, carry out the plan, look back). The analysis results regarding the pilot study carried out on 44 fifth-grade students have been presented in Table 2.

**Table 2** Results of pilot study for MPSAT

<i>n</i>	Number of items	<i>M</i>	<i>SD</i>	<i>P<sub>j</sub></i>	KR-20
44	20	11.8	3.6	.56	.84

As can be seen in Table 2, the reliability (KR-20) of MPSAT, which have been re-developed in accordance with pilot study results, is .84 and its mean difficulty (*P<sub>j</sub>*) is .56. It has been found appropriate to use the MPSAT, which have been prepared by the researcher in accordance with the analysis results explained above and positive opinions of field specialists, with the aim of data collection.

*Metacognitive Skills and Knowledge Assessment (MSA-TR)*. In order to measure the metacognitive knowledge and skills of students, an adapted version of MSA (Metacognitive Skills and Knowledge Assessment) (Desoete, Roeyers and Buysse, 2001) was used. The MSA is a multi-method inventory in which the predictions are compared with the student performance as well. The MSA assesses two metacognitive components (knowledge and skills) including seven metacognitive parameters (declarative, procedural, and conditional knowledge, and prediction, planning, monitoring, and evaluation skills (Desoete, Roeyers and Buysse, 2001). In the measurement of "declarative knowledge", children are asked to choose the easiest and the most difficult exercise out of five and to retrieve their own difficult or easy addition, subtraction, multiplication, division or word problem. In order for this hard/easy distinction to be made and graded properly, these operations have been determined through a test applied to fifth grade students of a primary school, in accordance with the method followed during the development of original inventory. As a result of this process, the operations have been placed in the inventory in a way that will grade the least successfully answered questions as the hardest and the most successfully answered ones as the easiest. The exercises on "procedural knowledge" require children to explain how they solved exercises. "Conditional knowledge" is assessed by asking for an explanation of why an exercise is easy or difficult and asking for an exercise to be made more difficult or easier by changing it as little as possible (Desoete, Roeyers & Buysse, 2001). In the assessment of "prediction", children are asked to look at exercises without solving them and to predict whether they would be successful in this task. Children might predict well and solve the exercise wrongly, or vice versa. Children were then scored on 'evaluation' doing the exercises on the same rating scale. The answers were scored and coded according to the procedures used in the assessment of prediction skills. For "planning", children had to put 10 sequences necessary to calculate in order. When the answers were put in the right order the children received 1 point. The following types of questions measured 'monitoring': What kind of errors can you make doing such an exercise? How can you help younger children to perform well on this kind of exercises? Complete and adequate strategies were awarded 2 points. Hardly

adequate but not incorrect strategies received 1 point. Answers that were neither plausible nor useful did not receive any points (Desoete, Roeyers & Buysse, 2001).

The inventory consists of 160 items and through this inventory a student can score a minimum point of 0 and a maximum point of 360. During the development process of the inventory (MSA), the test-retest correlation has been  $r = .81$  ( $p < .0005$ ) in the analyses ascertained by Desoete, Roeyers and Buysse (2001). To examine the psychometric characteristics of the metacognitive parameters, Cronbach alpha reliability analyses were conducted by the developers. For declarative knowledge, procedural knowledge, and conditional knowledge Cronbach  $\alpha$ 's were .66, .74, and .70, respectively. For prediction, planning, monitoring, and evaluation Cronbach alphas were .64, .71, .87, and .60, respectively (Desoete, Roeyers & Buysse, 2001).

The adaptation of the inventory to Turkish has been carried out by the researcher (Özsoy, 2007). The reliability of the inventory restudied in the adaptation process. The inventory applied 92 students and Cronbach  $\alpha$ 's of MSA-TR were .71 for declarative knowledge, .70 for procedural knowledge, and .79 for conditional knowledge. For prediction, planning, monitoring, and evaluation Cronbach  $\alpha$ 's were .73, .78, .80, and .76 respectively. We have resorted to the method test-retest in reliability study due to the scope and quality of the inventory. The inventory has been applied to 45 students two times at an eight weeks' interval and the consistency between this resting results have been analyzed. The correlation value between the two application has been found to be .85 ( $p < .05$ ).

