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RESEARCH ARTICLE

The Effect of Using Metacognitive Strategies in Mathematics Lesson on Students' Metacognitive Awareness

Hızır Küçükakça[1], Ayşe Elitok Kesici[2], Ji-Eun Lee[3]

[1] Graduate Student, Department of Educational Sciences Curriculum and Instruction, Aydın Adnan Menderes University

[2] Professor, Department of Educational Sciences Curriculum and Instruction, Aydın Adnan Menderes University

[3] Professor, Department of Teacher Development and Educational studies Oakland University

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Abstract

This study examines how teaching metacognitive strategies to students in a sixth-grade mathematics class affects their metacognitive awareness. Participants were 36 sixth-grade students in a middle school affiliated with the Ministry of National Education of Turkey in the 2020-2021 academic year. The students in the experimental group (n = 18) were taught a total of 40 mathematics lessons for eight weeks to improve their metacognitive awareness. The students in the control group (n=18) were taught mathematics in line with the regular mathematics curriculum. Using the Jr. Metacognitive Awareness Inventory, participants in both groups took a pre-test at the beginning and a post-test at the end of the study. To better interpret the data obtained, various statistical tests were performed. The pre-test and post-test averages of the groups were compared using the t-test for the normally distributed data for dependent and independent groups. The pre-test results showed no significant difference between the metacognitive awareness scores of the experimental and control groups ($p>0.05$). The comparison of post-test averages showed that students' metacognitive awareness differed significantly in favor of the experimental group ($p<0.05$). According to this, it was concluded that metacognitive strategy teaching in mathematics courses positively affected students' metacognitive awareness levels.

Keywords*:* junior metacognitive awareness inventory, metacognition, metacognitive strategy, metacognitive awareness

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- Corresponding Author: Ji-Eun Lee, email: lee2345@oakland.edu

I. INTRODUCTION

There are qualities that societies want each individual to have, and they want to bring these qualities to individuals through education and training programs in schools. One purpose of schooling is to raise productive and socially developed individuals by fostering individuals' ability to cope with the problems they will encounter throughout their lives, such as the skills to adapt to the ever-changing world faster and easier and the ability to think, research, and question (Boydak, 2010). From this point of view, today's educational institutions aim to raise individuals who are aware of and responsible for their own learning rather than individuals who accept the information as it is (Doğan, 2013). According to Balcı (2007), children need to be asked to research information, internalize it by questioning, and have basic skills to build this knowledge. If new generations are brought up with this quality, they can become life-long learners who continuously learn to learn.

Teachers today are faced with students who come to them with different levels of information about how they learn. Some students are active learners who know how they learn and can apply what they know to a variety of learning situations. Some may be average students who work hard and are aware of the strengths and weaknesses of their learning but are unable to streamline their learning adequately. Some students may be passive learners with little awareness of how they learn and how to organize their learning. Teachers are faced with students coming to them with various levels of metacognitive skills. Thus, there is a need for teaching programs that develop students' metacognitive awareness levels. For this purpose, the Ministry of National Education in Turkey updated the Mathematics Curriculum in 2018. According to the program, one of the special aims of the mathematics teaching program is to improve students' metacognitive equipment and skills and to provide them with the ability to manage their self-learning processes with awareness (Ministry of National Education, 2018).

This research aims to probe the effects of incorporating metacognitive strategies in sixth-grade mathematics instruction on students' metacognitive awareness. The overarching research question is as follows: Is there a significant difference in metacognitive awareness between sixth-grade students in the experimental group who received instruction incorporating metacognitive strategies and those in the control group who received instruction without incorporating metacognitive strategies? This research question will be investigated by examining the following aspects: (a) the difference between the metacognitive awareness pre-test scores of the control and experimental groups, (b) the difference between the metacognitive awareness post-test scores of the control and experimental groups, (c) difference between the control group's metacognitive awareness post-test and pre-test scores, and (d) difference between the experimental group's metacognitive awareness post-test and pre-test scores.

II. RELATED LITERATURE

Development of the Concept of Metacognition

The emergence of metacognition, which is accepted as an essential concept in learning processes, can be dated to the Ancient Classical Period (490 BC - 323 BC). Socrates said: "All I know is to know that I know nothing." It is possible to associate the sentence with metacognition. It is undeniable that the ideas of philosophers such as Plato and Aristotle, who are important representatives of epistemology, are also related to metacognition. Later philosophers (e.g., Strato, Galen, Alexander of Aphrodisias, and Plotinus) continued to develop concepts before the perception of metacognition from about 300 BC to Late Antiquity (Spearman, 1923). Much later, in the 20th century, studies on metacognition increased with the developments in education, technology, and psychology. Bühler (1907), Huey (1908), Binet (1973), Dewey (1910), and Locke (1689) were the pioneers of studies on metacognition. Other educational psychologists have also argued that cognitive information and regulatory processes are sub-components of the psychological structure of metacognition (Brown, 1987; Georghiades, 2004). On the other hand, Jean Piaget's work on cognitive developmental psychology revealed that cognitive developmental stages are analyzable, observable, and measurable. While Piaget continued his studies, John Flavell became the first scientist to conceptualize the term metacognition in 1976.

