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# Enhancing Primary School Students' Metacognitive Skills Through Realistic Mathematics Education: The Knowledge of Cognition Dimension

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**Abstract**

The purpose of this study was to examine how the knowledge of cognition dimension and metacognitive skills emerge and develop during mathematical problem-solving processes within the framework of the Realistic Mathematics Education (RME) approach. The study was designed as an action research conducted with primary school students. The participants consisted of eight fourth-grade students attending a public primary school in the city center of Aydın, Türkiye, who exhibited deficiencies in metacognitive indicators and had no diagnosis of learning disabilities reported by the Guidance and Research Center (RAM). Data were collected through mathematical problems, rubrics, and researcher diaries. The problems were designed in accordance with the principles of the RME approach, and a think-aloud protocol was employed during the problem-solving process. The six-week implementation consisted of four action cycles and incorporated thinking cards, peer thinking cards, and self-assessment cards, as well as strategies such as modeling, metacognitive prompting, think-aloud, paired problem solving, and identifying known information. The findings revealed improvements in students' knowledge of cognition skills. Problem awareness emerged as the first indicator during the process, followed by students' ability to relate problem situations to their prior knowledge. In the later stages, students were able to connect new problems with previously encountered ones and explain their solution strategies more consciously. Furthermore, real-life problem contexts, classroom discussions, peer interaction, and metacognitive prompts were found to make students' thinking processes more visible and to support the development of their metacognitive awareness. Consequently, the action plans implemented within the RME approach made significant contributions to the development of students' knowledge of cognition and metacognitive skills.

**Keywords:** Realistic mathematics education, primary school students, problem solving, metacognitive development.

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# Introduction

Contemporary educational perspectives require students to regulate their own learning processes while constructing knowledge, rather than receiving information through direct transmission. The increasing complexity of the problems encountered has intensified the need for individuals who are capable of questioning, generating solutions, and managing their own learning processes (Kadakal Tek, 2019). The ability to regulate the learning process necessitates that students take responsibility for their own learning. Accordingly, students must be able to recognize their learning strategies as well as their strengths and weaknesses (Kalemkuş, 2021). This awareness brings the concept of metacognition, one of the higher-order thinking skills, to the forefront. Metacognition refers to the set of skills that enable individuals to monitor and regulate cognitive processes such as learning, reasoning, problem solving, and comprehension (Karakelle, 2012). Metacognition plays a critical role in the successful completion of the problem-solving process (Flavell, 1976; Oğraş, 2011).

Mathematics education requires students not only to perform calculations but also to understand the problem situation, establish relationships between given and required information, and evaluate the solution process. Each of these processes necessitates the effective use of metacognitive awareness and regulation skills. Students who lack metacognitive skills tend to approach problems superficially, focus on speed-oriented procedures, and fail to question the solution process. In contrast, students who employ metacognitive strategies are able to manage the problem-solving process in a more conscious, controlled, and flexible manner. Students who cannot utilize metacognitive skills experience difficulties in understanding the problem, selecting appropriate strategies, and monitoring the solution process. Conversely, students who use metacognitive skills are able to establish relationships among the given information, question the correctness of their solutions, and recognize their errors (Bayezit & Aksoy, 2009; Aydemir & Kubanç, 2014). Individuals who can effectively employ metacognitive skills are able to reach more efficient solutions by following deliberate steps during the problem-solving process. Therefore, with recent changes and developments in education, metacognitive skills have become a significant area of research and practice (Dağ, 2022). These findings clearly demonstrate the importance of students' use of metacognitive skills in problem-solving processes.

Metacognition is defined as an individual's awareness of, monitoring of, and regulation of their own cognitive processes (Flavell, 1976). Brown (1987) conceptualizes metacognition as knowing what one knows, what one does not know, and which strategies to use and when. The effective use of metacognitive skills during problem solving enables students to question solution paths and change strategies when necessary (Garofalo & Lester, 1985; Schoenfeld, 1985). Studies conducted with primary school students indicate that instructional practices supported by metacognitive strategies significantly enhance students' problem-solving and problem-posing skills (Divrik Pilten, & Mentiş Taş, 2021). Gençer (2025) demonstrated that metacognition-oriented Realistic Mathematics Education (RME) supports students' metacognitive skills. In this context, it is necessary to foster students' metacognitive abilities in mathematics lessons. One of the instructional approaches that support these processes in mathematics education is Realistic Mathematics Education (RME), which centers on real-life problems that make mathematics meaningful for students and render their thinking processes visible (Freudenthal, 1991; Gravemeijer, 1994).

