The Effects of Student Mathematics Diaries on Achievement, Motivation and Metacognitive Awareness: Mixed Methods Design

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The aim of this study is to investigate the effects of mathematics (math) diaries on academic achievement, metacognitive awareness and motivation of students in a mathematics lesson. The case study was conducted with a qualitative, quasi-experimental design and a quantitative, embedded multiple-case design as a mixed research model. The sample of the quantitative part of the study consisted of 32 4th-grade students, 16 of whom were in the experimental group and 16 in the control group. The participants in the qualitative part of the study were 16 students from the experimental group where math diaries were used. The quantitative data collection instruments used in the study were the Perimeter Measurement Achievement Test for primary school students, the Mathematics Motivation Scale for primary school students and the Metacognitive Awareness Scale. The students' structured math diaries were used to collect qualitative data. The quantitative data obtained were analyzed using a One-Way ANCOVA and Paired Samples t-test, while the qualitative data from the math diaries were thoroughly analyzed using a qualitative content analysis. As a result of the one-way analysis of covariance, statistically significant differences were found between the adjusted posttest means of the groups, which were adjusted for pretest scores on student achievement, metacognitive awareness, and motivation. In the qualitative dimension of the study, positive improvements in students' achievement, metacognitive awareness, and motivation were observed from the beginning to the end of the implementation process, as revealed by the analysis of their math diaries.

Introduction

Geometry, an important branch of mathematics, is one of the most difficult subjects for students to understand because of its abstract structure. To understand the logic of the subject, students need to understand geometric concepts and have concrete experiences in an appropriate learning environment (Sarı & Tertemiz, 2017, p. 2). For this reason, this study addresses the subtopic of perimeter measurement with a constructivist approach and reflective thinking skills.

Educators should be concerned with making students aware of how they learn rather than what they have learned (Doğan, 2013, p. 7). This state of awareness reflects the concept of metacognition. Metacognitive awareness is an awareness of what a person knows and does not know, that they are able to control their own cognitive processes and that they are aware of their own learning strategies. Furthermore, metacognitive awareness is about taking responsibility, evaluating, organizing, and tracking one's own learning (Bağçeci, et al., 2011, p. 552). The constructivist approach helps individuals to create new knowledge by bringing their previous knowledge and experiences into the learning process through methods of conversation and reflection (Shunk, 1996). The constructivist approach contributes to developing an individual's high-level thinking skills by providing activities, environments, tools, and equipment that give the learner high-level cognitive skills (Murphy, 1997; as cited in Yurdakul, 2005, p. 289).

Reflective thinking is an important metacognitive skill in constructivism. By reflecting on the teaching process, individuals find the opportunity to reconstruct their experiences (Henderson, 1996; Moallem, 1997, as cited in Demiralp & Kazu, 2012, p. 30). This study

hypothesizes that children who use the method of reflective thinking will develop metacognitive awareness and, in this way, will begin to understand the path they are following in the learning process rather than just achieving an outcome.

Motivation is another important factor in education that shows the effectiveness of the learning and teaching process and illustrates the individual's willingness to implement certain behaviors (Akbaba, 2010). Two types of motivation are mentioned in the literature: intrinsic and extrinsic. Intrinsic motivation arises from orientations in a person's life due to interest, curiosity, and needs and is related to the person's genetic structure (Berkant & Yaren, 2020). In intrinsic motivation, the desire to succeed exists only for the purpose of gratification and without any reward. In extrinsic motivation, the desire to succeed arises from influences such as reward, punishment, pressure, or environmental stimulation (Akbaba, 2010). For example, a student who is motivated when praised by his teacher for a good grade on an exam is extrinsically motivated.

Motivation and academic achievement are closely related (Bymes, 2011; Middleton & Spanias, 1999; Randhawa & Gupta, 2000; Schiefele & Csikszentmihalyi, 1995). The relationship between academic achievement and motivation throughout the learning process is quite strong; a highly motivated person can achieve the desired level of success (Erten, 2007). Students who are motivated to learn actively participate in lessons; they exhibit behaviors such as establishing a relationship between old and new knowledge and asking questions about the subject (Bozkurt & Bircan 2015). External factors such as the learning environment and rewards, as well as the student's interests and needs, are very effective in motivating individuals throughout the learning process (Palmer, 2005).

Various strategies should be developed to improve students' academic achievement. One factor to be considered is student motivation (Akbaba, 2010). Using writing activities in the learning process as an alternative strategy is beneficial in learning mathematics (Borasi & Rose, 1989). Writing activities in mathematics lessons can be useful tools to assess situations such as students' attitudes, motivation, academic achievement, reflections, and metacognitive thoughts.

Joan Countryman (1992) has outlined the benefits of writing activities in mathematics as follows:

- It enables them to record what they are learning and what they are doing.
- It enables them to solve mathematical problems.
- It enables them to explain their mathematical ideas.
- It enables them to explain their learning processes.

An effective writing technique used in mathematics teaching is diaries (Urquhart, 2009). According to Hiemstra (2001), when writing a math diary, students reflect on what they know and what they do not know. This is not only an important assessment factor for students and teachers but also contributes positively to students' academic achievement. Writing a diary promotes student motivation, especially intrinsic motivation, and problem-solving skills (Hiemstra, 2001). Keeping a diary allows students to track their own learning process and improve their self-awareness (Güvenç, 2011). The impact of the student diaries was investigated in this study as an instrument of reflective thinking. In examining the impact of student diaries on metacognitive development, Graham (1994) examined the metacognitive awareness processes defined in the diaries in four dimensions: self-awareness,

knowledge awareness, task awareness, and strategy awareness - and showed that these dimensions emerged through reflective thinking. The definitions for these dimensions can be found below:

Self-awareness: Buss & Scheier (1976) define inner concentration on thoughts, feelings, or motives as self-awareness. Self-awareness means being aware of one's own learning characteristics and being able to evaluate them (Papaleontiou-Louca, 2003). It is the state of being aware of the learner's inner state, personal characteristics, goals, interests, strengths and weaknesses, abilities, feelings, and thoughts. In addition, it is also defined as knowledge of the learner's attitude towards the work to be done and his/her preferences concerning a subject. Furthermore, this dimension of awareness enables the learner to practice self-assessment and self-criticism.

Knowledge awareness: John Flavell, one of the first researchers in the field of metacognition and memory, defined these two areas as metacognitive knowledge and metacognitive regulation. These two components are used together to inform learning theory. According to Flavell (1979), awareness of knowledge includes understanding what one knows, what one does not know, and what one wants to know. This category can also include awareness of the knowledge of others. It is the state of being aware of the learner's prior knowledge, the relationship between that prior knowledge and the new knowledge, and the lack of knowledge in accomplishing a task. This dimension of knowledge awareness occurs when the learner not only successfully learns the information but also when he or she fails to learn it. In short, knowledge awareness is defined as the state of being aware of what the learner knows and does not know (Flavell, 1979).