Flavell (1976) first worked on memory and used the term "metamemory" to describe a person's knowledge of one's memory. Flavell (1979) also briefly defined metacognition as “thinking about thinking.” Flavell's definition was followed by many other definitions, often describing different emphases on components and processes associated with metacognition and contributing to the ambiguous nature of metacognition. While Costa (1984) expresses metacognition as the ability to know what one does not know, Brown (1985) defined it as the ability of an individual to control and direct individual own cognitive processes. Sternberg (1988), on the other hand, defined metacognition as a process in which a person plans what to do, watches while the plan is being done, and evaluates it after it is done. According to Butterfield et al. (1995), metacognition is the ability of individuals to know the factors about their cognition, create strategies related to these factors, and monitor and control their cognition in this way. The individual has also expressed metacognition generally as a set of intuitive applications used as an effective tool to help them organize their methods of solving problems. Kuhn (2000), on the other hand, expressed metacognition as being conscious of the thinking processes that exist on one's own and being able to control these processes. Ormrod (2004) defined it as what we know about our cognitive processes and how we use these processes to learn and remember them. Martinez (2006), on the other hand, defined it as monitoring and control of thought.

Components of Metacognition

Literature informs us of various definitions and models related to metacognition. Generally, these models examine metacognition in two related components: knowledge of cognition and regulation of cognition (Brown, 1987); Flavell, 1987; Schraw & Dennison, 1994). Knowledge of cognition refers to our awareness of our thought processes (Flavell, 1979), and regulation of cognition refers to our planning and control of these processes (Brown, 1987).

Metacognitive Knowledge

Metacognitive knowledge is described as knowledge, awareness, and a deeper understanding of one's own cognitive processes and products (Flavell, 1976). Scholars explain various frameworks with slightly different terminology and categorization to address multiple aspects of metacognitive knowledge. Schraw and Moshman (1995) include three types of metacognitive awareness: (a) declarative knowledge (knowing “about” things), (b) procedural knowledge (knowing “how” to do things), and (c) conditional knowledge (knowing the “why” and “when” aspects of cognition).

Flavell (1977) also identified three categories of metacognitive knowledge: (a) person, (b) task, and (c) strategy. Knowledge of person refers to both general knowledge of how people learn and process information and individual knowledge of one's own learning processes. Knowledge of task includes knowledge about the nature of the task and the type of processing requests that will be imposed on the individual. Knowledge of strategy contains conditional data on the time and place of information on cognitive and metacognitive monitoring (Braten, 2006). These variables result from the person, one’s actions, or the strategies the person uses, affecting metacognitive knowledge.

Metacognitive Control

In contrast to metacognitive knowledge, metacognitive control (metacognitive strategies) has been characterized as actual activities that we engage in to facilitate learning and memory (Schraw & Moshman, 1995). Metacognitive control consists of some algorithms during individuals’ cognitive processes. Özsoy (2008) expressed metacognitive control as the ability to benefit from metacognitive information strategically. Metacognitive control includes predicting an action or event, monitoring ongoing activity, controlling the consequences of actions, reality testing, and various other behavioral patterns to coordinate and control deliberate attempts to learn and solve problems (Brown & DeLoache, 1983). Veenman et al. (2004) claim that the components that make up metacognitive control are highly interdependent. Models in the literature are metacognitive control; planning a cognitive task by choosing appropriate strategies and cognitive resources; monitoring awareness of our progress and our ability to determine our performance through a cognitive task; it involves looking at the outcome and evaluating whether the learning outcome matches our learning objectives and whether the regulatory processes we use are effective (Schraw & Moshman, 1995).

Teaching Metacognitive Strategies

Teaching metacognitive strategies has a key role in education. When students learn how their cognitive processes work, they can control and use them more efficiently by reorganizing them to improve their learning (Ülgen, 1997). Through metacognitive strategies, students judge whether or not they can reach the result, determine the stages in which they will end the process, monitor the progress of the steps, and at the same time transfer the gained experiences to the new problems they encounter later (Gourgey, 1998). Training on developing metacognitive strategies increases students' metacognitive awareness (El-Hindi, 1996). Teaching students metacognitive strategies will enable them to continue learning throughout their education and life (Papaleontiou-Louca, 2014). Therefore, teaching students metacognitive strategies can positively contribute to developing their metacognitive awareness.

Literature shows various metacognitive strategies to improve students' metacognitive skills (Blakey & Spence, 1990). According to Blakey and Spence (1990), strategies such as defining what they know and what they do not know, talking about thinking, and developing self-control can be used in developing students' metacognitive skills. Schraw (1998) used a method called "strategy evaluation matrix" for strategy teaching, which focuses on the metacognitive knowledge dimension and aims to activate the students' declarative, procedural, and situational knowledge regarding the metacognitive knowledge subcomponent. Students are asked to complete each row of the matrix throughout the practice individually or as a group. Students were given time each week to think about the strategy used individually or as a small group. Reflection time may include exchanging ideas with other students about when and where to use a strategy. The students were then asked to review the matrix. Schraw reported that this method increases students' cognitive performance and encourages the use of strategy and that metacognitive strategies improve students' levels of metacognitive awareness of their metacognitive knowledge. She also stated that using summary matrices such as the strategy evaluation matrix in experimental studies can significantly improve metacognition.