To support the development of metacognitive skills in mathematics education, learning environments are needed that make students' thinking processes visible, are meaning-oriented, and are connected to real-life contexts. One approach that meets this need is Realistic Mathematics Education (RME). By centering instruction on real-life problems that make mathematics meaningful, RME enables students to consciously manage their reasoning, relational thinking, and solution processes. In this respect, RME emerges as an instructional approach that supports not only reaching correct answers but also questioning and reflecting on the solution process.

During the problem-solving process, individuals are expected to guide their thinking by asking themselves questions. In school settings, these processes are supported by teachers. However, students need to develop the ability to ask themselves questions and regulate their own thinking independently

(Yağcı, 2008). The teachability of thinking skills has led many countries to incorporate these skills into their curricula. In Türkiye, the emphasis placed on thinking skills in educational curricula has gradually increased (Arkan Sezgin et al., 2022; Özer, 2019). Mathematics courses serve as an important tool in fostering thinking skills. Accordingly, mathematics instruction should provide learning environments that increase students' active participation, stimulate interest, and support thinking processes (Uça, 2014). Altun (2006) emphasizes that effective learning environments in mathematics education should include features such as regulating individuals' mental activities, contextualizing instruction, and developing problem-solving skills.

One instructional approach that encompasses these characteristics is Realistic Mathematics Education (RME). Problems derived from daily life within RME contribute to students' reasoning and relational thinking skills. Students' active participation in the learning process supports the development of higher-order thinking and problem-solving skills (Ayvalı, 2013; Narin, 2023). The fact that RME supports the development of higher-level skills in mathematics education increases the importance of its use in mathematics teaching.

In the classroom where the study was conducted, the classroom teacher observed that students engaged in speed-oriented competition during the problem-solving process. Students tended to perform operations without sufficiently understanding the problem, failed to establish meaningful connections with the problem context, and were unable to consciously regulate their thinking processes. This situation led to overlooking given information and performing incorrect operations. Students' anxiety about solving problems quickly prevented them from effectively using metacognitive skills and resulted in incorrect solutions. These instructional problems revealed the need to improve the problem-solving process in the classroom. Based on this need, the classroom teacher, who was also the researcher, decided to conduct an action research aimed at improving the metacognitive skills of elementary school students. The prepared action plans were supported by the RME approach and metacognitive instructional strategies, and the instructional process was continuously improved by incorporating regulatory practices in response to emerging needs during each action cycle. Particular attention was paid to emphasizing the dynamic and holistic nature of the implementation process.

The aim of this study is to understand how primary school students' metacognitive knowledge dimension and metacognitive skills emerge while solving mathematics problems through the Realistic Mathematics Education (RME) approach, and to examine in detail the process of developing these skills. Accordingly, the research question is formulated as follows: "How do primary school students' metacognitive knowledge dimension and metacognitive skills develop when the Realistic Mathematics Education approach is used?"

Hanten et al. (2004) and Hartman (2002) argue that metacognition begins to develop between the ages of 5 and 7, while Bağ et al. (2006) suggest that children aged 6–9 start to use metacognitive strategies. Flavell (1979) describes the primary school years as a critical period in which awareness of learning processes and learning strategies begin to take shape. Considering that during middle childhood children start to define themselves, identify their strengths and weaknesses, and develop self-awareness, fostering metacognitive skills in fourth-grade mathematics instruction becomes particularly important.

A review of studies on metacognition with primary school students reveals that most research has employed quantitative research designs (Akış, 2022; Erdoğan, 2015; Koç, 2019; Swanson, 1990). The limited number of studies at the primary school level indicates a need for further research. In this regard, the present study, which integrates RME and metacognition at the primary level and is conducted through an action research design, offers a unique contribution to the literature.

# Method

## Research Design

In this study, action research was employed as a process-oriented research design that is open to development and improvement. The researcher also conducted the data collection process. Action research is a research approach that involves identifying problems or collecting and analyzing data to understand and solve an existing problem (Yıldırım & Şimşek, 2011). In action research, developments and changes related to the identified problem are examined in detail and in depth.