Task awareness: Wade and Reynolds (1989) define task awareness broadly as knowing what information in a text is relevant to success in a particular learning situation. It is the state of being aware of the importance of a task in which the student is involved. Being aware of the negative aspects of the task also means distinguishing the important and unimportant parts of the information contained in the task. According to Flavell (1979), It is awareness of what is necessary to accomplish a task. The desire to complete the task also shows that the student has task awareness. Task awareness helps students learn independently by identifying what information is appropriate for their study purposes (Wade & Reynolds, 1989).

Strategy awareness: This is the state of being aware of the strategy that the student prefers in the learning process. It is the ability to define why and how he uses the strategy he employs in the process. According to Ormrod (1990), it is the state of using learning strategies effectively and being aware of which learning method is effective and which is ineffective. Awareness of how the strategy affects himself and the learning process also indicates that the student has strategy awareness. Students with higher metacognitive awareness understand the similarity between the current learning task and previous tasks, know the necessary strategies for successful learning, and expect success because of knowing "how to learn" (Paris & Winograd, 1990). Chamot (1998) also noted that awareness of one's strategies is closely related to metacognition, adding that more successful learners have better and stronger metacognitive awareness. Finally, Cohen (2000) emphasises the importance of strategy awareness by stating that it is a key element of consciousness.

In this study, it is assumed that learning mathematics with the help of math diaries will reduces students' anxiety about mathematics, increases their motivation and thus improves their achievement in mathematics lessons.

The literature review revealed very few studies on this topic, especially at the primary level, that have used mixed methods. Due to the nature of the concepts being addressed in the study, it is important to take quantitative measures to examine the relationship between students' states at the beginning and end of the process. In addition, it is very important to observe the students' situation during the process and to record their development qualitatively.

Most studies on this topic in the national and international literature refer to secondary schools. Five studies were found at the primary school level. The studies conducted show that keeping a diary and writing activities in mathematics lessons increase academic achievement (Zeybek & Açıl, 2018; Yıldırım, 2016; Teuscher et al., 2015; Yılmaz, 2015; Eren, 2015; Ünlü, 2015; Aytaş, 2012; Çontay, 2012; Kasa, 2009; Steward, 1992), have a positive influence on attitudes towards mathematics (Küçük, 2019; Guce, 2018; Yıldırım, 2016; Teuscher et al., 2015; Ünlü, 2015; Kasa, 2009; Murcheson, 2010; Atasoy & Atasoy, 2006; Rose; 2005; Hasanoğlu & Tektaş, 2002), is effective in improving metacognitive behaviours (Kartalcı, 2018; Ünlü, 2015; Coffey, 2009; Murcheson, 2010; Pugalee, 2004), develops problem-solving and constellation skills (Küçük, 2019; Pilten & Pilten, 2016; Bicer et al., 2013; Wittcop, 2008; Pugalee, 2001), helps reduce math anxiety (Küçük, 2019; Banken, 2015; Emmert, 2015; Park et al., 2014), facilitates learning (Öztürk et al., 2016; Aytaş, 2012; Moore, 2007; Lefler, 2006), is an important tool for identifying learning difficulties (İnan, 2016), has a remarkable effect in identifying misconceptions (Ayyıldız, 2010), is an important tool for discovering individual needs (Banken, 2015), and helps them to understand mathematical problems and think more analytically about these problems (Walz, 2008).

Research Problems and Sub-Problems

In this mixed-methods quantitative-qualitative study, there is an experimental group in which math diaries are kept and a control group in which these diaries are not kept. A between and within-groups analysis was conducted to determine if there is a statistically significant difference between pre- and post-test mathematics achievement scores, pre- and post-test metacognitive awareness, and pre- and post-test mathematics motivation. Qualitatively, the aim is to determine: the effects of math diaries on students' success in problem solving and their expressions of success; metacognitive awareness and expressions of metacognitive awareness; and motivation towards mathematics and expressions of motivation.

Methods

A quantitative-qualitative mixed method was chosen for this study. A mixed method combines qualitative and quantitative methods, approaches, and concepts in one study (Creswell, 2003).

The research design was developed as a simultaneous triangulation of six basic designs (Creswell, 2003), which are types of mixed methods designs. The main purpose of concurrent triangulation is to test whether the results obtained are consistent with each other by applying the qualitative and quantitative data independently to the same research problem. In a concurrent triangulation design, quantitative and qualitative data are collected and analyzed simultaneously (Creswell, 2003).

Figure 1. Concurrent triangulation design

The quantitative dimension of the study is a pre-test-post-test designed using a quasi-experimental method with a control group. Quasi-experimental designs are used to establish cause-effect relationships and are defined as a type of research in which random samples cannot be done while adhering to the principles of a true experimental design (Büyüköztürk et al, 2014). The phases of the experimental design used in the quantitative dimension of the study are shown in Table 1.

Table 1
Quantitative Dimension Research Design

Groups	Pre-test	Experimental Process	Post-test
Experimental Group	ESPMAT MAS PSMMS	Keeping math diaries	ESPMAT MAS PSMMS
Control Group	ESPMAT MAS PSMMS	-----	ESPMAT MAS PSMMS

Note. In all groups:
ESPMAT: Elementary School Perimeter Measurement Achievement Test
MAS: Metacognitive Awareness Scale
PSMMS: Primary School Mathematics Motivation Scale

The qualitative dimension of the research was conducted using the case study method. The case study is a method used in situations where questions of 'how' and 'why' are investigated, the researcher has little influence on events, and the situation studied is a current phenomenon in the context of real life (Yin, 2003, p. 22). The characteristics of this study reflect the need for this method. For the qualitative dimension of this study, an embedded multiple-case design was developed from the four types of case studies mentioned by Yin (2003, p. 39). The embedded multiple-case design is important for future researchers as it reveals a previously unknown topic and provides a foundation or guide (Yıldırım & Şimşek, 2016, pp. 290-292).