Schoenfeld (1992) brought a different approach to teaching metacognition in his studies. He stated that the principles and perceptions of individuals are a component of their metacognition. Schoenfeld (1985, 1987) created courses that included using metacognitive strategies to improve students' metacognition. He asked various reflective questions to increase students' metacognitive awareness in these lessons, such as “What are you doing right now?”, “Why did you choose such a way?”, “Will the way you choose lead to a solution?”, “Do you have a different solution proposal?” These questions facilitate students' awareness of their metacognitive processes. Schoenfeld (1987) asserts that this method will increase students' positive attitudes towards mathematics and enable the transfer of learned concepts to daily life. This view supports Dewey's (1916/1980) understanding that school should be life itself, not preparation for life.

Measuring Metacognition

The abstract and often ambiguous nature of metacognition makes it challenging to measure (Veenman et al., 2006). Once we fully understand what metacognition is, it will be easier to measure it. Measuring metacognitive awareness; requires utilizing metacognition and research literature to develop a comprehensive understanding of metacognition, metacognitive processes, subprocesses, and research approaches. The research approach should allow for comprehensive data collection, analysis, and interpretation (Hughes, 2019). In this context, a detailed literature review and choosing the most appropriate research approach will enable a more objective measurement of metacognition.

Metacognitive awareness allows us to plan, track, and order our own learning. There are two different approaches to measuring metacognitive awareness: online and offline (Van Hout-Wolters, 2000; Veenman, 2005). Offline methods are used before or after the individual's learning performance, while online methods are used during the learning performance (Veenman, 2005). Questionnaires, scales, interviews, think-aloud protocols, teacher evaluation scales, monitoring checklists, online diaries, portfolios and calibration techniques, and inventories are used to measure metacognitive awareness (Karakelle & Saraç, 2007). It is seen that different quantitative and qualitative research methods and techniques are used to determine the level of metacognitive awareness. Each method has its advantages and disadvantages. Features such as the nature of the researched subject, and the quantity, and quality of the sample group to be studied play an important role in determining the method to be used. For example, one of the positive features of questionnaires is their ability to provide rapid and objective measurement of metacognition, even in large sample groups (Schellings & Van Hout-Wolters, 2011). The low validity of the metacognitive awareness scales can be shown as a negative aspect of the questionnaires (Harrison & Vallin, 2018). Therefore, measurement tools with high validity and reliability should be used to determine metacognitive awareness levels.

Metacognition in Mathematics Teaching and Learning

In the context of mathematics teaching and learning, various studies show that metacognition is considered one of the essential predictors of mathematical performance, and the use of metacognitive strategies increases the academic success of students in mathematics (Depaepe et al., 2010; Kahramanoğlu & Deniz, 2017; Kuzle, 2018; Ohtani & Hisasaka, 2018; Pehlivan, 2012). Sjuts (2003) also agrees that success in learning mathematics can be known through metacognition activities and identified three components of mathematical metacognition: (a) declarative, (b) procedural, and (c) motivational. Declarative metacognition includes the individual's own ideas, evaluations of operations, and awareness of strategic knowledge about solving a problem. Procedural metacognition refers to planning, examining, judging, and monitoring one's own actions. Motivational metacognition includes motivation, attitudes, and enthusiasm toward a situation. As it can be understood from these explanations, metacognition has an important function both in affective and cognitive acquisitions in mathematics learning.

Prior studies suggest the importance of metacognition in mathematics teaching and learning and the need to develop metacognition strategies. For this reason, if mathematics teachers purposefully teach their students metacognitive strategies, it affects the academic success, attitudes towards mathematics and problem solving skills of these students positively (Pehlivan, 2012). Problem solving skills also include metacognitive skills (Lester, 1982). In light of these explanations, taking into account the use of metacognitive strategies while teaching mathematics will contribute positively to the quality of mathematics teaching. As prior studies in mathematics education call for further investigations that can offer details of what students actually do metacognitively when learning mathematics and solving problems, more empirical studies that test valid and reliable strategies for monitoring and promoting metacognition are needed. Moreover, individuals who have developed metacognitive awareness will live with this awareness not only in mathematics class but also in all their learning and daily lives throughout their lives, and thus they will be able to cope with the problems they encounter more easily. In addition, metacognitive awareness will make important contributions to individuals becoming individuals who learn to learn.

III. METHOD

Research Design

Research designs that try to find cause and effect relationships between variables are called experimental designs. Experimental designs are classified as real experimental designs, semi-experimental designs and pre-experimental designs (Büyüköztürk, 2001). This study examined the effects of teaching metacognitive strategy to students in sixth-grade mathematics classes by incorporating students' metacognitive awareness in lessons and by comparing it with the control group. The research employed a semi-experimental design with a pre-test and post-test control group. Semi-experimental designs are preferred when authentic experimental designs are not applicable or insufficient (Karasar, 2019). In addition, the groups were created randomly. Both groups were administered a pre-test and a post-test before and after the teaching experiment. Applying a pre-test to the groups provided baseline information about the similarities and equivalences of the groups.

