

*Full Length Research Paper*

# The effect of using metacognitive strategies for solving geometry problems on students' achievement and attitude

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The purpose of this study is to identify the effect of using metacognitive strategies for problem solving in "geometry" on fifth grade students' achievement, metacognitive skills and attitude. Experimental method was used with a pretest/posttest control group design. Firstly, both groups were subject to a pretest that was comprised of "the achievement test", "the metacognitive skills inventory" and "the attitude toward mathematics scale". Next, the experimental group (39 students) was taught geometry for eight weeks by lesson plans and worksheets designed to improve the students' ability to use metacognitive skills for solving problems. In the meantime, the control group (36 students) was taught through traditional methods. In the end, the three data collection instruments were administered to both groups as a posttest. The data were analyzed via dependent and independent t-tests, and it is seen that the experimental group had significantly higher posttest scores when compared to the control group. More significant results were obtained when the findings revealed by statistical analyses were accompanied by student essays. It was observed that the students in the experimental group had developed a better attitude toward geometry and mathematics, which might be attributed to the improvement in their self-confidence. Furthermore, these students had developed the ability to perceive the importance of problem solving, to understand problems, to be involved in planned studying, and to control and be aware of the problem solving process. The improvement in their attitude toward geometry and mathematics led to a corresponding increase in their achievement.

**Key words:** Metacognition, mathematics, problem solving, achievement, attitude.

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## INTRODUCTION

Rapid advances and developments in today's science and technology have brought about a need for an educational reconstruction. The reconstruction will be deemed successful depending on the extent to which it satisfies the needs and requirements of the system and is consistent with the objectives specified. Primary mathe-

matics has an important role to play in meeting these needs and requirements. As a matter of fact, rapid advances in science and technology have made it obligatory for individuals to be good problem-solvers. Thus, improving problem solving skills has been the focal point of mathematics education and curricula.

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In today's world, more and more importance is attached to education and teaching. Accordingly, many nations throughout the world have been reorganizing their curricula. As with these nations, Turkey has always questioned its educational system (Balım and Kesercioglu, 2005: 53). The questioning has been accompanied by national and international assessment reports as well as a great deal of scientific research. An example of such reports would be PISA, TIMSS and PIRLS. According to these reports, Turkish students are not satisfactorily successful in mathematics and one of its sub-branches, namely geometry (Olkun and Aydogdu, 2003; Ardahan and Ersoy, 2002; MEBARGED, 2003). Part of the reason might be that geometry subjects are not attached due importance in Turkey. However, there must be some other reasons, since the country ranks among the least successful countries in mathematics. It is likely that one such reason is that teachers mislead students to memorization in their attempt to enable them to gain knowledge about and skills in geometry (Develi and Orbay, 2003: 1). In fact, most students regard geometry as a body of formulas or memorization of rules or figures (Olkun and Aydogdu, 2003: 8). In addition, the objective of geometry education in Turkey has always been to provide proof for a theorem, to arrange exercises that require a definition in a more sophisticated scheme of the figure where the conditions of the theorem are applied and to use the result of the theorem to come up with a new quality of the scheme (YÖK, 2002). However, the underlying principle behind geometry should be to help individuals become aware of their cognition and power of mathematical thinking while constructing their own world of relationships. As can be concluded from the assessment reports, Turkish students are not at the desired level when it comes to mathematics and geometry, suggesting that mathematics education must be altered and improved. For this reason, efforts have been made to reconstruct the curriculum in reference to the need for those individuals who are able to perceive mathematics, to use it in their daily life and working life, to solve problems in today's information society, to think and decide independently, to express their opinions, to communicate with others and to make data-based predictions (Fidan, 1986; Develi and Orbay, 2003; MEB, 1999; MEB, 2002; MEB, 2005; Baki, 2006; Baykul, 2005; Alkan, 2002; Çoban, 2002; Educational Reform Initiative, 2003).

Since it is one of the fundamental requirements of human beings for surviving, problem solving has been one of the main objectives of mathematics curricula (NCTM, 1989, 1991, 1995, 2000; MEB, 2002, 2005). With problem solving at the center of mathematics curricula, educationalists have started attaching particular importance to it. According to Swing and Peterson (1988), problem solving involves an understanding of pieces of mathematical information and to establish connections between these pieces. Consequently, problem solving

has been one of the most commonly studied subjects of mathematics since 1980.

In today's educational system, the interest has shifted from "teaching" to "learning". Then, how should students learn to solve mathematical problems? The best answer to the question is that they should learn in a way that will enable them to know what to do, to think, to establish new connections, to be aware of their own learning process and to come up with solutions to any problems when necessary (Ersoy and Gur, 2004: 5, Wheatly, 1991). One of the strongest contributions to such "learning" in mathematical problem solving will be the integration of "metacognitive strategies" into the educational process. The problem solving approach based on metacognitive strategies, coupled with a perspective that is centered on students and requires their active participation, will hopefully have a positive influence on their success in mathematical problem solving. A popular research subject in recent years, metacognition is based on the premise that "when one understands how his/her cognitive processes work, he/she will be able to control and rearrange these processes for more qualified learning (Ülgen, 1997)." The premise makes metacognition an important notion in the educational environment. Why is metacognition important and why should it be improved? According to Pugalee (2001), metacognition is important in that it makes sure that appropriate knowledge and strategies are used throughout the problem solving process. In other words, students use metacognition to explain their ways of thinking while solving problems (Ebdon et al., 2003). According to Larkin (2000), metacognition is important for the development of critical thinking and learning. In a quality learning environment, the student should be able to learn how to learn, how to remember and how to effectively control and direct her own learning (Loyens et al., 2008).

Metacognition is considered an essential component of effective learning, for it enables individuals to monitor and regulate their own cognitive performance (Schraw and Graham, 1997). Similarly, Hartman (1998) maintained that metacognitive awareness allows one to control and self-regulate his/her thinking and learning processes and learning outcomes. According to Kuiper (2002), metacognition, once learned, supports reflective thinking, helps problem solving, gives responsibility and improves self-confidence for quicker decisions for the rest of one's life. Kuiper (2002) argued that students with better self-regulation and metacognitive strategies, regardless of their grade/level, achieve higher academic accomplishment. According to O'Neil and Abedi (1996), there is a significant correlation between achievement and metacognition. Likewise, Gama (2000) held that metacognition plays a pivotal role in oral comprehension, reading comprehension, problem solving, attention, memory, social cognition, certain types of self-control and self-instruction.