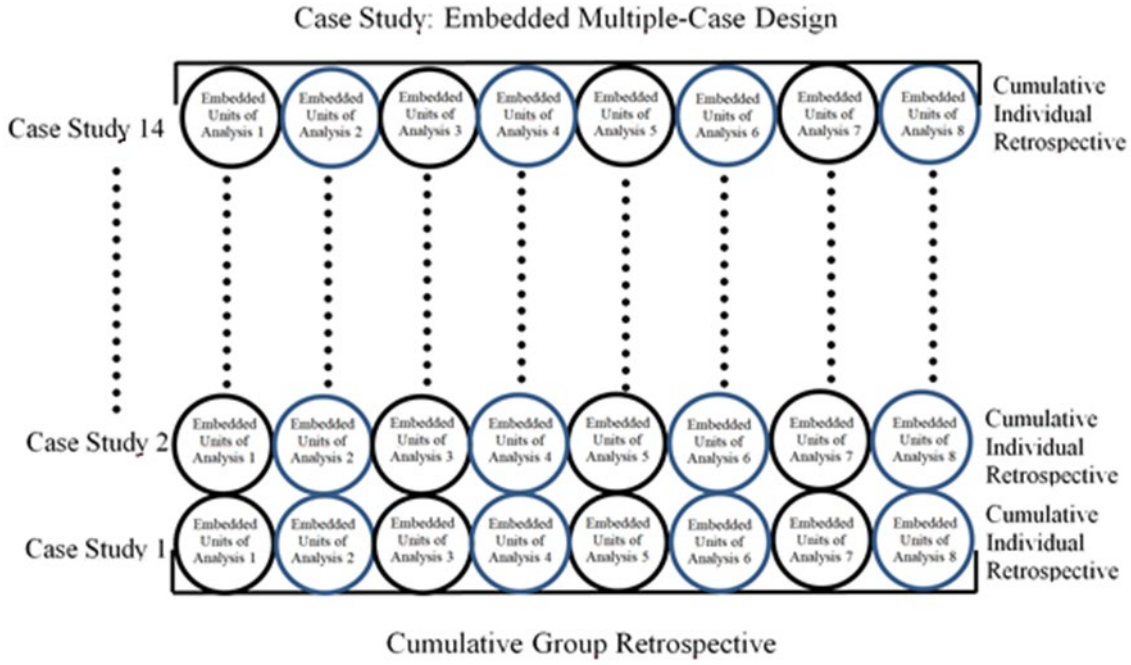


Figure 2. Qualitative Dimension Research Design

Study Group

The study group was determined using the Sequential Qualitative Mixed Method Design from mixed sampling types. In many studies conducted using this method, the sample used for the quantitative dimension is also used to determine the sample for the qualitative dimension. Therefore, the study group was determined as follows:

Study group on the quantitative dimension: The groups to be included in the quantitative dimension of the study were determined through a multi-stage sampling procedure. In the second semester of the 2017-2018 school year, 32 fourth-grade students of a government school with an intermediate socioeconomic level in Egeler district, Aydın province, formed the study group. Of these, 16 students are in the experimental group, and 16 students are in the control group.

Study group on the qualitative dimension: The groups to be included in the qualitative dimension of the study were determined as all the students in the experimental group from the previously determined study groups of the quantitative dimension according to the simultaneous sequential mixed method. In other words, the 16 students in the experimental group in which the math diaries were used formed the study group for the qualitative dimension of this study. In the qualitative dimension of the study, it was found that the diary records of two students of the 16 participants in the experimental group did not contain answers to some of the questions and the answers given were sometimes insufficient for analysis. Therefore, these students were excluded from the study. Thus, 14 students were identified as acceptable participants for the qualitative dimension of the study.

Data Collection Tools

Data Collection Tools Used for the Quantitative Dimension:

1. The Elementary School Perimeter Measurement Achievement Test (ESPMAT), whose KR20 value was determined to be 0.837 resulting from the reliability analysis developed by Genç and Öksüz (2018),
2. The Metacognitive Awareness Scale (MAS), which was developed by Sperling, Howard, Miller, and Murphy (2002) to measure metacognitive abilities and adapted into Turkish by Karakelle and Saraç by conducting validity and reliability studies, with a correlation value of 0.74 and a Cronbach's alpha value of 0.64 as the result of reliability analysis,
3. The Primary School Mathematics Motivation Scale (PSMMS), whose Cronbach's alpha value was determined to be 0.94 as the result of a reliability analysis developed by Ersoy and Öksüz (2015).

Data Collection Tools Used for the Qualitative Dimension:

Structured math diaries prepared by the researchers for the students served as qualitative data collection tools. A total of 8 diaries were distributed to the students during a three-week teaching process covering the learning domain of perimeter measurement. The first seven diaries distributed at the beginning of the process contained directed questions that asked students to share their opinions on how the mathematics lesson had gone that day, as well as a task that allowed them to measure their success on each perimeter measurement. The eighth and last diary distributed was prepared to ask for opinions about the three-week teaching process of the perimeter measurement learning domain.

The following steps were followed in the study:

- Three days before the implementation, the ESPMAT, MAS, and PSMMS obtained for the study were used as pre-test with the experimental and control groups.
- The Math Diaries were introduced three days after the pretest. The students were informed about the math diaries and the meaning of the reflective utterances, and the researchers obtained permission from the students to read these diaries.
- The eight math diaries were distributed to the students every week after each math lesson for about three weeks. These diaries were filled in by the students at home and collected at school the next day. New diaries were handed out to them on the same day.
- The eight math diaries were evaluated for each of the 14 participating students. A total of 112 math diaries were evaluated.
- As a result of the implementation process, the ESPMAT, MAS, and PSMMS pre-tests were administered to the experimental and control groups as a posttest.
- During this process, no intervention was implemented with the control group; observational studies were conducted.
- In the quantitative dimension of the study, the data obtained from the pretests and posttests were entered into the statistical programme and the necessary analyses were carried out.
- In the qualitative dimension of the study, each math diary was examined on the day it was collected from the students, and the necessary analyses were carried out.

Data Analysis

Analysis of the Quantitative Data

Statistical data analysis was carried out after implementing the data collection tools. A significance level of .05 was taken as a basis for the analysis of the data obtained. Information on the analyses conducted to answer the sub-problems of the study can be found in the table below:

Table 2.
Tests Used to Compare Data

Tests	Comparisons
Independent Samples t test	To determine the difference between the achievement, metacognitive awareness and motivational level of students in the experimental and control groups between the pre-test and post-test mean scores.
Paired samples t test	To determine the difference between the within-group achievement, metacognitive awareness and motivation level of the students in the experimental and control groups the pre-test and post-test mean scores
One Way ANCOVA (Repeated Measures One-Way Analysis of Covariance)	To determine the difference between posttest scores corrected for the pretest average scores of students in the experimental group and students in the control group on achievement, metacognitive awareness and motivation.

Analysis of the Qualitative Data

For the analysis of the math diaries in the qualitative research dimension, the method of content analysis was used. Content analysis is a method of qualitative data analysis that aims to uncover concepts and relationships by explaining the data obtained in studies. Data that are similar in this process are brought together under certain themes and interpreted in a way that is understandable to the reader (Yıldırım & Şimşek, 2016).