## Study Group

Since the research design was action research, the study group was determined using purposive sampling. In purposive sampling, the group that is most appropriate for the identified problem is selected (Pamuk, 2017). The study group consisted of eight fourth-grade students attending a public primary school located in the city center of Aydın. These students were identified as having deficiencies in metacognitive indicators and had no reports from the Guidance and Research Center (GRC) regarding any learning disabilities.

A preliminary assessment was conducted to identify students with deficiencies in metacognitive skills. Students were given a mathematics problem, and their problem-solving processes were examined. Student performances were evaluated using an analytic scoring rubric.

## Data Collection Instruments

Data were collected through mathematics problems, an analytic scoring rubric, and researcher journals. The mathematics problems used in the study were designed in accordance with the Realistic Mathematics Education (RME) approach. Based on a literature review, contextual problem situations related to the learning domain of measurement and connected to real-life contexts were developed. Care was taken to ensure that the problem situations were suitable for interactive learning environments and enabled students to perform measurements aligned with the relevant content areas.

Expert opinions from specialists in mathematics education and Turkish language education were consulted regarding the developed problems. A validation form was provided to the experts to evaluate the problems in terms of their appropriateness for students' grade level, use of student-friendly terminology, and alignment with the fundamental principles of the RME approach. Based on expert feedback, necessary revisions were made to ensure the suitability of the problems for the RME framework. In addition, the problems were sequenced from simple to complex and from routine to non-routine in order to gradually support students' problem-solving processes. A think-aloud protocol was implemented to reveal students' cognitive processes during problem-solving.

An analytic scoring rubric was used during the pre-assessment, interim assessments, and post-assessment phases. The rubric was developed based on the "awareness of problem understanding" and "reflecting on the problem" dimensions of the metacognitive knowledge component. To ensure content validity of the rubric items, feedback was obtained from experts in mathematics education and assessment and evaluation, and necessary revisions were made accordingly. The rubric items and their descriptions are presented in Table 1.

**Table 1.**

*Rubric*

| Indicators of Cognitive Knowledge | Scores | Descriptions |
|---|---|---|
| **Showing awareness of understanding the problem** | 0 | It shows no awareness of understanding the problem. |
| | 1 | This demonstrates one of the indicators of awareness regarding understanding the problem. |
| | 2 | It demonstrates at least two indicators of problem- |

| | | |
|---|---|---|
| | | understanding awareness.( awareness of what is desired, representation of the problem, etc.) |
| **Thinking about the problem** | 0 | She/he doesn't think about the problem. |
| | 1 | She/he has shortcomings in thinking about the problem. |
| | 2 | She/he thinks about the problem thoroughly. (relating it to prior knowledge and problems encountered before) |

In the pre-assessment phase, students were given a problem related to the topic of length measurements and were asked to solve it individually. During this process, no intervention was made in order to elicit students' natural problem-solving behaviors, and their performances were evaluated using a rubric. Throughout the implementation process, three interim assessments were conducted. In the second and third interim assessments, two problems were used in each phase to enable a more comprehensive evaluation of students' performance, and the average of the obtained scores was calculated. Since the pre-assessment was conducted on the topic of length measurement, a problem related to the same topic was also used in the post-assessment in order to ensure comparability.

## Data Collection and Implementation Process

Before the data collection process, the necessary ethical approval and permissions from the Ministry of National Education were obtained. Informed consent forms were completed by the students' parents. The real names of the students were not used, and all data were anonymized and coded in accordance with confidentiality principles during the analysis process.

To determine the study group, a pre-assessment was conducted to examine whether students demonstrated the metacognitive indicators included in the observation checklist. Subsequently, their existing skills were scored using a rubric, and students who did not exhibit metacognitive indicators and demonstrated low performance levels were included in the study group. The selected eight students were organized into three groups. The groups were formed heterogeneously, taking into account students' current performance levels and in-class interaction characteristics. Four action plans incorporating metacognitive development strategies and supported by the Realistic Mathematics Education (RME) approach were developed for these students.

Following the action plans, the implementation process was initiated and carried out in the students' regular classroom after school hours. During problem-solving activities, students were asked to use the think-aloud technique. Prior to its implementation, students were provided with preparatory training regarding the purpose and procedure of the think-aloud protocol. During problem solving, students were expected to verbalize their thoughts, the strategies they used, and the decisions they made. In cases where students did not verbalize their thoughts or when silence exceeded five seconds, prompting reminders were provided (Ostad & Sorenson, 2007). However, no corrective feedback regarding right or wrong answers was given; instead, only prompts aimed at making students' thinking processes visible were used.