As a result, as stated by Yurdakul (2004), metacognition

is closely intertwined with a number of significant concepts like learning to learn, life-long learning, flexible learning, independent learning and gaining responsibility for learning, and it is one of the indispensable variables in more effective education. Metacognition is generally described in the literature as a crucial part of successful learning and an essential component that enables one to study strategically and to solve problems successfully (Pugalee, 2001: 237). When presented with metacognitive experiences in learning environments designed to improve metacognitive knowledge and skills, students learn more and become more successful. In turn, as stated by Pappas et al. (2003), metacognition will have a positive impact on school performance. Recent studies on especially mathematics education have been focused on the development of metacognitive skills so that learners turn out to be individuals that can learn and solve problems (Pate et al., 2004). Research has reported that metacognition affects mathematical problem solving (Hacker, 1998) and that it is important for increased mathematical performance (Lucangeli and Cornoldi, 1997; Desoete et al., 2001). In fact, studies on metacognition in mathematics have been based on problem solving (Pesci, 2003).

Metacognition in problem solving is the basis for the use of appropriate knowledge and strategies. Metacognitive skills in problem solving should include planning, monitoring, evaluating and awareness. An effective internalization of these skills will often lead individuals to solve problems successfully. The idea is supported by a number of studies. In a pioneering study, Schoenfeld (1987, as cited in Gourgey, 1998:82) reported that metacognitive skills have a positive influence on students' problem solving performance. Schoenfeld maintained that students that are unsuccessful in problem solving choose problem solving strategies too quickly, allocate more time to practice and rarely stop to evaluate themselves to control whether they have fulfilled their objectives. Lack of self-monitoring and self-regulation behaviors causes such students to spend more time coming up with a solution and to choose wrong strategies. Even if they have enough knowledge to solve a problem, they end up with an unsuccessful solution. On the other hand, successful students spend most of their time analyzing the problem and making sure that they understand it. They try a number of approaches, control whether their strategies work or not, change them when necessary and evaluate themselves throughout the process. In the end, they come up with the solution in a faster and more accurate way.

Similarly, many researchers have argued that metacognition has a positive influence on mathematical learning and problem solving (Carr and Jessup, 1997; Yap, 1993; Kosmicki, 1993). Metacognition, or "one's knowledge of and control over his/her cognitive process", leads to the problem solving process and an improvement in the efficiency of target behaviors. In this

way, it has a positive effect on student performance. Whimbey and Lochhead (1981; as cited in Yılmaz, 1997: 13-14) emphasized the importance of practice in the development of problem solving skills and reported that students unable to succeed in problem solving lack metacognitive skills. They categorized the mistakes these students make and sources of such mistakes as Failure to Read the Problem, Failure to Think, Inattention to Problem Analysis and Being Inactive, and Lack of Patience. Another researcher, Zan (2000:144), listed the reasons for students' failure to solve problems as follows: ineffective time management (spending most of the time trying to solve the problem), inability to control the process, inability to control the procedures, inability to solve some problems despite knowing what subject they are related to (especially geometry problems), wrong ways of solving the problem, efforts to deal with theorems and information instead of understanding the problem, inability to plan and inability to evaluate their work.

In brief, those students unsuccessful in problem solving actually lack meta-cognitive skills. In addition, they experience anxiety and panic, and develop a negative attitude toward mathematics (Zan, 2000: 144). It seems that knowledge of procedures and strategies is as important for problem solving as mathematical knowledge. Overcoming ambiguity entails a detailed analysis of the situation, collection of necessary information, and selection, arrangement and use of information that will lead to solution. It is also essential that necessary controls are made.

Problem solving plays a critical role in mathematics and mathematics education (Koichu et al., 2003). Many studies have demonstrated that individuals differ from each other in their ability to organize, use and regain necessary information. These individual differences are mostly associated with metacognition (Swanson, 1992). Metacognitive knowledge and skills commonly develop with age, slowly and on their own. Even so, waiting for metacognitive knowledge and skills to get naturally developed would be a waste of time, considering how quickly world conditions change. Instruction is much more effective in the development of metacognitive skills when compared to maturing. This means that teachers should organize the learning environment in a way that will help students improve their metacognitive knowledge and skills. In other words, teachers should lead students to gain metacognitive knowledge and skills (Senemoğlu, 1997: 341). However, designing such lessons require teachers, first of all, to have metacognitive knowledge and skills themselves and to have gained metacognitive experiences. As stated by Wilburne (1997), problem solving is necessary for students, while it is a challenge to teachers. Teachers should not simply help students solve a problem; instead, they should help them learn how to operate a process to solve a problem. Therefore, it is essential that teachers, first of all, should be informed and instructed about how to enable their students to gain

**Table 1.** The experimental design in the study.

Groups	Pretest	Empirical procedure	Posttest
E	T1123	Metacognitive strategies	T2123
C	T1123	Traditional approaches	T2123

**Table 2.** The way the groups were formed.

Experimental group	Used metacognitive strategies
Control group	Used traditional learning approaches

such an experience.

### Problem statement

The purpose of this study is to identify the effect of metacognitive strategies used for mathematical problem solving on students' achievement, metacognitive skills and attitude, and, if the study proves to be successful, to emphasize the importance of metacognitive skills for effective problem solving in primary mathematics. In accordance with the purpose, the basic problem in the study is as follows: "Are there any significant differences in achievement, metacognitive skills and attitude between those students who are taught to solve mathematical problems via metacognitive strategies and those who are taught via traditional approaches?" In this respect, an answer is sought for to the following questions:

1. Was there a significant difference in achievement between the experimental group, which was taught to solve mathematical problems via metacognitive strategies, and the control group, which was taught on the basis of the ordinary curriculum?
2. Was there a significant difference in metacognitive skills between the experimental group, which was taught to solve mathematical problems via metacognitive strategies, and the control group, which was taught on the basis of the ordinary curriculum?
3. Was there a significant difference in attitude between the experimental group, which was taught to solve mathematical problems via metacognitive strategies, and the control group, which was taught on the basis of the ordinary curriculum?

## METHOD

### Research design

The study was experimental with a pretest/posttest control group design. The purpose was to reveal the difference in achievement, metacognitive skills and attitude between those students who were taught to solve mathematical problems via metacognitive strategies and those who were taught via traditional approaches. The

experimental design is presented in Table 1.

E stands for the experimental group whereas C represents the control group. A pretest was administered to both groups before the empirical procedure. The pretest was comprised of the achievement test, the metacognitive skills inventory and the attitude toward mathematics scale. In Table 2, T1<sub>1</sub> stands for the achievement test, T1<sub>2</sub> for the metacognitive skills inventory, and T1<sub>3</sub> for the attitude toward mathematics scale. The same data collection instruments were administered to the groups as a posttest, too (T2<sub>1</sub> standing for the achievement test, T2<sub>2</sub> for the metacognitive skills inventory, and T2<sub>3</sub> for the attitude toward mathematics scale).

The present study is also an action research. Action research requires teachers to conduct studies in the actual school or classroom environment with the aim of improving the instructional quality (Kuzu, 2009). Such research is not only fed by quantitative data. In other words, the objective is not to prove something; instead, it is an attempt to understand it and to come up with a solution. Therefore, the data for the study were collected not only through standardized tests, questionnaires and attitude scales but also via student views and observations. In other words, both qualitative and quantitative methods were employed. In this way, it was possible to collect data through qualitative methods and interpret them. In addition, the quantitative findings were made clearer and different aspects of the data on the participants were explored. In other words, the study was carried out with an integrated approach. The collective use of qualitative and quantitative paradigms yielded more generalizable and evident findings.