In this study, each of the 8 diaries of each student was analyzed individually as part of the content analysis. The analyses were conducted in the four stages of the qualitative research data analysis process: (1) coding the data, (2) finding themes, (3) processing the codes and themes, and (4) describing and interpreting the results (Yıldırım & Şimşek, 2016). Among the three types of coding styles introduced by Strauss and Corbin (1990) in the coding phase, an open coding type made according to predetermined concepts was considered appropriate.

The variables of academic achievement, motivation, and metacognitive awareness discussed in the study were established as the themes in the content analysis. Before the study began, a code list was prepared according to a theory and model used for qualitative analysis. Concepts related to three different themes were established, and the data obtained from the diaries were examined, coded, and assigned to the corresponding themes. Subsequently, the data obtained from the diaries were defined using the code list created for each theme. Finally, the findings are described in detail; the students' expressions in the math diaries are presented in the form of tables and comments.

Continuing the qualitative analysis process, each student's eight diaries were evaluated together, and individual retrospective analyses were conducted. In addition, each student's progress during the process was presented in an individual diagram in all three themes. After the individual retrospective analysis, a collective retrospective analysis was conducted for all participants.

Findings

Quantitative Findings in Relation to Academic Achievement

Findings in terms of between-groups achievement: After the assumptions of ANCOVA were met, the relationship between students' corrected posttest averages and pretest averages was examined, controlling for academic achievement.

Table 3.
Repeated Measures One-Way Covariance Analysis Results of Experimental and Control Groups of Achievement Posttest Average Scores Corrected According to Achievement Pre-Test Scores

Source of Variance	Sum of Squares	df	Mean Square	F	Significance Level (p)	Partial Eta Squared
Model	162,222[a]	2	81,111	64,011	,000	,815
Achievement pre-test	123,941	1	123,941	97,812	,000	,771
Group	36,127	1	36,127	**28,510**	**,000**	**,496**
Error	36,747	29	1,267			

According to the findings of the repeated measures one-way covariance analysis, a statistically significant difference was found between the post-test mean scores corrected according to the pre-test mean scores of the groups [$F_{(1,29)} = 28.510$; $p = .000$]. This finding shows that math diaries are more effective in increasing students' mathematical achievement than current instruction, which has no such focus, and that students' mathematical achievement differs significantly with diary use. The effect size in the study was found to be $d = .496$. This value shows that the implementation has a large effect. In a word, when the pretest scores are statistically controlled, 50% of the variance in the average of the corrected posttest scores is explained by the implemented method.

Findings in terms of within groups achievement: To find out if there was a significant difference between the groups' own measurements, i.e., the mean scores of pre-test and post-test achievement, a paired samples t-test was conducted. The results of the paired-samples t-test, which was conducted to determine if there was a significant difference between the experimental group's pre-test and post-test achievement scores, are shown in Table 4.

Table 4.
Paired Samples t Test Results Regarding the Comparison of Experimental and Control Groups Pre-Test and Post-Test Achievement Scores

Group	Measurement	N	$\bar{x}$	Std.	df	t	p
Experimental G.	Pre-test	16	7,38	2,156	15	-8,883	.000*
	Post-test	16	10,13	2,419			
Control G.	Pre-test	16	7,31	1,922	15	-2,611	,020
	Post-test	16	7,94	2,205			

*p<.05

Examining the table, due to the paired samples t-test analysis, a significant difference is found between the experimental group's mean achievement score ($\bar{x}$ = 7.38) before implementation and the mean achievement score ($\bar{x}$ = 10.13) after implementation of the math diaries [t = -8.883, p < .05]. The effect size calculated as a result of the test (d = 2.2) shows that this difference is very large. This finding shows that the math diaries have a significant impact on the students' mathematics achievement.

Also, when examining the table, the result of the paired samples t-test analysis shows a significant difference between the mean achievement score of the control group ($\bar{x}$ = 7.31) before implementation and the mean achievement score ($\bar{x}$ = 7.94) after implementation [t = -2.611, p <.05]. The effect size calculated as a result of the test (d = 0.6) shows that this difference is moderate. This finding can be explained by the fact that the students in the control group who did not use math diaries had learned the perimeter measurement domain in the curriculum.

Quantitative Findings in Relation to Metacognitive Awareness

Findings in terms of between groups metacognitive awareness: Once the assumptions of ANCOVA were met, the relationship between students' corrected posttest averages and pretest averages was examined, controlling for metacognitive awareness.

Table 5.
Repeated Measures One-Way Covariance Analysis Results of Experimental and Control Groups of Metacognitive Awareness Posttest Average Scores Corrected According to Metacognitive Awareness Pre-Test Scores

Source of Variance	Sum of Squares	df	Mean Square	F	Significance Level (p)	Partial Eta Squared
Model	132,054[a]	2	66,027	59,938	,000	,805
Metacognitive Awareness pre-test	110,929	1	110,929	100,699	,000	,776
Group	16,764	1	16,764	**15,218**	**,001**	**,344**
Error	31,946	29	1,102			

According to the findings of the repeated measures one-way covariance analysis, a statistically significant difference was found between the post-test mean scores corrected according to the pre-test mean scores of the groups [$F_{(1,29)}$ = 15.218; p = .001].

This finding shows that math diaries are more effective in promoting the development of students' metacognitive awareness than current instruction, which has no such focus, and that this practice significantly differentiates students' levels of metacognitive awareness.

The effect size in the study was found to be d = .344. This value shows that implementation has a large impact. In other words, when the pretest scores are statistically controlled, 34% of the variance in the mean of the corrected post-test scores is explained by the implemented method.

Findings in terms of within-groups metacognitive awareness: To find out if there was a significant difference between the groups' own measurements, i.e., the mean scores of pre-test and post-test metacognitive awareness, a paired samples t-test was conducted. The results of the paired samples t-test are shown in Table 6.

Table 6.
Paired Samples t Test Results Regarding the Comparison of Experimental and Control Groups Pre-Test and Post-Test Metacognitive Awareness Scores

Group	Measurement	N	$\bar{x}$	Std.	df	t	p
Experimental G.	Pre-test	16	28,38	2,247	15	-5,646	.000*
	Post-test	16	30,06	2,435			
Control G.	Pre-test	16	28.19	2,247	15	-1,168	,261
	Post-test	16	28.44	2,435			

*p<.05

Examining the table, as a result of paired samples t-test analysis, a significant difference is found between the experimental group's mean metacognitive awareness score ($\bar{x}$ =28,38) before implementation and the mean metacognitive awareness score ($\bar{x}$ = 30,06) after implementation of the math diaries [t = -5,646, p < .05]. The effect size calculated as a result of the test (d=1,4) shows that this difference is very large. This finding shows that the math diaries have a significant impact on the students' metacognitive awareness.