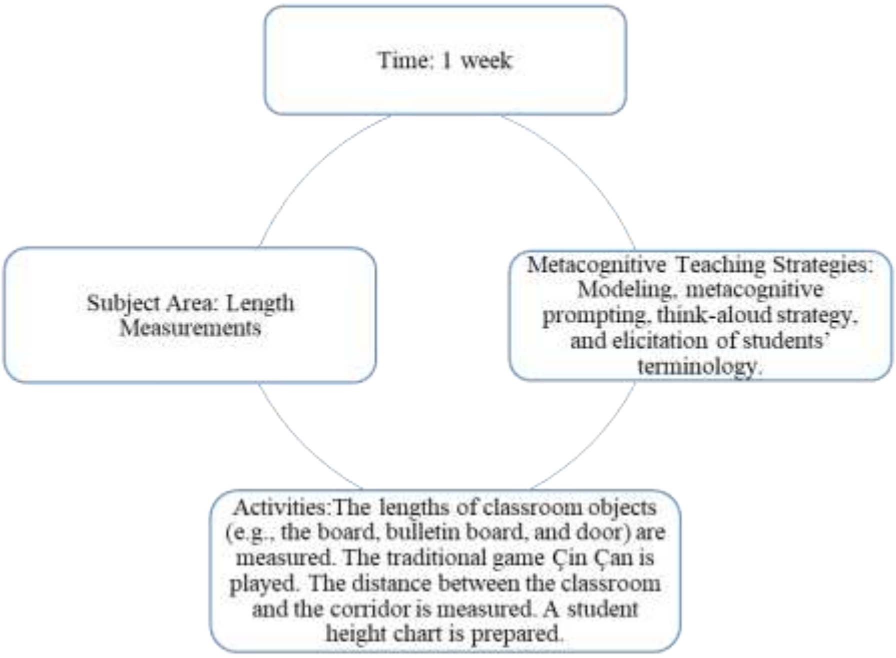
In the initial weeks of implementation, it was observed that the duration of think-aloud processes in group activities increased as students began to engage in metacognitive questioning. Although this increase in duration may be attributed to students' growing familiarity with the technique, the simultaneous qualitative and quantitative increase in metacognitive indicators observed in process records suggests that this change cannot be explained solely by procedural adaptation. Therefore, the increase in duration may be interpreted as an indication that students began to regulate their thinking processes more consciously and that their metacognitive skills were developing.

During the implementation process, the researcher assumed the role of facilitator and observer and refrained from intervening in students' problem-solving processes. Students' thinking processes were recorded via video, and systematic observations were conducted throughout the process. These observations focused on the metacognitive indicators demonstrated by the students. At the end of each action cycle, interim evaluations were conducted, and necessary revisions were made to the subsequent action plans based on the analysis results. The collected video recordings were later analyzed in detail, and students' metacognitive statements were evaluated together with researcher journals and rubric results.

The study included three interim assessments and a final assessment, and all performance evaluations were conducted individually. The action plans used in the study were designed by integrating the RME approach with metacognitive instructional strategies in a comprehensive manner. Students participated in activities with their group members according to the topic of the problem situation. These activities are described in detail within the action plans. Information regarding the first action plan is presented in Figure 1.

**Figure 1.**

*The First Action Plan*




An example of the action plans is presented in Figure 1. Through these and similar activities, the aim was to develop students' problem-solving, reasoning, and mathematical thinking processes based on real-life situations. In addition to activities aligned with the RME approach, the action plans also included various metacognitive instructional strategies designed to support students' thinking processes.

In the initial phases of the implementation, metacognitive guidance and researcher support were prioritized. However, no direct intervention was made in students' solution processes. In order to reduce the researcher's level of guidance and to increase students' active participation in the problem-solving process, a "Thinking Card" was introduced during the second action cycle. Based on the questions included on the card, students were expected to verbalize their problem-solving processes through think-aloud protocols, thereby aiming to facilitate the internalization of metacognitive questioning over time.

In the second action cycle, strategies such as metacognitive prompting, think-aloud, clarifying student terminology, and defining prior knowledge were utilized. The interim assessment results indicated that students had made progress in expressing their thinking processes; however, they still required peer support and reciprocal questioning.