### *Procedure*

Since the activities are supposed to be carried out by the classroom teachers, we have felt a need to inform the teacher in the treatment group about several issues. Before the study, the teacher has been provided with a totally eight hour oral instruction over two weeks. During this instruction process, treatment group's teacher informed about metacognition, metacognitive instruction, aims of present study, study process, activities will be used in the lessons and her roles during the study. By this instruction, a teacher guide file including information given in the instruction, activity plans, and problems will be used in the activities.

*Metacognitive strategy instruction using problem solving activities.* Following the implementation of pre-tests, an instruction process called 'metacognitive strategy instruction using problem solving activities' has been carried out so as to develop the metacognitive strategy of students in the treatment group. The purpose of instruction of metacognitive strategy through problem solving activities is to develop students' metacognitive skills practically during problem solving activities. For this study, we preferred to apply strategy instruction together with problem-based instruction, one of the instructional practices of constructivist learning theory. This method was used in previous studies in order to develop metacognitive skills and yielded successful outcomes (Wilburne, 1997; Goldberg & Bush, 2003). The fact that this method, found



appropriate theoretically, is supported by previous studies is the primary factor in our choosing it. The researcher planned all the activities carried out in treatment group.

Before starting the application activities, preparatory lessons, 80 minutes at total as (40'+40'), have been carried out in order to inform students generally about metacognition. During preparatory classes, students were provided with information about metacognition in accordance with their levels. Also, the students were given Metacognitive Problem Solving Table during these classes. Then, they were asked to act in accordance with the steps specified in this table while working on problem solving activities. An extended version of the table was hung on notice board of the class in order to provide reinforcement.

With the aim of using in metacognitive problem solving activities, the researcher has prepared problems compatible with the students' levels in accordance with National Primary School Curriculum (MEB, 2004). Throughout the application, each of these problems has been introduced to the students in the form of work-sheets. These work-sheets also include metacognitive strategy required to be used by the students in the form of check-lists. The students have been asked to proceed in accordance with the stages included in these control-lists and to fill them upon completing each stage. The role of the teacher during these activities is to supervise the operation of the activities and guide the students by asking questions which will make the process proceed properly and lead the students to thinking. While the students are busy with the problems in work-sheets during problem solving activities, the teacher has monitored them and asked questions when necessary such as '*What did you think when you first read the problem?*', '*Did you read the problem enough to understand it?*', '*Do you think you have understand the problem?*', '*Tell me what you have in your mind?*'. '*What will you do now?*', '*Will this work for the solution?*', '*Do you think you can solve this problem?*' in order to trigger the metacognitive thinking of the students. The reasons behind these questions addressed with the aim of arouse the students' opinions about themselves and the process is mainly to encourage students to ask questions themselves. Throughout the application studies lasting a total of nine weeks (19 lessons), the students have been made to deal with 23 word problems.

During nine-week (19 Class time) application, the students were made to work on 23 problems. During metacognitive problem solving activities, the following method was followed under the guidance of the teacher:

- Process of the activity: The students are reminded to study by taking into account the stages in Problem-Monitoring Table and worksheets.
- When the students are thought to be ready for the activity, they are provided with worksheets.
- They are asked to read the problem without doing something else. (Several times- until they believe that they have understood.)
- They are asked to carry on the study in accordance with the stages contained on the edges of worksheet. This is repeated during the process if necessary.
- They are asked to write about their opinion on worksheet as much as possible.
- While studying, students are monitored and addressed questions which will encourage them to think. The most important part is to encourage them to think about themselves.

- When most of the students have completed studying, several students are asked to share the way through which they have solved the problem. During this part, the students are especially encouraged to tell about their own thinking processes. (Why did you do so? / Why did you think so? / Could you have solved the problem in a different way?). One should not fail to remember that it will play an important role in their development of metacognitive skills to share their opinions – both to express their own thinking and monitor other students' thinking processes.
- At the end of study, the students are asked to evaluate themselves. The students are made to assess their own thinking skills.
- The students are asked to write their opinions regarding the study on a study diary.
- Worksheets are collected at the end of each problem. They are examined by the researcher and teacher, and students' development is monitored. Advices on student development are written on these sheets and they are given back to students. Here, the purpose is to make them monitor their own development.