However, considering the result of paired samples t-test analysis, no significant difference was found between the mean score of metacognitive awareness of the control group ($\bar{x}$ = 28.19) before implementation and the mean score of metacognitive awareness ($\bar{x}$= 28.44) after implementation [t = -1.168, p > .05]. This result shows that perimeter measurement instruction in the current program, which does not use math diaries, has no effect on increasing students' metacognitive awareness.

Quantitative Findings in Relation to Motivation

Findings in terms of between-groups motivation: Once the assumptions of ANCOVA were met, the relationship between students' corrected post-test averages and pre-test averages was examined, controlling for motivation.

Table 7.
Repeated Measures One-Way Covariance Analysis Results of Experimental and Control Groups of Motivation Posttest Average Scores Corrected According to Motivation Pre-Test Scores

Source of Variance	Sum of Squares	df	Mean Square	F	Significance Level (p)	Partial Eta Squared
Model	132,054[a]	2	66,027	59,938	,000	,805
Motivation_pre-test	110,929	1	110,929	100,699	,000	,776
Group	16,764	1	16,764	**15,218**	**,001**	**,344**
Error	31,946	29	1,102			

According to the findings of the repeated measures one-way covariance analysis, a statistically significant difference was found between the posttest mean scores corrected according to the pre-test mean scores of the groups [$F_{(1,29)}$ = 43.478; p = .000].

This finding shows that math diaries are more effective in developing students' motivation than current instruction, which has no such focus; students' motivation levels differ significantly.

The effect size in the study was found to be d = .60. This value shows that implementation has a large impact. When the pretest scores are statistically controlled, 60% of the variance in the mean of the corrected posttest scores is explained by the implemented method.

Findings in terms of within groups motivation: To find out if there is a significant difference between the groups' own measurements, i.e., the mean scores of motivation pre-test and post-test, a paired samples t-test was performed. The results of the paired samples t-test are shown in Table 8.

Table 8.
Paired Samples t Test Results Regarding the Comparison of Experimental and Control Groups Pre-Test and Post-Test Motivation Scores

Group	Measurement	N	$\bar{x}$	Std.	df	t	p
Experimental G.	Pre-test	16	78,56	7,642	15	-7,384	.000*
	Post-test	16	85,06	7,903			
Control G.	Pre-test	16	77,25	8,434	15	-1,246	,232
	Post-test	16	77,63	8,253			

*p<.05

When the table was examined, a significant difference was found between the mean motivation score of the experimental group ($\bar{x}$ = 78.56) before the implementation of the math diaries and the mean motivation score ($\bar{x}$ = 85.06) after implementation of the math diaries as a result of paired samples t-test analysis [t = -7.384, p < .05]. The effect size calculated as a result of the test (d = 1.8) shows that this difference is very large. This finding shows that the math diaries have a significant impact on the students' motivation.

Moreover, when the table was examined, no significant difference was found between the mean motivation score of the control group ($\bar{x}$ = 77.25) before implementation and the mean motivation score ($\bar{x}$ = 77.63) after implementation, as revealed by paired samples t-test analysis [t = -1.246, p > .05]. This result shows that perimeter measurement instruction in the current program, which does not use math diaries, has no effect on student motivation.

Qualitative Findings of the Study

In presenting the results of the qualitative analysis of the study, the analysis results for each of the eight math diaries that belonged to each of the 14 students were included first. After the daily analysis, the eight diaries of each student were treated collectively, and their individual retrospective analysis was made, showing the development of each student during the process in an individual diagram in three themes. Finally, the results of the collective retrospective analysis were compiled from the diaries of the 14 students.

As an example of this process, only the findings of one student are presented below in relation to the content analysis process and the theme of metacognitive awareness. The diaries of the other 13 students with other themes were also subjected to content analysis. Finally, after the results of the exemplary individual retrospective analysis, the collective retrospective analysis of the students for each theme was given.

Qualitative findings of student number 7 (S7) in relation to the theme "Metacognitive Awareness":

As a result of the examinations on the theme of metacognitive awareness, data was obtained on the following diaries of student number 7.

Diary 1 & Diary 2

When the student's first and second diaries were subjected to content analysis, no data on metacognitive awareness was found.

Diary 3

The student's third diary was analyzed within the framework of metacognitive awareness, and in this diary it says: " *Did you learn anything interesting in maths class today? If so, could you tell me about this interesting information?*" This question was asked of the student. The student answered this question as follows: "*Today an information was interesting and difficult, there was a question I didnt understand, the teacher give homework with questions similar to this question, but I cant do this homework*".

The student's statement that she believes she cannot do the homework assigned to her shows that she is aware of her prejudice. Considering how the student expresses this situation in her diary and the words she uses, it can be said that she is self-awareness.

Furthermore, the diary on metacognitive awareness says: "*I could not come to class today. I missed what you learned today on the topic of measuring perimeter. Can you tell me what you learned in a way that I can understand?*" The question was asked to the student. The student answered this question as follows: " *We continued with the unit square. I learned what I could nt learn yesterday. We only count the unit squares around the square, not inside the square.*"

With this statement, the student indicated that she learned a piece of information in the mathematics lesson that day that she could not learn in the previous lesson. Considering how the student expresses this situation in her diary and the words she uses, one can say that the student has knowledge awareness.

Table 9.
Metacognitive Awareness Table regarding the S7-D3

Self-Awareness	Knowledge Awareness	Task Awareness	Strategy Awareness
✓	✓	N/A	N/A

Note. In the table above:
X: Indicates that the specified form of awareness is present in the student
N/A: Indicates that there is no data.

Diary 4

The fourth diary was analysed within the framework of metacognitive awareness, and in this diary it says: "*I could not come to class today. I missed what you learned today on the topic of measuring perimeter. Can you tell me what you learned in a way that I can understand?*" This question was asked of the student. The student answered the question as follows: "*All sides of square are same length. So if you know one side, add it 4 times or multiply by 4 that is easy way. But you cant do that with the rectangle, because it has long and short sides. Sum short sides first. Then sum long sides. Then sum them all.*".

With this statement, the student showed in her diary that she had learned the information about the measurement of perimeter, which was taught in the mathematics lesson that day. Considering how the student expresses this situation in her diary and the words she uses, it can be said that she is aware of the knowledge.