Accordingly, in the third action cycle, in addition to the previously used strategies, paired problem-solving was incorporated. In this process, one student was expected to carry out the problem-solving process through think-aloud, while the other student asked guiding questions. For this purpose, students were provided with an "Elif and Friends Peer Question Card." The questions on the card were designed to support students' abilities to understand the problem, connect it with prior knowledge, and explain their solution processes. To prevent students from providing only short "yes" or "no" responses, prompts requiring elaboration such as "Can you explain?", "Can you describe it?" were included.

The card included questions such as: "Do you understand the problem?", "If yes, can you rephrase the problem in your own words?", "What information do you need to solve the problem?", "What do you already know about this topic?", "Can you compare this problem with previously encountered problems?"

Observations from the third action cycle showed that students not only answered questions but also began to question and evaluate each other's thinking processes. Based on this development, in the fourth action cycle, a question-generation strategy was added to the existing strategies in order to enable students to take greater responsibility for metacognitive processes. Thus, it was aimed that students would not only respond to given questions but also generate their own questions to support the problem-solving process and manage their thinking processes independently.

## Data Analysis

The verbal data obtained through the think-aloud protocol were transcribed into written form prior to analysis. Before initiating data analysis, a coding approach based on the conceptual framework proposed by Strauss & Corbin (1990) was employed in order to construct a conceptual framework for metacognitive skills. Accordingly, the relevant literature was first reviewed, and the theoretical foundation of the study was established. In this study, metacognitive skills were addressed based on Brown's (1987) Metacognitive Model and examined within the component of metacognitive knowledge. The metacognitive knowledge component was analyzed under two dimensions: awareness of problem understanding and reflecting on the problem.

An analytic scoring rubric was used to determine students' performance in the pre-assessment, interim assessments, and post-assessment phases. The maximum possible score on the rubric was 4, which indicated a high level of performance. Accordingly, scores between 2 and 3 were considered moderate, while scores between 0 and 1 were considered low.

Descriptive analysis, video-protocol analysis, document analysis, and constant comparative analysis techniques were employed in the data analysis process. Within the scope of descriptive analysis, an analytical framework was developed based on the predetermined conceptual framework, and the data were organized, summarized, and interpreted accordingly. Video-protocol analysis was used to examine in detail students' thinking and decision-making processes during problem solving. Document analysis was conducted on student worksheets, researcher journals, and evaluation forms. Through constant comparative analysis, findings obtained from different data sources were compared in order to identify similarities and differences.

The behavioral indicators included in the analytical framework were consistent with the metacognitive awareness indicators in the "Metacognitive Awareness Scale for Children (MAS-C) Form A" developed by Karakelle & Saraç (2007). This alignment contributed to strengthening the theoretical basis of the analytical framework and supported the construct validity of the study.

## Validity and Reliability

During the data collection and analysis process, independent coding was conducted by a second field expert in order to minimize potential researcher bias. Intercoder agreement was calculated to ensure reliability. In addition, students' work products, video recordings, researcher notes, and analytic scoring rubric data were compared with one another, thereby enhancing validity through data triangulation.

According to Silverman (2013), interpretations and conclusions in qualitative research should be credible. Since the data were obtained using multiple data collection tools, credibility was ensured through triangulation. The direct relevance of the study group to the research topic is related to validity. The use of purposive sampling increased access to an appropriate data set for the study. To determine intercoder consistency, the similarity formula proposed by Miles & Huberman (1994) was used. An intercoder agreement rate of 90.3% indicated satisfactory internal consistency. The Kappa statistic, one of the methods used to determine rater reliability for the analytic scoring rubric, was also employed. The Kappa value was calculated using the SPSS software package. In interpreting the Kappa statistic (κ), the agreement levels suggested by Landis & Koch (1977) were used. In this context, a κ value of .729 indicated substantial agreement.

## Researcher Role

In this study, the researcher assumed both the roles of practitioner teacher and reflective researcher in accordance with the nature of action research. The researcher was actively involved in all stages of the process, including planning, implementation, observation, and evaluation. Throughout the process, observations and experiences were systematically recorded through researcher journals. This role enabled close monitoring of students' learning processes, identification of emerging needs, and timely implementation of necessary adjustments.