### Study group

The study was conducted on fifth grade students from a primary school located in the Central Anatolia Region of Turkey during the 2011 to 2012 Academic Year. Initially, all the fifth grade students in the school were compared in reference to their report cards for the fourth grade as well as the views of their teachers. In this way, it was possible to have two classrooms with similar levels as the experimental and control groups. The pretests administered to both groups confirmed the equivalence of their levels (Tables 4, 8 and 12). The experimental group was comprised of 39 students whereas the control group consisted of 36 students. The groups were formed in the following way: Table 3 presents certain characteristics of the students in the groups.

The experimental group was comprised of 39 students whereas the control group consisted of 36 students. While the experimental group had 17 female (43%) and 22 male (56%) students, the control group contained 19 female (51%) and 17 male (48%) students (Table 3). The findings suggest that the groups were similar to each other in the number of students and the distribution of these students by gender.

### Study plan

All the procedures for the study were as follows.

First, the experimental and control groups were formed in the way described earlier.

"Geometry", a unit in the mathematics curriculum for fifth grade students, was selected in accordance with the review of literature and opinions of field experts.

Both groups were subject to a pretest, which was comprised of the achievement test, the metacognitive skills inventory and the attitude toward mathematics scale.

Both groups were provided to solve the same problems but with different lesson plans. The problems were solved in reference to metacognitive strategies in the experimental group with the lesson plans prepared by the researchers whereas they were dealt with via

**Table 3.** The distribution of the participants by gender.

Group	Number of students	Gender	
		Female n (%)	Male n (%)
Experimental group	39	43	56
Control group	36	51	48
Total	75	47	52

**Table 4.** The independent t-test table on the comparison between the experimental and control groups in their pretest scores in the achievement test.

Group	N	X	Ss	t	p
Experimental group pretest	39	72,0513	9,0115	2,404	0.115
Control group pretest	36	66,1111	12,2539		P>0.05

no particular approach in the control group. They were lectured according to the standard plans provided by the National Ministry of Education of Turkish Republic.

The experimental and control groups were subject to the following procedures by the researcher. The process lasted for eight weeks (8 × 120 min). The procedures for the experimental group (A) were as follows:

**A.** The classes were taught in accordance with metacognitive strategies used for problem solving.

**A.1.** First, the problems were solved under the teacher's guidance so that the students could be familiar with and enabled to learn about the stages of the problem solving process. After they had been solved and the teacher made sure that the students had learned about these stages, they were enabled to carry out the stages of the metacognitive process. At the beginning of each class, in particular, the teacher asked a number of questions, set a model for the students, and, therefore, enabled them to be more familiar with the use of metacognition for problem solving.

**A.2.** The students read the problem on their own. They were asked whether they had failed to understand any part of the problem. They were provided with further explanation when necessary.

**A.3.** Problem solving represents a significant aspect of mathematics education. Before attempting to solve a problem, students should understand it, retrieve relevant information, be aware of similar problems and know about mathematical meanings of the words used in the problem. An improvement in problem solving can be realized only if students recognize the problem, use former information to solve it and decide what steps to follow for solution. The students were provided with the following instructions so that they could be guided to recognize the problem, to use strategies and to do their own planning:

*Read the problem carefully. Ask your teacher and friends any unfamiliar word in the problem.*

*Consider the punctuation. Underline the highlights of the problem.*

*Check that you have understood the problem. Read once again!*

*Explain the problem in your own words (Write down how you understand the problem).*

Explaining the problem in their own words means students writing down what they understand from the problem without referring back to it. The objective is to enable students to identify the main idea in the problem and realize that they should understand the problem before attempting to solve it. In fact, the primary indicator of understanding a problem is to explain it in one's own words (Polya,

1973).

*Think about what subject the problem is related to. Remember what you have learned about it. Think how your former knowledge can help you.* Students associate the problem with the subject they have already learned and think how to use their former knowledge to solve it. They explain the connection and their own opinions.

*Have you solved a similar problem before? If yes, in what ways is the problem similar to a previous problem or what you have learned? Explain.* If students have already solved a similar problem, they explain the way they are similar to each other in reference to what they have learned. Students need to be cognitively competent in order to solve problems. Therefore, when students try to find what subject(s) the problem is related to and think whether they have solved a similar problem before, they decide how to apply their cognitive competence to the problem or realize how competent or incompetent they are cognitively. Furthermore, all these steps will help them decide how to solve the problem.

*Before attempting to solve the problem, do you think it will be difficult for you to solve it? If yes, explain why.* If a student says no to the question, he/she has understood the problem and associated it with similar problems they have already dealt with. If he/she says yes, then he/she will explain why it will be difficult for him/her to solve it. In this way, he/she will become aware of his/her thinking process and, in turn, attempt to overcome the difficulty, of course, depending on its degree. For instance, if he/she has a problem because of not understanding the problem properly, he/she will try to understand it better. If he/she thinks that he/she does not have enough knowledge to solve it, he/she will go back to the drawing board and revise the subject the problem is related to. The objective here is to enable students to realize what they know and what they do not know. In this way, they are provided with an opportunity to decide on their own cognitive competence.

*Write down what is given and asked for.* This is a behavior commonly exhibited and encouraged in the Turkish educational system. It is important in that it enables students to see the problem in a more clear way. What is given and asked for in a problem is written down in a kind of table with two columns.

*Summarize the problem.* The process entails writing down the problem using certain symbols and abbreviations. It enables students to check that they have fully understood the problem and to interpret it in a better way.

*Predict the solution without carrying out any procedures. Explain your prediction.* Predicting the solution without carrying out any procedures does not mean expressing the solution, or result. It means providing an approximate answer using rough estimates.

*Draw a figure or scheme related to the problem.* Although not

necessary for every problem, the technique helps students solve problems. Drawing a figure or scheme related to the problem means illustrating the problem.

*Decide on your objective before attempting to plan your studies. Think what you need to solve the problem.* The process involves allocating some time to students so that they think about the problem and the stages they are going to follow. When asked about the objective of the problem before they attempt to plan their studies, students are provided with an opportunity to decide what procedures they need to carry out to solve the problem.

*List the procedures to be followed to solve the problem (Do your planning).* Students list the procedures to be followed along with their justifications. In this way, an attempt is made to enable students to develop an ability to plan things. In other words, students firstly have to understand the problem, then identify the objective of the problem, and, finally list the procedures they are going to carry out.

*Check that your action plan is accurate.* In association with the problem, students check that their action plan is accurate. They correct any mistakes. In this way, students are enabled to develop an ability to control the procedures that they are carrying out.