Participants

The participants comprised 36 sixth-grade students in a public school affiliated with the Ministry of National Education in Aydın, Turkey, during the fall semester of the 2020-2021 academic year. Eighteen students formed the control group, and the other 18 formed the experimental group. According to Senemoğlu (2020), the development of metacognitive strategies is examined in three periods: (a) birth to the age of five, when strategies are not useful and cannot be transferred, (b) 6-9 years of age when strategies can be used, but strategies cannot be developed, and (c) fourth grade of primary education, when students can grasp the strategies and benefit from suitable strategies. The research participants in this study were in the third period, where they could produce and apply metacognitive strategies.

Data Collection Tools

This study aimed to develop the metacognitive awareness of the experimental group students. For this reason, we looked for the instrument in accordance with the purpose of the study. To select appropriate instruments, we consider two criteria: (a) an instrument suitable for our research participants and (b) a self-report tool considering the feasibility of multiple iterations. While the research literature shows the paucity of self-report instruments designed to assess school-age students' metacognitive processes (Ning, 2019), we identified an instrument, which is called the Junior Metacognitive Awareness Inventory (Jr. MAI), that met our selection criteria,

The Jr. MAI was developed by Sperling, Howard, Miller, and Murphy (2002) to measure students' metacognitive skills in grades 3 – 9. The Jr. MAI (version B) contains a total of 18 items, and each item is rated on a 5-point Likert-type scale which ranges from "never" to "always" to report respondents' level of agreement. The Cronbach Alpha internal consistency coefficient of the inventory is 0.89, which indicates that it is reliable, and students' metacognitive awareness levels can be determined through the findings obtained with the inventory (Karakelle & Saraç, 2007). We selected this instrument because it is a self-report measure specifically designed to assess school-age students' metacognition. In this study, Jr. MAI was applied at the beginning and end of the experimental process of research in both the experimental and control groups to measure the students' metacognitive awareness.

Data Collection

The research was conducted face-to-face. The students were informed about the purpose of the study, its content, and procedures before conducting the teaching experiment. To improve their metacognitive awareness, a total of 40 hours of mathematics lessons were taught for eight weeks to the students (n=18) in the experimental group of the study. The researcher prepared lesson plans for the experimental group, following the 5E instructional model. This model includes five instructional phases: Engage, Explore, Explain, Elaborate, and Evaluate (Bybee, 2009). In the engage phase, the lesson starts with a short, engaging activity for students to access their prior knowledge and make connections. The explore phase provides activities that allow students to explore the new material. Teachers help students synthesize their learning from the earlier phases in the explain phase. The elaborate phase offers activities that students can apply what they have learned. In the evaluate phase, formal and informal assessments occur. Appendix A shows an example of an activity used in the lesson.

In the experimental group's lessons, Schoenfeld's reflective questioning method (1987) was used to improve students' metacognitive awareness. For example, the following reflective questions were asked during the lesson: "What are you doing right now?", "Why did you choose such a path?", "Will your preferred path lead to a solution?", "Do you have a different solution proposal?" Through these questions, the teacher tried to serve the students to be aware of their own metacognitive processes. A total of 32 activities, based on Schraw & Dennison's (1994) strategy evaluation matrix, were used, and four activities per week were applied to the students. Students filled out a weekly evaluation form at the end of each week for the 8-week duration (see Appendix B for an example of a weekly evaluation form). This implementation process was intended to teach students metacognitive strategies and develop their metacognitive awareness.

With the students in the control group (n=18), mathematics lessons were taught in line with the Secondary School Mathematics Curriculum developed by the Ministry of

National Education (2018). The typical teaching methods used in this group include teacher-led lectures, inquiry, learning by discovery, and learning by doing.

Analysis of Data

The sample size is influential in determining the statistical tests to be used in the research. As the number of people in the group increases, it is accepted that the data approaches the normal distribution and parametric tests can be used. However, there is no common consensus on this issue. Some researchers consider that the data do not meet the assumptions of normality when the number of groups falls below 30. If the number of groups is less than 6, it is recommended to use non-parametric tests. In addition, it is evident in the literature that researchers working with experimental designs with a small number of groups use parametric tests if the data meet the normality assumption (Büyüköztürk et al., 2019). In this study, as there were eighteen students in the experimental and control groups of the research, we first examined whether the data met the assumption of normality.