Table 10.
Metacognitive Awareness Table regarding the S7-D4

Self-Awareness	Knowledge Awareness	Task Awareness	Strategy Awareness
N/A	✓	N/A	N/A

Diary 5

The fifth diary was analysed within the framework of metacognitive awareness, and in this diary, it says: "*How did you feel about the topic you covered in maths class today? How did you feel today compared to your previous maths lessons? I wonder what you were thinking. Can you share your thoughts with me?*" This question was asked of the student. The student answered the question as follows: "*I feel better today than in days before. my mom buy me a testbook. I solve questions about perimeter at home. I cant solve them all, its hard for me, but its get better.*"

With this statement, the student indicated that she supported her learning process with the strategy of using different resources. Considering the way the student expresses this situation in her diary and the words she uses, it can be said that she has strategy awareness.

Furthermore, the diary on metacognitive awareness says: " *I could not come to class today. I missed what you learned today on the topic of measuring perimeter. Can you tell me what you learned in a way that I can understand?*" The question was put to the student. The student responded by saying, " *We learned a triangle, since its sides are equal, can easily find perimeter of triangle, like a square, but triangle has 3 sides, so multiply one side by 3.*"

With this statement, the student showed in her diary that she had learned the information about the measurement of perimeter, which was taught in the mathematics lesson that day. Considering how the student expresses this situation in her diary and the words she uses, it can be said that she is aware of the information.

Table 11.
Metacognitive Awareness Table regarding the S7-D5

Self-Awareness	Knowledge Awareness	Task Awareness	Strategy Awareness
N/A	✓	N/A	✓

Diary 6

The sixth diary was analyzed within the framework of metacognitive awareness, and in this diary, it says: "*How did you feel about the topic you covered in maths class today? How did you feel today compared to your previous maths lessons? I wonder what you were thinking. Can you share your thoughts with me?*" The question was put to the student. The student responded by saying: "*I did well in today. I think the testbook was good for me because there are different questions in this testbook. I solve them at home, so I can answer the questions our teacher asks in class more easily.*".

In this statement, the student indicated that she supported her learning process with the strategy of using different resources.

The student was also asked a question coded SQ6 in the metacognitive awareness diary. The student responded to this question, " *You can understand it better if we draw a rectangle (there is a rectangular shape). Now find perimeter of rectangle 10+14=24 then side of triangle 24/3=8*".

With this statement, the student indicated that she supported the problem-solving process in the diary with the strategy of drawing shapes. Looking at the student's utterances about

these two situations in the diary and the words she uses, we can say that there is an awareness of strategy. In the same statement, the student assessed her own achievement during the mathematics lesson that day and indicated her preferences for the learning process. Considering the way the student expresses this situation in her diary and the words she uses, it can be said that she has self-awareness.

Furthermore, the diary on metacognitive awareness says: "*If there is a point that you did not understand in today's mathematics lesson, can you explain it to me here?*" The question was put to the student. The student responded by saying, " *I understand most of the questions today, a few of them were difficult, I could nt solve them, I just want to learn these questions*".

With this statement, the student indicated that she had difficulties in solving some questions and wanted to complete this task successfully. Considering how the student expresses this situation in her diary and the words she uses, it can be said that there is an awareness of the task.

Table 12.
Metacognitive Awareness Table regarding the S7-D6

Self-Awareness	Knowledge Awareness	Task Awareness	Strategy Awareness
✓	N/A	✓	✓

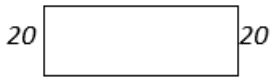
Diary 7

The seventh diary was analysed within the framework of metacognitive awareness, and in this diary, it says: "*How did you feel about the topic you covered in maths class today? How did you feel today compared to your previous maths lessons? I wonder what you were thinking. Can you share your thoughts with me?*" The question was put to the student. The student responded by saying: "*It was a lot of fun today, we had a race in class, a question solving race. everyone wanted to be first but one who solved all the questions correctly was first, the one who finished first was not first. So I solved the questions slowly because if I did it quickly I could have done it wrong I had to be careful.*"

In this statement, the student commented on her inner state during her mathematics lessons that day and gave a self-assessment of her achievement in lesson. Considering how the student expresses this situation in her diary and the words she uses, it can be said that she is self-awareness. In the same statement, the student states that she enjoyed the task of solving questions in the competition that took place that day during the mathematics lesson and what positive and negative situations she experienced during this task. Considering how the student expresses this situation in her diary and the words she uses, it can be said that there is task awareness.

The student was also asked a question coded SQ7 in the metacognitive awareness diary. The student responded to this question:

"Let me show you this question on the figure you will understand better



There are two short sides 20+20=40 and subtract from the perimeter 100-40=60 and since there are two long sides the answer is 60/2=30"

With this statement, the student indicated that she supported the problem-solving process in the diary with the strategy of drawing shapes. Looking at the student's utterances about these two situations in the diary and the words she uses in her utterances, we can say that there is an awareness of strategy.

Table 13.
Metacognitive Awareness Table regarding the S7-D7

Self-Awareness	Knowledge Awareness	Task Awareness	Strategy Awareness
✓	N/A	✓	✓

Diary 8

The eighth diary was analyzed within the framework of metacognitive awareness, and in this diary, it says: "*You spent almost 3 weeks in maths class learning how to measure circumference. How did you feel during this time? Can you write to me how you felt while learning about this topic?*" The question was put to the student. The student responded by saying: "*At first I feel bad because I did nt understand anything at all, mathematics was always difficult for me, but then I begin to understand that the topic of perimeter measurement is fun and I began to feel very good. And from now on I will always use a testbook, there are different questions that I solve, they help me understand*.".

In this statement, the student gave a self-assessment of the achievement of the three-week mathematics lesson on perimeter measurement throughout the teaching process. In addition, in his statement, the student stated his inner state of mind, interests, and thoughts. Considering how the student expresses this situation in her diary and the words she uses, it can be said that she has self-awareness. In the same statement, the student indicated that she supported her learning process with the strategy of using different resources. Considering how the student describes these two situations in her diary and the words she uses, it can be said that she has strategy awareness.

Furthermore, the diary on metacognitive awareness says: "*My friend, I am a little forgetful. But I do not want to forget what I have learned about measuring perimeter. Can you explain to me what you learned in mathematics class about measuring perimeter?*" The question was put to the student. The student responded by saying: "*We have learned how to measure perimeter in unit squares. We have learnt how to measure perimeter of a triangle, square and rectangular. for example by multiplying one side by 4 for a square and by 3 for a triangle. We also learned how to measure perimeter in different questions, we learned some shortcuts, that's it.*"

With this statement, the student reproduced the information she had learned in the mathematics lesson about measuring perimeter. Considering how the student expresses this situation in her diary and the words she uses, it can be said that she is aware of the information.

Furthermore, the diary on metacognitive awareness says: "*How did it affect you when I came into your life while you were learning about measuring the perimeter in maths class? Did I help you, did I make you happy, or did I bore you? I am very curious about your feelings towards me.*" The question was put to the student. The student responded by saying: " *Yes, you made me very happy. Sometimes people feels the need to write and as I write you have made me see the qualities of myself. For example when you asked me what I had learn, I understand what I could nt learn before while I was writing to you. that was just one example. Thank you for that my dear diary* ☺".