*Carry out your procedures.* Find out and write down the solution. Students put the action plan that they did in the previous stage into action and come up with the solution to the problem.

**A.4.** The students were enabled to control their studies and evaluate their learning during and after the problem solving process. In this way, it was possible to detect any points where they had difficulty and to provide feedback accordingly. In this regard, the students were presented with the following questions at the end of each problem:

*Check that your procedures are accurate and sensible.* Students go back to control each stage from beginning to end.

*Is your answer correct? If your answer is wrong, decide where you did wrong and redo the procedures from beginning to the end.* Students decide whether their answer is correct or not. If their answer is wrong, they review the procedures from the beginning to the end. They detect the source of their mistake and redo the problem solving process. Furthermore, the students were enabled to have a control over the problem solving process thanks to the questions.

**A.5.** Throughout the process, the students were provided with guidance so that they could monitor the process in a better way. They were asked questions as to the process. In this way, they were made more aware of what they were doing. They were reminded to follow these steps while solving the problems.

The teacher walked around the classroom and asked students such questions as "What are you doing?", "Why are you doing so?" and "How will this help you solve the problem?" The objective was to enable them to monitor, regulate and evaluate not only the problem solving process but also their own activities.

**A.6.** Throughout the process, the students used a notebook in which they could explain the way they solved the problems in a detailed way and report their thinking processes.

**A.7.** When most of the students solved or stopped trying to solve the problems, the teacher stopped asking them further questions. Some students were made to go to the board to show the way they solved the problems. Great care was taken to choose those students who came up with the solution in different ways. Afterward, the chosen students explained their strategies and metacognitive thoughts. The other students discussed whether the solutions were sensible or not, whether the problem solved was similar to other previous problems or not, what subject the problem was related to, and how such information could help them to solve other problems.

**A.8.** Following the discussion, the students wrote down the different strategies used by their friends for solving the problems.

**A.9.** In light of the discussion, the students expressed their ideas about the efficiency of the problem solving processes and the

solutions, and evaluated themselves.

The use of metacognitive strategies enabled the students to be more active in the classes, which, in turn, led them to follow these strategies and to internalize the problem in a better way. Since the researcher participated in the study in person, she was able to intervene in when the students failed to understand something, which enabled the study to be conducted in a more reliable way.

In the control group, on the other hand, the problem solving process was based on traditional approaches. The procedures for the control group (B) were as follows:

**B.1.** The subjects were covered in the same way and the same problems were solved. However, the way the problems were solved was not based on metacognitive strategies.

**B.2.** At the beginning of the class, the teacher attracted the attention of the students to it and directly taught them the knowledge or skills required for a particular subject. In the control group, the problems were solved in the following way:

**B.3.** The problems were presented to the students. Each student read and solved them on his/her own.

**B.4.** When most of the students solved or stopped trying to solve the problems, some of them were chosen to show and explain to their friends the way they solved the problems.

**B.5.** Any mistake was corrected. Finally, the problems were solved by the teacher. Accordingly, the students corrected any mistakes in their own solutions and wrote down the final solutions in their notebooks.

After all these procedures, both groups were subject to the posttest, which consisted of the achievement test, the metacognitive skills inventory and the attitude toward mathematics scale.

#### Data collection

The data for the study were collected through the achievement test, the metacognitive skills inventory and the attitude towards mathematics scale. The following procedures were followed while these instruments (Kendir, 2012) were developed.

#### The achievement test

Firstly, the achievement test was designed, developed and administered in order to collect data on the dependent variable. In this respect, the educational attainments in "Geometry", a unit in the mathematics curriculum for fifth grade students, were identified and presented in a table of specifications along with the subjects they were related to. In this way, an attempt was made to ensure the content validity of the questions in the test. Designed in this way, a total of 40 multiple-choice questions were developed in consultation with subject matter experts and testing and evaluation experts. The test was administered to a total of 98 students in four classrooms that were similar to the ones included in the study. In accordance with the results, an item analysis was conducted on each question. Next, twenty items with an item difficulty (P<sub>i</sub>) ranging between 0.40 and 0.60 and discrimination index (r<sub>pb</sub>) higher than 0.30 were admitted into the standardized achievement test. The remaining 20 items which do not provide these requirements were excluded from the test. Ultimately, the researchers had a 20-item standardized achievement test with an intermediate item difficulty and high discriminating index. The reliability of the ultimate test was analyzed via the KR-20 method. The test had a KR-20 coefficient of 0.93.

The achievement test was administered to the experimental and control groups twice as a pretest and posttest. Great care was taken to encourage the students to come to the school on the day of the test and to administer the tests to the groups on the same day. Each correct answer was assigned 5 points whereas incorrect

**Table 5.** The independent t-test table on the comparison between the experimental and control groups in their posttest scores in the achievement test.

Group	N	X	Ss	t	p
Experimental group posttest	39	82,4359	6,0558	6,974	0.000
Control group posttest	36	67,5000	11,8019		P<0.05

or unclear answers were assigned 0 point. The highest and lowest possible score in the test was 100 and 0 respectively.

### **The metacognitive skills inventory**

The inventory was developed by O'Neil and Abedi (1996) to measure students' self-evaluation skills and later adapted to Turkish by Sönmez Ektem in 2007. It consisted of 20 items. The rating of the responses was based on the following criteria: four points for "absolutely yes", three points for "yes", two points for "no" and one point for "absolutely no". The highest and lowest possible scores in the inventory were 80 and 20 respectively. The inventory was administered to a total of 100 students by O'Neil and Abedi and found to have a reliability coefficient of 0.91. It was administered by the researchers to a total of 100 fourth grade students in three classrooms as a pilot scheme and had a Cronbach's alpha of 0.76.

### **The attitude scale**

The attitude scale was developed by Sönmez Ektem (2007) in order to measure students' affective tendency towards mathematics. The scale had a total of 25 items, which were revised in accordance with the opinions of experts before being administered as a preliminary test. The rating of the responses was based on the Likert scale: "strongly agree" (4 points), "agree" (3 points), "neutral" (2 points), "disagree" (1 point) and "strongly disagree" (0 point). The highest and lowest possible scores in the test were 100 and 0 respectively. As a preliminary test, the scale was administered to a total of 100 fourth grade students in three classrooms. The scale had a Cronbach's alpha of 0.91, which was considered sufficient.

### **Student views**

The experimental group was asked to write an essay on their views of the overall process. In this way, an attempt was made to identify the way they viewed the use of metacognitive strategies for solving math problems. The writing process came one week after the empirical procedure. The essays were assessed by the researcher.

### **Data analysis**

The data were analyzed in a detailed way in reference to the study questions and the conceptual framework. The findings were revealed in this way. The organized information was evaluated with a consideration given to the metacognitive behaviors of the fifth grade students observed. Afterward, the data were interpreted in order to give meaning to the findings, to explain the correlations between the findings and to draw conclusions.