The researcher was careful not to direct students toward any specific solution path at any stage of the implementation process. In particular, in order to enable students to independently develop their own problem-solving strategies, the researcher avoided providing direct explanatory hints and instead used only metacognitive questions and prompts aimed at supporting students' thinking processes. In this way, students were encouraged to become aware of, monitor, and evaluate their own thinking processes. Throughout the entire implementation, the researcher acted as a facilitator, guide, and reflective practitioner, striving to preserve the natural structure of the learning environment.

# Findings

## Pre-Assessment Findings

Students' existing performance related to metacognitive skills was evaluated in terms of scores and performance levels using an analytic scoring rubric. The scores obtained by the students in the pre-assessment and the corresponding performance levels are presented in Table 2.

**Table 2.**

*Students' Pre-Assessment Scores and Performance Levels*

| Students | Score | Level |
|---|---|---|
| Mehmed | 0 | Low |
| Özlem | 1 | Low |
| Mert | 0 | Low |
| Halenur | 0 | Low |
| Ahmet | 0 | Low |
| Hakan | 0 | Low |
| Asiye | 0 | Low |
| Zehra | 0 | Low |

Table 2 presents the pre-assessment metacognitive skill scores and levels of the nine students. Özlem obtained 1 point, while the other students scored 0 points and were therefore classified as low level. The students did not demonstrate indicators of awareness of problem understanding, such as representing the problem in a different way or recognizing what was required in the problem. Likewise, they did not exhibit indicators of reflecting on the problem, such as making connections with previously encountered problems or activating prior knowledge. Based on these findings, it can be stated that the students did not demonstrate awareness of problem understanding. Özlem, on the other hand, was able to make connections with previously encountered problems; however, she did not question her prior knowledge. Due to deficiencies in reflecting on the problem, she was awarded 1 point.

## Findings Related to the First Action Plan

In the first interim assessment, the scores obtained by the students from the analytic scoring rubric and the corresponding performance levels are presented in Table 3.

**Table 3.**

*Students' Scores and Performance Levels in the First Interim Assessment*

| Students | Score | Level |
|---|---|---|
| Mehmed | 2 | Moderate |
| Özlem | 2 | Moderate |
| Mert | 2 | Moderate |
| Halenur | 2 | Moderate |
| Ahmet | 1 | Low |
| Hakan | 2 | Moderate |
| Asiye | 1 | Low |
| Zehra | 2 | Moderate |

According to Table 3, Ahmet and Asiye obtained the lowest scores and were classified at a low level. In the first interim assessment, students began to demonstrate indicators of awareness of problem understanding. However, no student exhibited indicators of reflecting on the problem. Therefore, it can be stated that students had not yet developed the skills of relating problems to prior knowledge or connecting them with previously encountered problems.

When the first interim assessment scores are compared with the pre-assessment scores, an increase in student performance is observed. This finding indicates that students' metacognitive skills have begun to develop. As seen in the student statement related to awareness of problem understanding, the student visualized the problem and expressed it in his/her own words:

> *"The teacher, there is a frog here. One day it jumped and fell into a 15-meter-deep well. (While summarizing the problem situation, the student reenacts it with an eraser.) Each time it jumps 4 meters, but because it is slippery, it falls down 1 meter when it comes up, teacher, so it happens like this. (The student takes the eraser and moves it slightly downward from the pencil case.) Teacher, look, it jumps like this 4 meters, then falls down like this. Then it comes up again, jumps, and falls down 1 meter. The question here is: on which jump does the frog come out of the well?"*

## Findings Related to the Second Action Plan

In the second interim assessment, the scores obtained by the students from the analytic scoring rubric and the corresponding performance levels are presented in Table 4.

**Table 4.**

*Students' Scores and Performance Levels in the Second Interim Assessment*

| | Perimeter Measurements | Area Measurements | Mean |
|---|---|---|---|

| Students | Score | Score | Mean Score | Mean Level |
|---|---|---|---|---|
| Mehmed | 2 | 3 | 2,5 | Moderate |
| Özlem | 2 | 3 | 2,5 | Moderate |
| Mert | 2 | 2 | 2 | Moderate |
| Halenur | 2 | 2 | 2 | Moderate |
| Ahmet | 1 | 2 | 1,5 | Moderate |
| Hakan | 2 | 3 | 2,5 | Moderate |
| Asiye | 2 | 3 | 2,5 | Moderate |
| Zehra | 3 | 3 | 3 | Moderate |