In this statement, the student explained that he was aware of the importance of keeping a math diary. He also mentioned the positive situations he experienced while completing this task. Considering how the student expresses this situation through the diary and his words, it can be said that there is an awareness of the task.

Table 14.
Metacognitive Awareness Table regarding the S7-D8

Self-Awareness	Knowledge Awareness	Task Awareness	Strategy Awareness
✓	✓	✓	✓

Individual Retrospective Analysis Results Related to Student Number 7's Metacognitive Awareness

Table 15.
Results of Individual Retrospective Analysis of S7's Metacognitive Awareness

Student (7)	D1	D2	D3	D4	D5	D6	D7	D8
Self-Awareness	N/A	N/A	✓	N/A	N/A	✓	✓	✓
Knowledge Awareness	N/A	N/A	✓	✓	✓	N/A	N/A	✓
Task Awareness	N/A	N/A	N/A	N/A	N/A	✓	✓	✓
Strategy Awareness	N/A	N/A	N/A	N/A	✓	✓	✓	✓

Looking at the eight diaries of the student with the number seven as a whole, there is no information on the four dimensions of metacognitive awareness in the diaries kept by the student in the early stages of the implementation process. As the process progressed, it seems that some dimensions of metacognitive awareness emerged in the student. Towards the end of the implementation process, it became clear that at least three of the four dimensions of metacognitive awareness were present in the student. Considering the students' statements in the table and the diary analysis, it can be said that the math diaries she kept had a positive influence on the development of the student's metacognitive awareness during the research process.

Figure 3. Diagram of S7's Self Awareness

Figure 4. Diagram of S7's Knowledge Awareness

Figure 5. Diagram of S7's Task Awareness

Figure 6. Diagram of S7's Strategy Awareness

In the diagrams above:
SA: Self Awareness KA: Knowledge Awareness
TA: Task Awareness STA: Strategy Awareness

Collective Retrospective Analysis on Academic Achievement

A retrospective analysis of 14 students who kept a math diary during the three-week period of the mathematics lesson, including their academic achievement development and perceptions from the beginning to the end of the study, was conducted and presented in a table below.

Table 16.
Collective Retrospective Analysis Regarding the Academic Achievement

Diaries	Academic Achievement					
	AS		NPA		PPA	
	rs	$\bar{x}$	n	%	n	%
D1	21	1,5	3	21,4	0	0
D2	8	0,5	3	21,4	1	7,14
D3	40	4,8	7	50	5	35,7
D4	14	1	7	50	7	50
D5	46	3,2	2	14,2	9	64,2
D6	46	3,2	2	14,2	8	57,14
D7	52	3,7	0	0	12	85,7
D8	50	3,5	0	0	14	100

Note. In the table above:
AS: Achievement Score
NPA: Negative Perception of Achievement
PPA: Positive Perception of Achievement
rs: Rubric Score

A total of 112 diaries were collected from 14 students over three weeks. Based on the answers to the information questions in each diary, the students' achievement score is presented with the frequency, percentage, and arithmetic mean. As a result of the content analysis, the statements that students' perceptions of success are negative or positive are also

presented descriptively with frequency and percentage, and the values obtained for academic success are shown in the table above. Looking at the table; while student achievement scores were low at the beginning of the implementation, student achievement increased relatively as the process progressed, and student achievement scores increased in the final diaries. When examining whether students perceive success positively or negatively, it is seen that students' negative perception of success tends to decrease as they progress, while their positive perception of success tends to increase. A correlation analysis was carried out in the SPSS program regarding the change in the values of the negative perception of success and the positive perception of success and evaluated with the Spearman analysis. The correlation coefficient was determined to be -.78. In other words, it was statistically proven that there is a negative and high-level relationship between these two variables.

Collective Retrospective Analysis on Metacognitive Awareness

A retrospective analysis of 14 students who kept a math diary during the three-week period during the mathematics lesson, including their metacognitive awareness development and perceptions from the beginning to the end of the study, was conducted and presented in a table below.

Table 17.
Collective Retrospective Analysis Regarding the Metacognitive Awareness

Diaries	Metacognitive Awareness							
	SA		KA		TA		STA	
	n	%	n	%	n	%	n	%
D1	0	0	1	7,1	0	0	0	0
D2	0	0	2	14,2	0	0	4	28,5
D3	3	21,4	6	42,8	2	14,2	10	71,4
D4	9	64,2	7	50	4	28,5	3	21,4
D5	9	64,2	12	85,7	9	64,2	3	21,4
D6	13	92,8	3	21,4	11	78,5	10	71,4
D7	13	92,8	5	35,7	10	71,4	10	71,4
D8	12	85,7	13	92,8	14	100	8	57,1

A total of 112 diaries were collected from 14 students over three weeks. The metacognitive awareness values, which indicate the students' level of metacognitive awareness for each diary as frequency and percentage, are shown in the table above. In the first diaries, very few students' statements on the dimensions of metacognitive awareness were found. In the third and fourth diaries, which refer to the continuation of the process, significant developments were observed, especially in the dimensions of self-awareness and strategy awareness. In the sixth and seventh diaries, towards the end of the implementation process, clearly visible developments in self-awareness, task awareness, and strategy awareness came to the fore. Looking at the last diary of the implementation process, we see that almost all 14 students made statements encompassing all dimensions of metacognitive awareness. From the table, we can see that the math diaries have a positive impact on the development of students' metacognitive awareness throughout the research process.

Collective Retrospective Analysis on Motivation

A retrospective analysis of 14 students who kept a math diary during the three-week period during the mathematics lesson, including their motivation development and perceptions from the beginning to the end of the study, was conducted and presented in a table below.