The statistical techniques used in the study involved arithmetic mean, standard deviation and t-test. The statistical analyses were carried out via the Excel 7.0 and SPSS 16.00.

## **FINDINGS**

This section focused on the tabulated findings on the sub-problems revealed before and after the experimental procedure.

### **The findings related with the achievement**

The first sub-problem in the study was as to whether there was a significant difference in their achievement between the experimental group, which was taught to solve mathematical problems via metacognitive strategies, and the control group, which was taught in accordance with traditional approaches. In this respect, a comparison was made between the pretest and posttest scores of the control group. This was also the case for the experimental group. Next, there was a comparison between the pretest and posttest scores of both groups in the achievement test. The findings are presented in Table 4.

The mean score of the experimental group in the pretest was  $X=72.05$  whereas the control group had a mean score of  $X=66.11$  (Table 4.). The t-test was conducted to assess the significance of the difference. The t-test results showed that the difference (2.404 t) was not significant when compared to the accepted level of significance (0.05). The finding suggested that the groups were similar to each other before the experimental procedure.

The mean scores of the groups in the posttest were as presented in Table 5. The t-test was conducted to assess the significance of the difference between the groups. The t-test results showed that the difference (6.974 t) was significant when compared to the accepted level of significance (0.05). The finding suggested that metacognitive strategies improved the students' achievement at a higher level when compared to traditional approaches.

The mean score of the control group in the pretest was  $X=66.11$  whereas the group had a mean score of  $X=67.5$  in the posttest (Table 6). The t-test was conducted to assess the significance of the difference. The t-test results showed that the difference (0.797 t) was not significant when compared to the accepted level of significance (0.05). In other words, there was not a significant difference between the pretest and posttest scores of the control group. Therefore, traditional approaches had little effect on the students' achievement.

The mean scores of the experimental group in the

**Table 6.** The dependent t-test table on the comparison between the pretest and posttest scores of the control group in the achievement test.

Achievement test for the control group	N	X	Ss	T	P
Pretest	36	66.11	12.25	0.797	0.431
Posttest	36	67.50	11.80		P>0.05

**Table 7.** The dependent t-test table on the comparison between the pretest and posttest scores of the experimental group in the achievement test.

Achievement test for the experimental group	N	X	Ss	T	P
Pretest	39	72.05	9.01	-7,887	0.000
Posttest	39	82.43	6.05		P<0.05

**Table 8.** The independent t-test table on the comparison between the experimental and control groups in their pretest scores in the metacognitive skills inventory.

Group	N	X	Ss	t	p
Experimental group pretest	39	44,4103	3,5667	2,437	0.127
Control group pretest	36	42,6667	2,4842		P>0.05

**Table 9.** The independent t-test table on the comparison between the experimental and control groups in their posttest scores in the metacognitive skills inventory.

Group	N	X	Ss	t	p
Experimental group posttest	39	54,4615	5,7438	7,587	0.003
Control group posttest	36	46,4167	2,8422		P<0.05

pretest and posttest were as presented in Table 7. The t-test was conducted to assess the significance of the difference. The t-test results showed that the difference (-7.887 t) was significant when compared to the accepted level of significance (0.05). Therefore, metacognitive strategies had a more profound effect on the students' achievement than traditional approaches.

### The findings related with the metacognitive skills

The second sub-problem in the study was as to whether there was a significant difference in their metacognitive skills between the experimental group, which was taught to solve mathematical problems via metacognitive strategies, and the control group, which was taught in accordance with traditional approaches. In this respect, a comparison was made between the pretest and posttest scores of the control group. This was also the case for the experimental group. Next, there was a comparison between the pretest and posttest scores of both groups in the metacognitive skills inventory. The findings are presented in Table 8.

The mean score of the experimental group in the pre-

test was  $X = 44.41$  whereas the control group had a mean score of  $X = 42.66$  (Table 8). The t-test was conducted to assess the significance of the difference between the groups. The t-test results showed that the difference (2.437 t) was not significant when compared to the accepted level of significance (0.05). In other words, there was not a significant difference between the experimental and control groups in their pretest scores. The finding suggested that the groups had similar metacognitive skills before the experimental procedure.

The experimental group, which was taught how to solve mathematical problems via metacognitive strategies, had a mean score of  $X = 44.41$  in the pretest on their metacognitive skills. Following the procedure, their mean scores rose to  $X = 54.46$ . On the other hand, the control group, which was subject to traditional approaches, had a mean score of  $X = 42.66$ . Following the procedure, their mean scores rose to  $X = 46.41$  (Table 9). A review of the mean scores suggests that the experimental group had a considerable improvement in their metacognitive skills while the control group had a little increase. The difference between the groups in their posttest scores had a t value of 7.587, which was significant when compared to the accepted level of significance (0.05). The



**Table 10.** The dependent t-test table on the comparison between the pretest and posttest scores of the control group in the metacognitive skills inventory.

Metacognitive test for the control group	N	X	Ss	T	p
Pretest	36	42.66	2.48	-8,688	0.000
Posttest	36	46.41	2.84		P<0.05

**Table 11.** The dependent t-test table on the comparison between the pretest and posttest scores of the experimental group in the metacognitive skills inventory.

Metacognitive test for the experimental group	N	X	Ss	T	p
Pretest	39	44.41	3.56	-15.32	0.000
Posttest	39	54.46	5.74		P<0.05

**Table 12.** The independent t-test table on the comparison between the experimental and control groups in their pretest scores in the attitude scale.

Group	N	X	Ss	t	p
Experimental group pretest	39	56,0513	2,6352	7,457	0.146
Control group pretest	36	51,9722	2,0352		P>0.05

finding suggests that metacognitive strategies improved the students' metacognitive skills at a higher level than traditional approaches.

The mean score of the control group, which was taught how to solve mathematical problems through traditional approaches, in the pretest was  $X=42.66$  whereas the group had a mean score of  $X=46.41$  in the posttest (Table 10). The t-test results showed that the difference ( $-8.688$  t) was significant when compared to the accepted level of significance (0.05). Though the t-test was conducted to assess the significance of the difference, it can be said that, traditional approaches had a little effect on the students' metacognitive skills.

The mean scores of the experimental group in the pretest and posttest were as presented in Table 11. The t-test was conducted to assess the significance of the difference. The t-test results showed that the difference ( $-15.32$  t) was significant when compared to the accepted level of significance (0.05). Therefore, when Tables 10 and 11 are compared, it's seen that metacognitive strategies improved the students' metacognitive skills at a higher level than traditional approaches.

### The findings related with the attitude toward mathematics

The third sub-problem in the study was as to whether there was a significant difference in their attitude toward mathematics between the experimental group, which was taught to solve mathematical problems via metacognitive strategies, and the control group, which was taught in

accordance with traditional approaches. In this respect, a comparison was made between the pretest and posttest scores of the control group in the attitude scale. This was also the case for the experimental group. Next, there was a comparison between the pretest and posttest scores of both groups in the attitude scale. The findings are presented in Table 12.