*Treatment integrity.* We resorted to the reliability of the application in order to receive information about to what extent the teacher had complied with the instruction carried out in the experimental group. With this purpose in mind, we used a “Teacher Observation Form” to use for collecting the data regarding the reliability of the application. The observation form includes the acts expected from teacher during the instruction. The instruction carried out by the teacher was observed by the researchers and an assistant observer by turns and these observations were recorded on observation form. The observations concluded that the teacher of treatment group had carried out the applications expected from herself at a 93.3 percentage (mean of two observers). It was determined from the observations in control group that the teacher had displayed these behaviours only at an average of 18 percent.

*Control condition.* However, no instruction planning has been made in the control group during the application stage of the study and the existing normal process has been allowed to go unaffected. But in order to define the process in the control group as well and to determine how different it is from the experimental group, the students in the control group have been made to solve the problems used in the experimental group in their ways. The observations in control group indicated that the teacher generally presented the problem to students, gave time for solution and then solved the problem on board and asked the students to control their solutions. Observations carried out in control group showed that the teacher did not use any other methods apart from this.

Following the nine-week application, the students have been exposed to the PSAT and MSA-TR as post-tests. And the results obtained have been analyzed in order to seek for answers for the study problems. During the analysis of obtained data, the analysis of variance (ANOVA) has been used in order to find out whether the experimental operation has proven effective or not with the significance level of .05. Also *Cohen's f* (Cohen, 1988) has been used to calculate the effect size.

## Results

### *Metacognitive knowledge and skills*

The mean scores of students regarding the pre-test and post-test obtained in the MSA-TR and the standard deviation values have been presented in Table 3.

**Table 3** Pre-test and post-test mean scores of MSA-TR

	Group	<i>n</i>	<i>M</i>	<i>SD</i>
Pre-test	Experimental	24	118.33	47.725
	Control	23	115.52	47.351
Post-test	Experimental	24	156.54	55.448
	Control	23	115.57	49.788

As can be seen in Table 3 while the mean scores obtained in the MSA-TR by the students in the treatment group who have been exposed to metacognitive instruction through metacognitive problem solving activities was 118.33 before the treatment, this increased to 156.54 following the experiment. The same mean scores of the students in the control group are 115.52 and 115.57 respectively. Therefore, there has been an increase in metacognitive knowledge and skills of students in the treatment group, the students in the control group have not experienced such a change in the same skill.

The results of ANOVA conducted in order to determine whether there has been a significant difference between the metacognitive knowledge and skills of the students in the treatment and control group when a comparison is made between before and after the experiment have been presented in Table 4.

**Table 4** ANOVA results for the MSA-TR

Source of variance	Sum of squares	<i>df</i>	Mean square	<i>F</i>	<i>p</i>
Between subjects	221765.809	46			
Group (Experimental/Control)	11259.583	1	8553.394	23.389	.000
Error	210506.226	45	365.699		
Within subjects	33601.809	47			
pretest-posttest	8592.415	1	8592.415	23.496	.000
Group*Test	8553.394	1	8553.394	23.389	.000
Error	16456.457	45	365.699		
Total	255367.618	93			

The results showed that the metacognitive strategy instruction in the treatment group have led to a significant difference [ $F_{(1,45)} = 23.389, p < .05$ ] between the treatment and control group in terms of the level of metacognitive knowledge and skills. The obtained results indicate that in the scores regarding the MSA-TR, the metacognitive problem solving activities, which have enabled a further advance when compared to level before the experiment, have proven more effective than the group that have not been exposed to the instruction of metacognitive strategy in terms of the development of metacognitive skills. Also effect size calculation results show that the treatment has a large effect ( $f = .446$ ).