Table 18.
Collective Retrospective Analysis Regarding Motivation

Diaries	Motivation									
	MNF		LEM		LIM		HEM		HIM	
	n	%	n	%	n	%	n	%	n	%
D1	2	14,2	0	0	0	0	0	0	0	0
D2	3	21,4	0	0	3	21,4	0	0	0	0
D3	3	21,4	1	7,14	8	57,14	0	0	1	7,14
D4	2	14,2	1	7,14	6	42,8	1	7,14	4	28,5
D5	1	7,14	0	0	2	14,2	3	21,4	9	64,2
D6	1	7,14	0	0	3	21,4	2	14,2	8	57,14
D7	0	0	0	0	1	7,14	3	21,4	12	85,7
D8	0	0	0	0	0	0	1	7,14	14	100

In the table above:
MNF: Motivation Not Found
LEM: Low Extrinsic Motivation
LIM: Low İntrinsic Motivation
HEM: High Extrinsic Motivation
HIM: High İntrinsic Motivation

A total of 112 diaries were collected from 14 students over three weeks. The motivation scores indicating the students' motivation level for each diary with frequency and percentage can be found in the table above. Looking at the table, we notice that in the first diaries, the students gave almost no information about motivation to learn. In the middle of the implementation process, it was observed that most students had a low level of intrinsic motivation. Towards the end of the process, it is observed that this low level of intrinsic motivation increased significantly among the students, and a high level of intrinsic motivation was observed in more than half of all students, especially in the last three days. While students were not externally motivated at the beginning of the process, high levels of external motivation were observed in some students toward the end of the process. It can be seen from the table that the math diaries have a positive impact on increasing student motivation throughout the research process.

Conclusions and Discussion

Results of the comparative analysis of the quantitative and qualitative data

In this study, a comprehensive mixed-methods analysis was conducted, with qualitative and quantitative data supporting each other.

The quantitative dimension of the study examined the difference between the achievement results of the students in the experimental group before and after the implementation. According to the results of the analysis of covariance, a statistically

significant difference was found between the mean scores of the post-test groups corrected for the pre-test mean scores [$F_{(1,29)} = 28.510$; p= .000; d = .496]. This result shows that math diaries are more effective in improving students' math achievement than current instruction without such a focus. Moreover, the difference is of medium effect size. Within the qualitative dimension of the study, the results of the content analysis of the math diaries kept from the beginning to the end of the implementation process are evaluated to determine the students' achievement levels. While the achievement scores of the students in the experimental group were low in their diaries at the beginning, their achievement scores were found to increase as the diaries were kept. Student problem solutions and expressions in the diaries kept, especially in the last days of the implementation, show that there is a significant increase in the achievement of the students. These qualitative results support the significant difference in the quantitative dimension of the study. According to Hiemstra (2001), students who keep a math diary reflect in their diary what they know and what they do not know; this also contributes positively to students' academic achievement. The literature reveals other studies that have come to similar conclusions, namely that the diaries used in mathematics lessons and the writing activities carried out increase students' academic achievement (Yıldırım, 2016; Crooker, 2015; Yılmaz, 2015; Eren, 2015; Ünlü, 2015; Kasa 2009; Lefler, 2006). In addition, Çavuş and Özden, in their 2012 study to determine students' views on student diaries, found that students expressed that the diaries increased their achievement in the lessons.

In the quantitative dimension of the study, the difference between the metacognitive awareness scores of the students in the experimental group before and after the implementation was examined. According to the results of the analysis of covariance, a statistically significant difference was found between the mean scores of the post-test groups, corrected according to the pre-test mean scores [$F_{(1,29)} = 15.218$; p = .001; d = . 344]. This result shows that math diaries are more effective in developing students' metacognitive awareness than current teaching without such a focus. Moreover, the effect size of the difference is medium. The qualitative dimension of the research examined the results of the content analysis conducted to determine the development of metacognitive awareness in the math diaries that the students kept from the beginning to the end of the implementation process. It was found that students in the experimental group did not make statements about any dimension of metacognitive awareness in their initial diaries. However, as the process progressed, it was found that the students' statements included some of the four dimensions of metacognitive awareness. It was observed that at least three of the four dimensions of metacognitive awareness were included in the students' statements, especially in the diaries kept during the last days of the implementation. Thus, in the qualitative dimension of the research, the developments of students' metacognitive awareness during the process support the significant difference in the quantitative dimension of the research. Polat and Uslu (2012) found that keeping a diary for students during lessons based on the metacognitive strategy is one of the most important tools for improving metacognitive skills and awareness. The Ministry of Education Mathematics (MEB, 2018) curriculum states that students can write down their ideas about the topic being covered based on their own thoughts, understanding, learning, and the relationship between mathematics and other disciplines. In this context, Blakey and Spence (1990) found that using a notebook where students can reflect on their thoughts, identify points they did not understand, and make short notes improves metacognitive skills. Mathematics teachers believe that writing activities and diaries support meaningful learning because they make incomplete learning noticeable (Öztürk & Işık, 2016). In addition, there are also studies in the literature that support the results of this study,

which have concluded that writing activities and diaries improve metacognition (Kartalcı, 2018; Demirci, 2016; Ünlü, 2015; Çavuş, 2015; Güvenç, 2011; Betty, 1994).

The quantitative dimension of the study examined the difference between the motivation scores of the students in the experimental group before and after the implementation. According to the results of the analysis of covariance, a statistically significant difference was found between the groups in the mean scores of the posttest, corrected according to the mean scores of the pretest. [$F_{(1,29)} = 43.478$; $p = .000$; $d = .60$]. This result shows that math diaries are more effective in increasing student motivation than current instruction without such a focus. Moreover, the effect size of the difference is high. Within the qualitative dimension of the research, the results of the content analysis were used to determine the level of motivation of the students in the math diaries kept from the beginning to the end of the implementation process. While it was found that students in the experimental group were not motivated in their initial diaries, it was observed that their internal and external motivation increased from low to high levels as they continued to keep a diary during the process. In particular, for the math diaries kept in the final days of the implementation process, it was found that most students had high internal motivation for mathematics lessons. Writing a diary has a positive effect on students' motivation, especially intrinsic motivation and problem-solving ability (Hiemstra, 2001). As with the other variables, these qualitative results in relation to motivation support the significant difference in the quantitative dimension of the study. Looking at the results of the study conducted by Küçük (2019), a significant difference was found between the motivation and thoughts of students doing writing activities compared to teaching mathematics and the motivation and thoughts of students not doing writing activities in favor of students doing writing activities, just like in the quantitative dimension of this study. Moreover, there are studies in the literature that conclude that students' motivation and emotions toward mathematics change and develop positively thanks to diaries and writing activities (Guce, 2018; Emmert, 2015; Çontay, 2012; Murchison, 2010). Furthermore, Park (2003) concluded that diaries, as in the qualitative aspect of this study, serve as a tool to motivate students to participate in lessons by increasing their interest in the lesson. These findings of the study also support the statement of MEB (2018) that it can help students to explain their attitude toward mathematics and their motivation for the lessons.

In the context of this study, which investigates the impact of math diaries on Grade 4 students in primary school, the following recommendations are made:

(1) Due to the lack of literature, the effect of math diaries can be studied at different grade levels, especially at the primary level, (2) the teaching process can be planned more effectively, especially by providing feedback through math diaries, (3) The effect of math diaries can also be studied in terms of phenomena not addressed in this study, such as problem-solving skills, affective traits, level of remembering and self-perception.

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