Normality Test. To determine whether or not the scores obtained from the Jr. MAI show normal distribution, we employed multiple methods as follows:

1. Descriptive statistics: We used descriptive statistics, such as arithmetic mean, mode, and median, to check for normality. The equality of mean, mode, and median values represents the normal distribution. In this context, the convergence of mean, mode, and median can indicate that the distribution is approaching normal. Since there is no defined criterion for the descriptive statistics mentioned here, it can be stated that it is more appropriate to evaluate it together with the results of other tests (Büyüköztürk et al., 2019).
2. Graphical analysis: The histogram and normal Q-Q graph, in which the normal distribution curve is also plotted, are mostly used in graph analysis. In the normal Q-Q graph, if the points are on or close to the 45-degree line, conformity to the normal distribution can be mentioned (Büyüköztürk et al., 2019).
3. Skewness and kurtosis coefficient values: When the skewness and kurtosis coefficients are close to 0 within the limits of ± 1, and the skewness and kurtosis indexes calculated by dividing the skewness and kurtosis coefficients by their own standard errors are close to 0 within the limits of ± 2, the normal distribution conditions are met (Büyüköztürk et al., 2019).
4. Shapiro-Wilk Test: This is a tool to determine the conformity of the distribution to normality in case the group size is less than 35. The fact that the p-value calculated as a result of the test is greater than 0.05 ($p > .05$) can be interpreted as the scores at this significance level do not deviate much from the normal distribution (Mertler & Vannatta, 2005).

T-tests. In this study, according to the normality test, t-tests were performed. The t-tests for independent samples were used to examine the difference between the Jr. MAI pre-test scores of the control and experimental groups and between the Jr. MAI post-test scores of the control and experimental groups. The t-test for independent samples is a powerful parametric test used to test the significance of the difference between the means obtained from two independent samples. Experimental designs and comparative screening designs are used to compare the means of two groups (Büyüköztürk et al., 2019). Dependent sample t-tests were used to determine whether there was a difference between the averages of the pre-test and post-test scores of Jr. MAI in the experimental and control groups. The t-test for dependent samples is a parametric test used to test the significance of the difference between the means obtained from two dependent samples. Experimental designs with pre-test and post-test control groups are used to compare the means of measurements obtained from a group at different times (Büyüköztürk et al., 2019). The significance level of p = 0.05 was used to analyze the data.

IV. FINDINGS

Descriptive Statistics and Normality Tests of the Jr. MAI Pre-tests

Table 1 presents the descriptive statistical analysis results of the Jr. MAI pre-tests. As shown in Table 1, the mean, mode, and median values of the Jr. MAI pre-tests of the experimental and control groups are very close to each other.

Table 1. Descriptive statistics analysis results of Jr. MAI pre-tests

Groups	N	Mean	Mode	Median	SD	Max.	Min.	Range
Experimental	18	65.80	63	65.50	7.637	82	53	29
Control	18	65.06	66.00	66.00	6.717	76	55	21

Histogram graphs and normal Q-Q graphs of the Jr. MAI tests of the experimental and control groups are presented in Figure 1 and Figure 2. The histogram graphs in Figure 1 show that the scores of the pre-tests of the Jr. MAI belonging to the experimental and control groups are consistent with the normal distribution curve. The normal Q-Q graphs presented in Figure 2 show that the scores of the pre-tests of the Jr. MAI belonging to the experimental and control groups are pretty close to the 45-degree normal Q-Q line.