*Mathematical problem solving achievement*

The mean scores of students regarding the pre-testing and post-testing obtained in the MPSAT and the standard deviation values have been presented in Table 5.

**Table 5** Pre-test and post-test mean scores of MPSAT

	Group	<i>n</i>	<i>M</i>	<i>SD</i>
Pre-test	Experimental	24	25.00	12.07
	Control	23	29.13	11.64
Post-test	Experimental	24	46.46	9.03
	Control	23	27.83	9.63

As can be seen in Table 5, while the mean score obtained in the MPSAT by the students in the treatment group who have been exposed to metacognitive instruction through metacognitive problem solving activities was 25.00 before the experiment, this increased to 46.46 following the experiment. The same average points of the students in the control group are 29.13 and 27.83 respectively. Therefore, there has been an increase in problem solving achievement of students in the treatment group; the students in the control group have not experienced such a change in the same skill.

The results conducted in order to determine whether there has been a significant difference between the mathematical problem solving achievement level of the students in the experimental and control group when a comparison is made between before and after the experiment have been presented in Table 6.

**Table 6** ANOVA results for the MPSAT

Source of variance	Sum of squares	df	Mean square	<i>F</i>	<i>p</i>
Between subjects	7365.425	46			
Group (Experimental/Control)	1234.968	1	1234.968	9.065	.004
Error	6130.457	45	136.232		
Within subjects	9545.352	47			
pretest-posttest	2385.246	1	2385.246	26.069	.000
Group*Test	3042.692	1	3042.692	33.254	.000
Error	4117.414	45	91.498		
Total	16910.777	93			

The results showed that the instruction of metacognition strategy in the treatment group have led to a significant difference [ $F_{(1,45)} = 33.254, p < .05$ ] between the treatment and control group in terms of the level of mathematical problem solving achievement. The obtained results indicate that in the scores regarding the MPSAT, the metacognitive problem solving activities, which have enabled a further advance when compared to level before the experiment, have proven more effective than the group that have not been exposed to the instruction of metacognitive strategy in terms of the development of problem solving achievement. The effect size Cohen's *f* (Cohen, 1988) of metacognitive strategy instruction on mathematical problem solving achievement also calculated. Results show that the treatment has a large effect ( $f = .484$ ).

According to the results of present study there has been an increase in both metacognitive and problem solving achievement level of the students in the treatment group. However, there is not such an increase in the control group. Considering these results, it can be concluded that the metacognitive strategy instruction lead to an increase in problem solving achievement.

## **Discussion**

In this study, we have implemented an instruction process intended to develop metacognitive strategy in fifth grade students from the primary school and analyzed whether there has been an advance on problem solving achievement following the instruction. With this objective in mind, the problem of the study has been expressed as '*Does metacognitive strategy instruction in fifth grade of the primary school have an impact on problem solving achievement?*'. As a result of the present study, at the end of the experimental process there has been observed a significant difference between the groups who have been exposed to the instruction of metacognitive strategy and those who have not been, in terms of metacognitive knowledge and skills. This conclusion supports the former studies (El-hindi, 1996; Goldberg & Bush, 2003; Marge, 2001; Wilburne, 1997) which maintain that there is an attempt to develop metacognitive skills in students at different and similar levels, and metacognitive skills can be increased through instruction. In support of the results of former studies, the results of this study suggest that metacognitive skills can be developed through instruction. Also we have observed that there is a meaningful difference between the students in the experimental group and control group in terms of the problem solving achievement level. This finding proves that the instruction of metacognitive strategy has a distinctive impact on increasing the problem solving achievement levels of students supporting the studies conducted by Lucangeli, Galdersi and Cornoldi (1995). Considering the outcomes of the study, as an answer for the study problem, it can be concluded that, the instruction of metacognitive strategy lead to an increase in problem solving achievement level. This outcome of the study supports the previous studies (Desoete, Roeyers & Buyse, 2001; Goldberg & Bush, 2003; Gourgey, 1998; Kramarski, Mevarech & Liberman, 2001; Lucangeli & Cornoldi, 1997; Marge, 2001; Swanson, 1990; Whimbley & Lochhead, 1986; Wilburne, 1997) in which the correlation between problem solving and metacognitive skills is studied.