The mean score of the experimental group in the pretest was  $X=56.05$  whereas the control group had a mean score of  $X=51.97$  (Table 12). The t-test was conducted to assess the significance of the difference. The t-test results showed that the difference ( $7.457$  t) was not significant when compared to the accepted level of significance (0.05). In other words, there was not a significant difference between the experimental and control groups in their pretest scores. The finding suggested that the groups had similar attitudes before the experimental procedure.

The experimental group, which was taught how to solve mathematical problems via metacognitive strategies, had a mean score of  $X=56.05$  in the pretest on their attitudes. Following the procedure, their mean scores rose to  $X=61.71$ . On the other hand, the control group, which was subject to traditional approaches, had a mean score of  $X=51.97$ . Following the procedure, their mean scores rose to  $X=55.95$  (Table 13). A review of the mean scores suggests that the experimental group had a higher increase in their mean scores in the test on their attitudes when compared to the control group. The t-test was conducted on the difference between the groups in their posttest scores. The difference had a t value of  $7.879$ , which was significant when compared to the accepted

**Table 13.** The independent t-test table on the comparison between the experimental and control groups in their posttest scores in the attitude scale.

Group	N	X	Ss	t	p
Experimental group posttest	39	61,7179	3,8929	7,879	0.004
Control group posttest	36	55,9544	2,1239		P<0.05

**Table 14.** The dependent t-test table on the comparison between the pretest and posttest scores of the control group in the attitude.

Attitude test for the control group	N	X	Ss	T	p
Pretest	36	51.97	2.03	-8,442	0.000
Posttest	36	55.94	2.12		P<0.05

**Table 15.** The dependent t-test table on the comparison between the pretest and posttest scores of the experimental group in the attitude scale.

Attitude test for the experimental group	N	X	Ss	T	p
Pretest	39	56.05	2.63	-9,296	0.000
Posttest	39	61.71	3.89		P<0.05

level of significance (0.05). The finding suggests that the experimental group, which was taught with metacognitive strategies, had significantly higher scores in the posttest than the control group.

The mean scores of the control group in the pretest and posttest were as presented in Table 14. The t-test was conducted to assess the significance of the difference. The difference (-8.442 t) was significant when compared to the accepted level of significance (0.05), but still it can be said that, traditional approaches had little effect on the students' attitude toward math.

The mean scores of the experimental group in the pretest and posttest were as presented in Table 15. The t-test was conducted to assess the significance of the difference. The difference (-9.296 t) was significant when compared to the accepted level of significance (0.05). Therefore, metacognitive strategies improved the students' attitudes at a higher level than traditional approaches.

### The findings on student views

The students in the experimental group were asked to write an essay on their views of the use of metacognitive strategies for solving mathematical problems. These views were obtained one week after the empirical procedure. The following are several extracts from the essays:

**Cihan:** *"I lacked self-confidence. I have started to believe in myself and like mathematics. Once uninteresting to me, mathematics has aroused my interest now. It has*

*turned into fun thanks to the strategies and games that we were involved in."*

**Sude:** *"I have started to believe in myself, for I have learned how to solve problems. I would give up when I failed to solve them and would not make a second effort. However, my teacher encouraged me, led me to different ways of solution, provided me with clues, and, thus, I came up with the solution. I have started to like geometry."*

**Askinnur:** *"I did not like geometry, for I did not like mathematics. Both were boring to me, for I could not understand them. However, our teacher came up with something that we had never tried before: metacognition. Thanks to what we did, I have started to see mathematics not in the old way but as something fun like music and painting. As our teacher says, geometry is actually a rebus. Now I believe that I can be more successful in geometry."*

As can be concluded from these views, nearly all students had an improvement in their attitude toward mathematics, geometry and problem solving. The underlying reason must be the increase in their self-confidence. This, in turn, might be attributed to the fact that they better learned geometry and how to solve problems. In fact, the students in the experimental group were provided with individual guidance and, thus, enabled to fill the gap. Abdussamet and Aleyna express their views in this respect as follows:

**Abdussamet:** *"Our teacher helps us when we fail to understand something. I did not use to know if I was doing right or wrong while solving problems. Now, our*

*teacher guides us with questions while we are dealing with problems. In this way, we are able to see whether our ways of solution are correct or incorrect."*

**Aleyna:** *"We used to solve problems too quickly; therefore, we could not understand most of them. We learned that we should solve problems more slowly and carefully. While solving problems, we realized that we did not know some subjects. Our teacher referred back to these subjects and retaught the parts that we failed to understand. She solved sample questions and reinforced our knowledge of these subjects. In this way, we learned about subjects that we did not use to know."*

As can be concluded from the views, an attempt was made to enable students to be aware of their thinking processes and the steps they followed while solving problems. When students associated a problem with a formerly-covered subject or subjects and realized their cognitive deficiency, the teacher made an effort to refer back to these subjects in order to fill the gap. The ability to solve problems involves a cognitive competence, too. Therefore, it is essential that each student should think about what subject a problem is associated with, that he/she should decide how to apply his/her cognitive competence in that subject to the problem, that he/she should realize in what subjects he/she is cognitively deficient, and that he/she should make himself/herself cognitively competent in those subjects.

Another important issue emphasized in the student essays is that mathematical problems are solved too quickly and students are rarely provided with enough time to find a correct solution to problems. Another advantage of using metacognitive strategies in the problem solving process is that students are provided with the opportunity to solve problems more slowly and in a more careful and controlled manner. In fact, it is one of the fundamental objectives of metacognition that students should constantly control their activities during and after the problem solving process. In this way, students are provided with an opportunity to regulate and evaluate themselves. The following is an extract that supports this idea:

**Yeter:** *"Mathematics has started to be more entertaining. I have started to like thinking about the problem, planning and drawing figures. I used to make a lot of mistakes while solving a problem, for the process was too fast. Our teacher asked us whether we had understood or not. When we reported that we had not understood, he/she would go over the problem again too quickly. This time I could not report that I had still not understood. With this method, we solve problems slowly through games. I do not make mistakes now. Even if I make a mistake, I see where I am wrong and understand problems in a better way."*

This view of Yeter's supports the idea above. It is regarded as an indicator of understanding the problem to

think about it, to express views about it and to illustrate it with figures or schemes. In addition, individuals become successful in solving a problem when they realize their mistakes and decide on the source of such mistakes.