Metacognition Pre-test Experiment Metacognition Pre-Test control

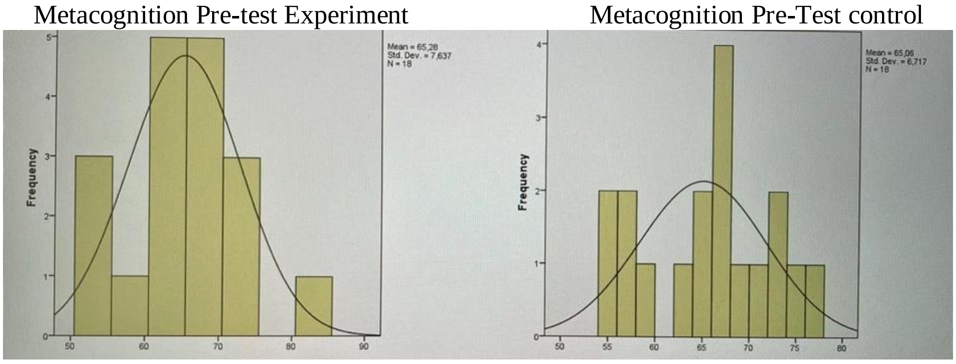

Figure 1. Histogram charts of the Jr. MAI pre-test

Normal Q-Q Charts Pre-test experiment Normal Q-Q Charts Pre-test Control

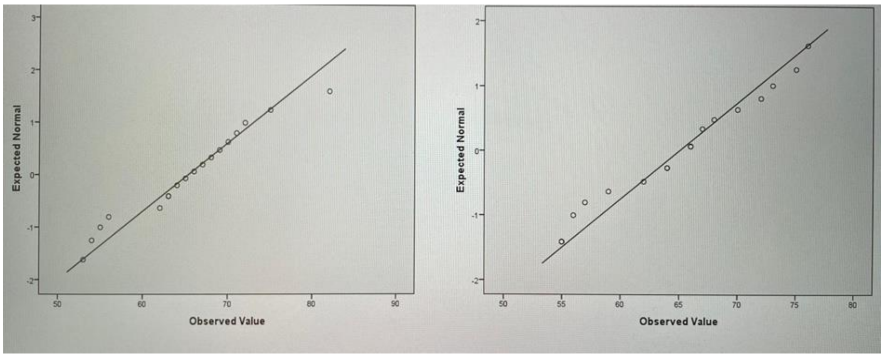

Figure 2. Normal Q-Q charts of the Jr. MAI pre-tests

The skewness and kurtosis coefficients of the Jr. MAI pre-tests of the experimental and control groups, the standard errors of the skewness and kurtosis coefficients, and the skewness and kurtosis indices are presented in Table 2. As shown in Table 2, the skewness and kurtosis coefficient values of the pre-tests of the Jr. MAI belonging to the experimental and control groups are less than ±1. In addition, it is seen that the skewness and kurtosis indexes obtained as a result of dividing the skewness and kurtosis coefficients by their own standard errors are less than ±2 for both groups.

Table 2. Skewness and Kurtosis coefficients and standard errors of skewness and Kurtosis coefficients, and skewness and Kurtosis indices of the Jr. MAI pre-tests

Groups	Skewness Coefficient	Kurtosis Coefficient	Standard Errors of Skewness	Standard Errors of Kurtosis	Skewness İndices	Kurtosis İndices
Experiment	0.154	0.049	0.536	1.038	0.287	0.047
Control	-0.058	-0.979	0.536	1.038	-0.108	-0.943

The Shapiro-Wilk Test results of the Jr. MAI pre-tests of the experimental and control groups are presented in Table 3. For both groups, the test did not show the evidence of non-normality (experimental group: W =0.966, p-value =0.720; control group: W =0.948, p =0.388).

Table 3. Shapiro-Wilk test results regarding the Jr. MAI pre-tests

Groups	Shapiro-Wilk Statistics	df	Sig.(p)
Experiment	0.966	18	0.720
Control	0.948	18	0.388

According to all the information above, the Jr. MAI pre-test results of the control and experimental groups seem suitable for normal distribution.

Descriptive Statistics and Normality Tests on Jr. MAI Post-Tests

Table 4 shows that the experimental and control groups' mean, mode, and median values regarding the Jr. MAI post-tests are pretty close to each other.

Table 4. Descriptive Statistical Analysis Results of Jr. MAI Post-Tests

Groups	N	Mean	Mode	Median	SD	Max	Min	Range
Experiment	18	71.39	73	73.00	7.594	85	55	30
Control	18	61.94	61	62.00	7.619	76	46	30

Histogram graphs and normal Q-Q graphs of the Jr. MAI post-tests of the experimental and control groups are presented in Figure 3 and Figure 4. Figure 3 shows that the scores of the Jr. MAI post-tests of the experimental and control groups are consistent with the normal distribution curve. The normal Q-Q graphs in Figure 4 also show that the scores of the Jr. MAI post-tests of the experimental and control groups are quite close to the 45-degree normal Q-Q line.

Metacognition Post-test Experiment Metacognition Post-Test control

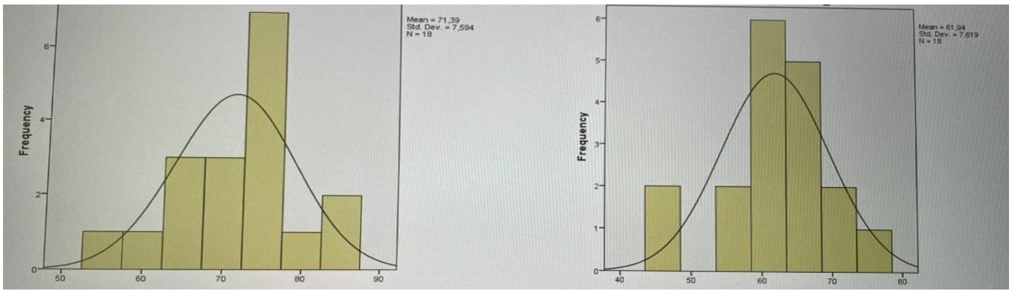

Figure 3. Histogram charts of the Jr. MAI post-tests

Normal Q-Q Charts Post-test experiment Normal Q-Q Charts Post-test Control

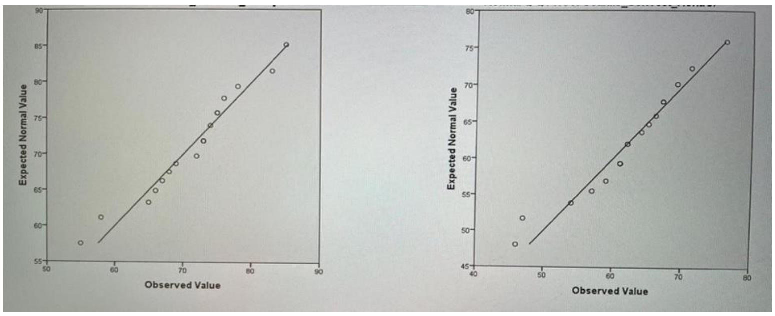

Figure 4. Normal Q-Q Charts of the Jr. MAI Posttests

The skewness and kurtosis coefficients of the Jr. MAI post-tests of the experimental and control groups, the standard errors of the skewness and kurtosis coefficients, and the skewness and kurtosis indices are given in Table 5. The result shows that the skewness and kurtosis coefficient values of the Jr. MAI post-tests of the experimental and control groups are less than ±1. In addition, the skewness and kurtosis indexes obtained as a result of dividing the skewness and kurtosis coefficients by their own standard errors are less than ±2 for both groups.