The results revealed that, there was an increase in problem solving skills of the students who have been exposed to the instruction of metacognitive strategy. For this reason, metacognition can be used as a useful tool in order to develop the problem solving skills which is included among the primary objectives of primary school curricula and which plays an important role in the academic development of students. Accordingly it is suggested that, all instruction processes should include the instruction of metacognitive skills. Results of the study also showed that supporting the students with questions regarding their own thinking processes during problem solving activities, triggers metacognitive behaviours. For this reason, an application towards this aim during problem solving activities in schools will be useful for students. Present study supported that in Math courses metacognitive strategy instruction improves problem solving achievement. For further studies, investigating the effect of metacognitive strategy instruction on student achievement in courses such as arts and social sciences is suggested.

## References

- Artz, A.F. and Armour-Thomas, E. (1992). Development of a cognitive-metacognitive framework for protocol analysis of mathematical problem solving in small groups. *Cognition and Instruction*, 9, 137-175.
- Brown, A.L. (1980). Metacognitive development and reading. In R.J. Sprio, B. Bruce, & W. Brewer (Eds.), *Theoretical issues in reading comprehension*. Hillsdale, NJ: Lawrence Erlbaum Associates.
- Cardelle-Elawar, M. & Corno, L. (1985). A factorial experiment in teachers' written feedback on student homework: Changing teacher behavior a little rather than a lot. *Journal of Educational Psychology*, 77, 162-173.
- Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2<sup>nd</sup> ed.). Hillsdale, NJ: Lawrence Erlbaum.
- Demetriou, A., & Efklides, A. (1990). The objective and subjective structure of problem-solving abilities: metacognitive awareness from early adolescence to middle age. In H. Mandl, E. de Corte, S. N. Bennett, & H. F. Friedrich (Eds.), *Learning and instruction in an international context. Volume 2.1. Social and cognitive aspects of learning and instruction* (pp. 161–179). Oxford: Pergamon Press.
- Desoete, A., Roeyers, H. & Buysse, A. (2001). Metacognition and mathematical problem solving in grade 3. *Journal of Learning Disabilities*, 34, 435-449.
- Desoete, A. & Roeyers, H. (2002). Off-line metacognition – A domain-specific retardation in young children with learning disabilities. *Learning Disability Quarterly*. 25, 123-139.
- Desoete, A. (2008). Multi-method assessment of metacognitive skills in elementary school children: How you test is what you get. *Metacognition and Learning*, DOI.10.1007/s11409-008-9026-0.
- El-Hindi, A.E. (1996). Enhancing metacognitive awareness of college learners. *Reading Horizons*, 37, 214-230.
- Flavell, J. H., & Wellman, H. M. (1977). Metamemory. In R. V. Kail, & J. W. Hagen (Eds.), *Perspectives on the development of memory and cognition* (pp. 3–33). Hillsdale: Erlbaum.
- Flavell, J.H. (1979). Metacognitive and cognitive monitoring: A new area of cognitive developmental inquiry. *American Psychologist*, 34, 906-911.
- Flavell, J. H. (1988). The development of children's knowledge about mind. In J. W. Astington, P. L. Harris, & R. O. Olson (Eds.), *Developing theories of mind* (pp. 21–29). Cambridge, UK: Cambridge University Press.
- Flavell, J.H. (1999). Cognitive development: Children's knowledge about the mind. *Annual Review of Psychology*, 50: 21-45.
- Garrett, A. J., Mazzocco, M. M. & Baker, L. (2006). Development of the metacognitive skills of prediction and evaluation in children with or without math disability. *Learning Disabilities Research & Practice*, 21(2), 77–88.
- Goldberg, P.D. & W.S. Bush (2003). Using metacognitive skills to improve 3<sup>rd</sup> graders' math problem solving. *Focus on Learning Problems in Mathematics*. Fall, 2003.
- Goos, M., Galbraith, P., Renshaw, P. (2000). A money problem: A source of insight into problem solving action. *International Journal for Mathematics Teaching and Learning*. 80.
- Gourgey, A.F. (1998). Metacognition in basic skills instruction. *Instructional Science*, 26, 81-96.
- Hacker, D.J. & Dunlosky, J. (2003). Not all metacognition is created equal. *New Directions For Teaching And Learning*, 95, 73-79.
- Huitt, W. (1997). *Metacognition*. Educational Psychology Interactive. Valdosta, GA: Valdosta State University.
- Jager, B., Jansen, M., & Reezigt, G. (2005). The development of metacognition in primary school learning environments. *School Effectiveness and School improvement*, 16, 179-196.
- Kramarski, B., Mevarech, Z.R. & Liberman, A. (2001). The effects of multilevel– versus unilevel-metacognitive training on mathematical reasoning. *Journal for Educational Research* 94(5), 292–300.
- Lester, F. K. (1994). Musings about mathematical problem solving research: 1970-1994. *Journal for Research in Mathematics Education*, 25 (6), 660-675.