**Fadime:** *I realized that I had deficiencies in problem solving. In fact, I have realized that problem solving is different than the way we used to solve problems. We did not use to solve them; we just memorized them. Now I know how to solve problems. Thanks to the procedures that our teacher taught us, I have started to solve problems in an easier way. Now mathematics is not a course that I am fearful of."*

**Hasan:** *"I did not use to like mathematics. I just saw it as a course that I had to pass and to succeed at. Now it does not seem the same to me. For example, I have started to understand and solve problems better now that we use certain procedures and solve problems by drawing figures and playing games."*

**Ertugrul:** *When I failed to understand parts of geometry while solving problems, I realized that I had to learn them and that I should not memorize them as I used to do. Except for a few rules, geometry is actually a puzzle. I have fully understood geometry. I have realized how important it is to solve problems in a correct way. I have learned how important it is to understand the question."*

**Ilayda:** *These practices enabled me to like mathematics better. I have started to think that all problems are easy. I am now more eager to find an answer to anything that bothers me about a problem. I have started to look into those subjects that I used to avoid. Our teacher told us that mathematics is a course that is able to get cross; that is, it will get cross with us and become more difficult to understand if we do not pay enough attention to it. I guess we offended mathematics, but this is not the case now. I am interested in it. I have realized that mathematics is an interesting course."*

One interesting thing about the views above is that understanding a problem and learning how to solve it have a positive influence on students' attitude toward a course.

During the practices, an attempt was made to enable students to start solving problems only after they had fully understood them. That is because understanding a problem and deciding on the necessary procedures mean solving it. In conclusion, student views and observations during the practices suggest that the problem solving process based on metacognitive strategies has important influences on students in that they make students more successful, they enable students to perceive the importance of problem solving and they improve students' attitude toward mathematics.

## DISCUSSION

In this section, the findings on the sub-problems of the

study are interpreted and discussed.

### The discussion related with achievement

The first sub-problem in the study was as to whether there was a significant difference in their achievement between the experimental group, which was taught to solve mathematical problems via metacognitive strategies, and the control group, which was taught in accordance with traditional approaches. The analysis of the first sub-problem involved determining any possible difference between the experimental and control groups in their scores in the achievement test on "Geometry", a unit of mathematics. The statistical analysis and findings suggest that there was a difference between the experimental group, which was subject to metacognitive strategies, and the control group, which was taught with traditional approaches, in their achievement, with the difference being in favor of the experimental group. The finding indicates that students' achievement is affected in different ways by the use of metacognitive strategies and traditional approaches in "Geometry", a unit in the mathematics curriculum for fifth grade students. The difference in favor of the experimental group must have resulted from the use of metacognitive strategies. It is reported in the literature that it is not surprising that students using metacognitive strategies for solving problems exhibit high levels of achievement. Such studies (O'Neil and Abedi, 1996; Küçük-Ozcan, 1998; Thomas, 2003) report that the use of metacognitive strategies in the process can be associated not with knowledge about subject matter but with planning, cognitive strategies, monitoring and being aware, and that an increase in the harmony between these components generally leads students to succeed in solving problems.

As revealed by the observations throughout the study, those students using metacognitive strategies in the problem solving process are more sensitive to understanding a problem and they associate it with one they have already solved and their existing knowledge about it. As stated by Çakıroğlu (2007), being aware of the problem is only possible when students have fully understood it. Considering that critical reading is a linguistic skill that every reader needs to have in today's world of information (Çifçi, 2010), metacognitive strategies, which enable students to maintain controlled understanding, can be argued to make students using them for reading more successful. In a study on students' problem solving strategies, Ballew (1985) (as cited in Altun, 1995) provided 19 sixth grade students with problems suitable for seventh and eighth grade students (problems with one procedure, problems with many procedures, problems that require much knowledge, problems that contain insufficient information) and analyzed their mistakes and successful strategies. The students were made to think

aloud while solving the problems. The mistakes were analyzed via recording tapes. The identified mistakes fell into four groups: (1) calculation (addition, subtraction, multiplication, division for natural numbers and rational numbers), (2) problem interpretation (the correct procedures in the correct order), (3) reading (unassisted problem reading), and (4) completion (combination of the procedures and correct solution). The distribution of the mistakes by the groups was as follows: 26% for calculation, 47% for reading and problem interpretation, and 26% for completion. In other words, the mistakes mostly resulted from problem reading and interpretation. Therefore, one can argue that success in problem solving is mainly correlated with reading comprehension, or understanding the problem. Nearly all the studies that support this idea (Thomas, 2003; Özsoy, 2010) report that understanding the problem is highly influenced by metacognition. The present study confirms the fact that reading and understanding occupy a prominent place in problem solving and that metacognitive strategies have an important role to play when students fail to understand what they read (Bonds and Bonds, 1992; Underwood, 1997).

The findings suggest that students generally become successful when they are aware of what they need to do and able to control the procedures. Similarly, Follmer's (2000) (as cited in Yazgan, 2002) study, whose purpose was to analyze the effect of strategic reading and problem solving instruction on improving the thinking processes that students encounter while solving non-routine, verbal mathematical problems, reported that the instruction designed to enable students to use and apply verbal reading and problem solving strategies improved students' ability to "be aware of how to solve (metacognition)" and their self-confidence. In another study on students' ability to control themselves throughout the problem solving process, which is another important factor in the use of metacognitive strategies, McLeod (1985) argued that the problem-solver's self-control in solving mathematical problems is an essential component of effective problem solving and reported that the problem-solver is more successful when he/she is aware of what he/she is doing and when he/she is able to control himself/herself while implementing a solution plan.

According to Schunk (2009:190), teaching metacognitive strategy only in association with one task means students wrongly thinking that the strategy can only be applied to that task. In that case, learning transfer is impossible. Therefore, students should be provided with the opportunity to read different types of texts with different qualities, to solve problems, to interpret them, and to get involved in a number of reading and writing activities in which different methods are employed. In the present study, the students in the experimental group reflected on their thoughts and activities about the problem solving process in their essays. Studies report that "writing" is significant to be successful in learning

metacognition and that it especially improves one's "self-regulation" behavior. Even though "writing" and "metacognition" are thought as two different things, research has demonstrated that there is a close interplay between the two (Demircioğlu, 2008). It is reported that writing in mathematical problem solving helps students to explain their ideas and to reflect on their activities. Buerger (1997) noted that their metacognitive skills are improved when students write their ideas about the problem solving process in an explanatory way. Similarly, Pugalee (2004) maintained that writing not only increases students' achievement but also makes it easier for students to understand the problem. There are a number of studies that show metacognition increases students' achievement (Artzt and Armour-Thomas, 1992; Muchlinski, 1996; Gourgey, 1998; Mevarech, 1999; Blank, 2000; Riley, 2000; Zan, 2000; Kapa, 2001; Marge, 2001; Goldberg and Bush, 2003; Küçük-Ozcan, 1998), which supports the present study.

Therefore, it can be argued that students need to use metacognitive strategies in order to understand the problem properly and make fewer mistakes in the process, that they improve their self-regulation skills and self-confidence to the extent that they can use these strategies and express their thoughts clearly, and that they finally experience a significant increase in their achievement.