Table 5. Skewness and Kurtosis coefficients, standard errors of skewness and Kurtosis coefficients, and skewness and Kurtosis indices of Jr. MAI post-tests

Groups	Skewness Coefficient	Kurtosis Coefficients	Standard Errors of Skewness	Standard Errors of Kurtosis	Skewness Indices	Kurtosis Indices
Experiment	-0.417	0.486	0.536	1.038	-0.777	0.468
Control	-0.570	-0.593	0.536	1.038	-1.063	-0.571

The Shapiro-Wilk Test results of the Jr. MAI post-tests of the experimental and control groups are presented in Table 6. For both groups, the test did not show the evidence of non-normality (experimental group: W = 0.962, p-value = 0.648, control group: W = 0.953, p = 0.479).

Table 6. Shapiro-Wilk test results regarding the Jr. MAI post-tests

Groups	Shapiro-Wilk statistics	df	Sig.(p)
Experiment	0.962	18	0.648
Control	0.953	18	0.479

When all the findings above are evaluated together, the Jr. MAI post-test scores obtained from the experimental and control groups have a normal distribution.

Difference in Pre-test Scores

To determine whether there is a difference between the average scores of the Jr. MAI pre-tests of the experimental and control groups, t-tests were performed for independent samples. Table 7 shows the t-test results of the Jr. MAI pre-tests for the experimental and control groups. The results show that the averages of their scores are very close to each other (experimental group: M = 65.28, control group: M=65.06). In addition, there was no statistically significant difference between the experimental and control groups in terms of metacognitive awareness (p > .05). In the context of this study, it can be stated that the students in the control and experimental groups had equal metacognitive awareness before the teaching intervention.

Table 7. Independent sample t-test results of the pre-tests of the Jr. MAI

Groups	N	Mean	Standard Deviation	Degrees of freedom	t	p
Experiment	18	65.28	7.637	34	0.093	0.927
Control	18	65.06	6.717			

Difference in Post-test Scores

To determine whether there is a difference between the average scores of the Jr. MAI post-tests of the experimental and control groups, t-tests were performed for independent samples. Table 8 shows the t-test results of Jr. MAI post-tests for the control and experimental groups. The experimental group's post-test score average (M=71.39) is considerably higher than the control group's (M=61.94). In addition, the t-test result indicates that there was a statistically significant difference between the experimental and control group students in terms of metacognitive awareness ($p < .05$). In the context of this study, it can be stated that the metacognitive awareness of the students in the experimental control and experimental groups differed in favor of the experimental group after the teaching intervention.

Table 8. Independent sample t-test results of the Jr. MAI post-tests

Groups	N	Mean	Standard Deviation	Degrees of freedom	t	p
Experiment	18	71.39	7.594	34	3.725	0.001
Control	18	61.94	7.619			

Difference in Control Group's Pre- and Post-Tests

To determine whether there is a difference between the mean scores of the Jr. MAI pre-test and post-test of the control group, a t-test was performed for dependent samples, as shown in Table 9. The results show that the control group's pre-test and post-test mean scores differ, and the post-test average (M = 61.94) was lower than the pre-test average (M = 65.06). However, the t-test result indicates that there was no statistically significant difference between students' pre-test and post-test metacognitive awareness ($p >.05$). In the context of this study, it can be stated that there was no change in students' metacognitive awareness in the control group after the application.

Table 9. Dependent sample t-test results of the control group's Jr. MAI pre-and post-Tests

Tests	N	Mean	Mean Difference	Standard Deviation	Degrees of freedom	t	p
Pre-test	18	65.06	-3.12	6.717	17	1.646	0.118
Post-test	18	61.94		7.619			

Difference in Experimental Group's Pre- and Post-Test

To determine whether there is a difference between the averages of the Jr. MAI pre-test and post-test scores of the experimental group, a t-test was performed for dependent samples. Table 10 summarizes the results, showing that the experimental group's pre-test and post-test mean scores differ. The post-test mean score (M = 71.39) is considerably higher than the pre-test mean score (M = 65.28). Additionally, the t-test result indicates a statistically significant difference between the experimental group’s Jr. MAI pre-test and post-test ($p < .05$). Thus, it can be stated that the metacognitive awareness in the experimental group differed positively after the teaching intervention.