- Livingston, J. A. (1996). *Effects of metacognitive instruction on strategy use of college students*. Unpublished manuscript, State University of New York at Buffalo.
- Lucangeli, D., Galderisi, D. & Cornoldi, C. (1995). Specific and general transfer effects of metamemory training. *Learning Disabilities. Research and Practice*, 10, 11–21.
- Lucangeli, D. & Cornoldi, C. (1997). Mathematics and metacognition: What is the nature of relationship? *Mathematical Cognition*, 3, 121-139.
- Lucangeli, D., Cornoldi, C, & Tellarini, M. (1998). Metacognition and learning disabilities in mathematics. In T.E. Scruggs & M.A. Mastropieri (Eds.), *Advances in Learning and behavioral disabilities* (pp. 219-285). Greenwich: JAI Press Inc.
- M.E.B. Talim ve Terbiye Kurulu Başkanlığı (2004). *İlköğretim Programı*. Ankara: Devlet Kitapları Müdürlüğü Basımevi.
- Marge, J.J. (2001). The effect of metacognitive strategy scaffolding on student achievement in solving complex math word problems (Doctoral Thesis). Riverside, CA: University of California.
- Mayer, E.R. (1998). Cognitive, Metacognitive and Motivational Aspects of Problem Solving. *Instructional Science*, 26, 49-63.
- Mevarech, Z.R. & Kramarski, B. (1997). IMPROVE: A multidimensional method for teaching mathematics in heterogeneous classrooms. *American Educational Research Journal* 34(2), 365–395.
- McDougall, D. & Brady, M.P. (1998). Initiating and fading self-management interventions to increase math fluency in general education classes. *Exceptional Children*, 64, 151-166.
- McLoughlin, C. & Hollingworth, R. (2001). *The weakest link: Is web-based learning capable of supporting problem-solving and metacognition?* 18<sup>th</sup> Annual Conference of the Australasian Society for Computers in Learning in Tertiary Education, 9-12 December 2001, Melbourne, Australia.
- Montague, M. (1992). The Effects of Cognitive and Metacognitive Strategy Instruction on the Mathematical Problem Solving of Middle School Students with Learning Disabilities. *Journal of Learning Disabilities*, 25, 230-248.
- Naglieri, J.A. & Johnson, D. (2000). Effectiveness of a cognitive strategy intervention in improving arithmetic computation based on the PASS theory. *Journal of Learning Disabilities*, 35, 591-597.
- National Council of Teachers of Mathematics (1989). *Curriculum and evaluation standards for school mathematics*. (1st ed.). Reston, VA.
- Nelson, T. O., & Narens, L. (1990). Metamemory: A theoretical framework and new findings. In Bower, G.H. (Ed.), *The psychology of learning and motivation Vol.26* (pp.125-141), New York: Academic Press.
- Otani, H. & Widner, R.L. (2005). Metacognition: New issues and approaches. *The Journal of General Psychology*, 132(4), 329-334.
- Özsoy, G. (2005). Problem çözme becerisi ile matematik başarısı arasındaki ilişki. *Gazi Eğitim Fakültesi Dergisi*, 25(3), 179-190.
- Özsoy, G. (2007). İlköğretim beşinci sınıfta üstbilis stratejileri öğretiminin problem çözme başarısına etkisi [Doctoral thesis]. Ankara: Gazi Üniversitesi Eğitim Bilimleri Enstitüsü.
- Özsoy, G. (2008). Üstbilis. *Türk Eğitim Bilimleri Dergisi*, 6(4), 713-740.
- Polya, G. (1988). *How To Solve It*. New Jersey, NJ: Princeton University Pres.
- Pugalee, D.K. (2001). Writing, mathematics, and metacognition: looking for connections through students' work in mathematical problem solving. *School Science and Mathematics*, 101, 236-245.
- Schoenfeld, A. (1985). *Mathematical Problem Solving*. San Diego, CA: Academic Press.
- Schoenfeld, A. (1992). Learning to think mathematically: Problem solving, metacognition, and sense making in mathematics. In D.A. Grouws (Ed.), *Handbook of Research on Mathematics Teaching and Learning* (pp. 165–197). MacMillan, New York.
- Schraw, G. (1997). The Effect of Generalized Metacognitive Knowledge on Test Performance and Confidence Judgements. *The Journal of Experimental Education*, 65 (2), 135-146.
- Schraw, G. (1998). Promoting General Metacognitive Awareness. *Instructional Science*, 26, 113-125.
- Schraw, G. & Moshman, D. (1995). Metacognitive theories. *Educational Psychology Review* 7(4), 351-371.
- Subaşı, G. (1999). Bilişsel öğrenme yaklaşımı bilgiyi işleme kuramı. *Mesleki Eğitim Dergisi*, 1(2), 27-36.