### **The discussion related with metacognitive skills**

In the analysis of the second sub-problem, an attempt was made to identify whether there was a significant difference between the experimental and control groups in their metacognitive skills. The statistical analysis and findings suggest that there was a significant difference between the experimental group, which was subject to metacognitive strategies, and the control group, which was taught with traditional approaches, in their metacognitive skills, with the difference being in favor of the experimental group. The difference is likely to have resulted from the success of the metacognitive instruction provided for the experimental group.

Martini (2002) reports that students' problem solving performance is affected positively when they have developed the ability to determine the contents of the problem and to describe the necessary elements for solving it, to select an appropriate plan or strategy to solve it, and to monitor and evaluate self-performance. These abilities are defined by the author as metacognitive skills. In the present study, the students in the experimental group improved their metacognitive skills. The improvement probably stemmed from the activities that would help students develop these abilities.

Early studies on problem solving (Bookman, 1993; Cai, 1994; Lucangeli et al., 1997) demonstrated that successful problem-solvers employ, more often than others, such

skills as planning, monitoring and evaluating their thoughts in the problem solving process. Later studies appear to be fully consistent with these early findings.

According to Kramarski et al. (2001), those students who have difficulty in problem solving actually have problems with understanding the problem, planning the solution process, selecting the correct strategy, reflecting on the solution and deciding on the sensibility of the solution. According to Cardella-Elawar (1995), unsuccessful students read the problem too quickly, do not believe that there might be more than one solution to the problem, and do not know how to carry out their procedures and how to control their solution process. Similarly, Zan (2000) studied the characteristics of unsuccessful students and found that they lack metacognitive skills. Many studies have revealed that teaching metacognitive skills not only improve such abilities but also have an influence on students' achievement. For instance, Paik (1991) studied the effect of metacognitive strategies used for problem solving on students' problem solving process and the extent to which they can gain metacognitive skills. Paik worked with eight groups of tenth grade Korean students. The researcher taught some of these students via metacognitive skills and others with the traditional approach. The researcher found a significant difference between the groups in their metacognitive skills and problem solving performance, with the difference being in favor of the experimental group. In other words, the students in the experimental group not only developed their metacognitive skills but also had an improvement in their problem solving performance. This finding supports the present study in that students can be enabled to gain metacognitive skills through the educational process.

### **The discussion related with attitude toward mathematics**

In the analysis of the third sub-problem, an attempt was made to determine whether there was a significance difference between the experimental and control groups in their scores in the attitude scale. The statistical analysis and findings suggest that there was a difference between the experimental group, which was subject to metacognitive strategies, and the control group, which was taught with traditional approaches, in their scores in the attitude toward mathematics scale, with the difference being in favor of the experimental group. The finding must have resulted from the fact that the students in the experimental group had been taught through traditional approaches until the study, that problem solving based on metacognitive strategies was more interesting to them, that these students were more motivated, that they were eager to solve problems because this was the first time they had participated in such a practice, and that the instruction satisfied their expectations.

Similar reasons are reported in Bozan's (2010) study. According to Bozan, the reason why most students are unsuccessful in problem solving is that they consider the problem far away from themselves, they are not motivated to solve it, and therefore, they fail to monitor and regulate their activities. Thus, it is essential that students should be enabled to develop the ability to "self-regulate" so that they will have higher motivation and develop a positive attitude. That is because self-motivation is commonly defined as "gaining a new strategy about something, transferring it to other situations and understanding the essence and function of the process."

Studies on the effect of metacognitive instruction on students' attitudes (Paris and Winograd, 1990; as cited in Sönmez Ektem, 2007) consider self-regulation and self-monitor as two basic characteristics of metacognition. Such studies report that learning is not simply a cognitive process; instead, it requires one's active participation. The finding seems to support the present study in that individuals evaluating themselves are those who can reflect on their own knowledge levels, abilities, motivation levels and learning characteristics.

In another study, Wilburne (1997) studied the effect of metacognitive strategies on students' success in problem solving and their attitude toward mathematics. The author found that metacognitive strategies had a positive influence on students' success in problem solving and their attitude toward mathematics. Similarly, Marsh (1992) discovered that students' learning is affected by their beliefs in what they can and cannot do. This is dependent not only on their knowledge and skills but also on their attitudes, expectations and learning processes (Gourgey, 1998; Hartman, 1998).

All these findings extracted from the literature support the finding of the present study that metacognitive instruction in the problem solving process has a positive influence on students' attitude toward mathematics.

## CONCLUSION AND RECOMMENDATIONS

An attempt was made in the present study to determine whether the experimental group, which was taught how to solve problems through metacognitive strategies, and the control group, which was taught through traditional approaches, significantly differed from each other in their achievement, metacognitive skills and attitude toward mathematics. There were clear differences between the groups in all the three variables, with the differences being in favor of the experimental group. Therefore, it can be argued that geometry subjects should be taught in a learning environment with activities that will support the development of metacognitive skills so that students will be more successful, have a more positive attitude, and, in particular, develop their metacognitive skills.

The data analysis involved not only worksheets but also student essays. The analysis suggested that the

improvement in the experimental group's attitude toward geometry and mathematics was mainly caused by the increase in their self-confidence. Furthermore, the students in the experimental group were observed to develop the abilities to understand the importance of problem solving, to understand the problem, to study in a planned way, and to control and be aware of the process. They also developed their reflective thinking skills.

An action research as a sub-unit of experimental design, the present study will hopefully bridge the gap between theory and practice. The study method enabled the researcher to be active in the classroom, to gain new knowledge and to broaden her pedagogic repertoire. Considering how much experiences she gained will contribute to her later studies and practices, the findings are only the visible part of the iceberg.

In the light of all these findings, the following recommendations could be made:

Environmental conditions should be arranged on the basis of metacognitive strategies and the educational process should be planned accordingly so that students, starting from the early years of primary education, can be enabled to develop a positive attitude toward mathematics, to maintain this attitude throughout their learning life, and to have self-confidence in the problem solving process.

Enough time should be allocated to problem solving in primary mathematics and students should be encouraged to be slower and more careful in the problem solving process. They should be discouraged from attempting to solve a problem without fully understanding it. Here it's seen that the experimental group differed from the control group in three attainment (achievement, metacognitive skills and attitude towards mathematics). But it should not be forgotten that it is a necessity to measure if these effects are long lasting and in latter studies the posttests should be applied to see the persistency.

Teachers should provide students with guidance throughout the problem solving process; they should try to enable them to fill any gaps. In this way, they can reveal and correct any mistakes or wrong learning in the use of metacognitive strategies.

Teachers themselves should be provided with in-service training on problem solving and metacognitive association so that they can carry out the process in a reliable way.

Opportunities should be provided for metacognitive strategies to be used not only in mathematics but also in other courses, especially in Turkish language teaching.

Reflective teachers should be encouraged to use action research, a tool for innovation in education based on critical thinking, more often in order to conduct studies on their own classroom or school practices.

## NOTE

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