Table 10. Dependent sample t-test results of the experimental group's pre-test and post-tests

Tests	N	Mean	Mean Difference	Standard Deviation	Degrees of freedom	t	p
Pre-test	18	65.28	6.11	7.637	17	2.430	0.026
Post-test	18	71.39		7.594			

V. DISCUSSION

The research findings show that the experimental and control groups were at similar levels in terms of metacognitive awareness before the intervention. In experimental designs with pre-test and post-test control group, the fact that the groups were created by unbiased assignment necessitates the pre-test averages to be equal. If the measurement made at the beginning of the experimental process is significantly different from each other, it becomes difficult to compare and interpret the groups (Karasar, 2019).

According to the independent sample t-test conducted in the research, it was determined that the mean metacognitive awareness scores of the experimental and control groups differed significantly in favor of the experimental group. This result showed that the students in the experimental group had higher average of metacognitive awareness scores. It indicates that teaching metacognitive strategies in mathematics class effectively increased students' metacognitive awareness levels. The study results imply that the interventions used in this study play an essential role in developing students' metacognitive skills. Such interventions included defining what students know and what they do not know (Blake & Spence, 1990), making weekly assessments about metacognitive strategy (Schraw, 1998), and the in-class reflective questioning activities (Schoenfeld, 1987).

The findings show that the metacognitive awareness level of the control group did not change before and after the application. This group used the current Ministry of National Education's (2018) Secondary School Mathematics Curriculum in Turkey, using the standard in-class methods that the students are accustomed to and not introducing a different application for the course. These findings imply that students’ metacognitive awareness might not be naturally developed without intentional and purposeful use of metacognitive strategies in mathematics lessons. In this regard, it is plausible that the current Ministry of National Education's (2018) Secondary School Mathematics Curriculum in Turkey lacks methods and activities to improve students’ metacognitive awareness.

In contrast, the research findings show that the level of metacognitive awareness of the experimental group increased considerably after the teaching intervention, which incorporated teaching metacognitive strategies for eight weeks, a total of 40 lesson hours. Thus, we conclude that this intervention contributed to the students' increased metacognitive awareness. Similar to the findings of this study, studies conducted by Çobanoğlu (2019) and Kaplan and Aykut (2022) also confirm that the post-test mean scores of the experimental group were higher than the pre-test mean scores after the intervention of using metacognitive strategies.

In sum, the research results showed that teaching students metacognitive strategies would support the development of students' metacognitive awareness and, therefore, could contribute positively to students' educational processes and lifelong learning skills.

Limitations and Suggestions for the Future Research

While this study confirms the effects of teaching metacognitive strategies on students' metacognitive awareness, we acknowledge some limitations of the study. First, our study is limited to sixth-grade mathematics instruction. Future research can be conducted in different subject matters and grade levels to confirm our research findings. Second, our quasi-experimental study is limited to the intervention through 40 mathematics lessons over eight weeks. As the length of intervention might be an influential factor, future quasi-experimental research with more extended intervention periods can be conducted to examine the changes in students' metacognitive awareness. Third, this study employed a quasi-experimental design with small samples. Therefore, semi-experimental studies with larger sample sizes can focus on different teaching methods, other than teaching metacognitive strategies, that are thought to have the potential to improve students' metacognitive awareness levels. Lastly, while this study primarily focused on the quantitative analysis, future qualitative and mixed studies can offer a more nuanced interpretation of the factors and aspects related to students' metacognitive awareness.

VI. CONCLUSION

This study contributes to the ongoing effort to optimize students' learning opportunities by focusing on their metacognitive awareness in mathematics learning. In addition, it leads to some implications for teacher training and school curriculum design. It might be a new skill for teacher candidates to learn how to teach metacognitive strategies effectively. Thus, teacher education programs need to consider offering courses or other opportunities related to metacognition. Additionally, in-service training can be organized to increase teacher expertise in metacognition. Since students' metacognitive development will contribute positively to both formal education and lifelong learning processes, it is desirable to include activities that purposefully support the metacognitive development of students in the curriculum of the Ministry of National Education of Turkey. Metacognition is not limited to a specific aspect of the individual; instead, it concerns the entire cognition of the individual. Therefore, the educational environment can be created to improve students' metacognitive awareness in all classes and at all grade levels.

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Appendix A

Numbers And Transactions Actıvıty Example

In this example activity, students were asked questions that activated their use of metacognitive strategies while solving a problem.

Question: Damla reads 5 times as many pages as the previous day for three days. Since Damla read 5 pages of a book on the first day, find the number of pages she read on the 3rd day using exponential expressions.

1) What information have I learned about this question before?

(Declarative information)

2) What information about this question have I not learned/remembered/needed before?

(Declarative information and procedural information)

3) How will I complete the missing information?

(Procedural knowledge and situational knowledge)

4) How will I go about solving this question?

(Metacognitive strategy (planning, forecasting…))

Solution:

Appendix B

Weekly Evaluatıon Form (Week 1)

Below are selected attainment of the topics covered this week. Indicate at the bottom of the form what kind of path you followed in the achievements that you are sufficient and how you can follow the path of the achievements that you think are insufficient.

ATTAİNMENTS	My learnings	My shortcomings.
Writes the repeated multiplication of a natural number with itself as an exponential expression and calculates its value.		
Performs four operations with natural numbers, taking into account the operation priority.		