- Sungur, S. (2007). Contribution of motivational beliefs and metacognition to students' performance under consequential and nonconsequential test conditions. *Educational Research and Evaluation*, 13(2), 127-142.
- Swanson, H.L. (1990). Influence of metacognitive knowledge and aptitude on problem solving. *Journal of Educational Psychology*, 82, 306-314.
- Teong, S.K. (2002). The effect of metacognitive training on mathematical word-problem solving. *Journal of Computer Assisted Learning*, 19, 46-45.
- Tertemiz, N. & Çakmak, M. (2003). Problem çözme. Ankara: Gündüz Eğitim ve Yayıncılık.
- Ülgen, G. (2004). *Kavram Geliştirme: Kuramlar ve Uygulamalar*. Ankara: Nobel Yayın Dağıtım.
- Van de Walle, J. (1989). *Elementary School Mathematics*. New York: Longman.
- Veenman, M.V.J., Wilhelm, P. & Beishuizen, J.J. (2004). The relation between intellectual and metacognitive skills from a developmental perspective. *Learning and Instruction*, 14, 89-109.
- Whimbley, A. & Lochhead, J. (1986). *Problem solving and comprehension*. Hillsdale, NJ: Lawrence Erlbaum Associates.
- Victor, A.M. (2004). The effects of metacognitive instruction on the planning and academic achievement of first and second grade children. (Doctoral Thesis). Chicago, IL: Graduate College of the Illinois Institute of Technology.
- Wilburne, J. M. (1997). The effect of teaching metacognitive strategies to preservice elementary school teachers on their mathematical problem solving achievement and attitude. (Doctoral Thesis). Philadelphia: Temple University.
- Winne, P.H. (1997). Experimenting to bootstrap self-regulated learning. *Journal of Educational Psychology*, 89, 1-14.
- Yurdakul, B. (2004). Yapılandırıcı öğrenme yaklaşımının öğrenenlerin problem çözme becerilerine, bilişötesi farkındalık ve derse yönelik tutum düzeylerine etkisi ile öğrenme sürecine katkıları. (Doctoral thesis). Ankara: Hacettepe Üniversitesi Sosyal Bilimler Enstitüsü.
- Yimer, A. (2004). Metacognitive and cognitive functioning of college students during mathematical problem solving. (Doctoral Thesis). Illinois State University.