When Table 4 is examined, it is seen that Zehra achieved the highest score with 3 points. However, all students were evaluated at a moderate performance level. While no indicators of "reflecting on the problem" were observed in the first interim assessment, it was found that the indicator of "relating to prior knowledge" within this dimension emerged in the second interim assessment. In parallel with this development, students' scores increased compared to the first interim assessment results. Nevertheless, one of the most challenging indicators for students in the second interim assessment was the ability to relate the problem to previously encountered problems. In fact, no student was able to obtain a score for demonstrating this indicator. This finding suggests that although students made progress in relating problem situations to their prior knowledge, they had not yet reached a sufficient level in establishing connections with previous problem-solving experiences.

In the "Measurement of Perimeter" problem, students were found to be insufficient in demonstrating the "awareness of problem understanding" indicator. Students stated that they had difficulty due to the problem being presented in video format. It is thought that the difficulty experienced in this indicator stemmed from this situation.

> *"Have I encountered this type of question before? Yes, in the pool problem. We were finding the perimeter."*

> *"I wonder if I have encountered a similar question before? There was a pool question, for example."*

An analysis of student statements shows that although students were able to recall previously encountered problems, they were not able to establish similarities and differences between those problems and the current one.

## Findings Related to the Third Action Plan

In the third interim assessment, the scores obtained by the students from the analytic scoring rubric and the corresponding performance levels are presented in Table 5.

**Table 5.**

*Students' Scores and Performance Levels in the Third Interim Assessment*

| | Weighing | Measuring liquids | Mean | |
|---|---|---|---|---|
| Students | Score | Score | Mean Score | Mean Level |
| Mehmed | 3 | 4 | 3,5 | High |
| Özlem | 3 | 3 | 3 | Moderate |
| Mert | 3 | 3 | 3 | Moderate |
| Halenur | 3 | 3 | 3 | Moderate |
| Ahmet | 2 | 3 | 2,5 | Moderate |
| Hakan | 3 | 3 | 3 | Moderate |

| | | | | |
|---|---|---|---|---|
| Asiye | 4 | 4 | 4 | High |
| Zehra | 4 | 4 | 4 | High |

When Table 5 is examined, it is seen that the highest scores were obtained by Asiye and Zehra. Both students received 4 points and were evaluated at a high performance level. Another student who demonstrated high-level performance was Mehmed. The performance of the remaining students was determined to be at a moderate level.In the third interim assessment problems, it was found that all students except Ahmet fully demonstrated the indicators of "awareness of problem understanding." Although students showed improvement in the "reflecting on the problem" dimension compared to previous assessments, only Asiye and Zehra were able to fully demonstrate this skill. Sample statements from these students are as follows:

> *"The teacher, we did a caravan problem, it is similar to this one. There was also a rule there. The total had to be 140. Here, for example, there is an 8 kg condition. The second box is 3000 g. In that problem, the number of children was not given; we were supposed to determine it, as long as the total was 140 kg. It is the same here. I will do it like in that problem."*

> *"In the Meryem's birthday problem, we filled glasses with juice. There was a total of 4 liters. I subtracted what we used from the total. I need that here. I will use that information here as well. Here I will find the amount of juice consumed by Çiğdem's family. Since it asks how many liters are left, I will subtract like in that problem. When it asks for the remaining amount, we used subtraction. We found the consumed juice by adding. I will do it the same way."*

In other words, all students were able to make connections using their prior knowledge related to the problem. However, it was determined that they were not yet able to demonstrate sufficient performance in establishing connections with previously encountered similar problems.

## Findings Related to the Fourth Action Plan

In the final assessment, the scores obtained by the students from the rubric and the corresponding performance levels are presented in Table 6.

**Table 6.**

*Students' Scores and Performance Levels in the Final Assessment*

| Students | Score | Level |
|---|---|---|
| Mehmed | 4 | High |
| Özlem | 3 | Moderate |
| Mert | 4 | High |
| Halenur | 4 | High |
| Ahmet | 3 | Moderate |
| Hakan | 4 | High |
| Asiye | 4 | High |
| Zehra | 4 | High |

When Table 6 is examined, it is seen that six students obtained the highest score and were evaluated in the high-level category. In comparison with the third interim assessment results, it was determined that Özlem showed no improvement in performance. Asiye and Zehra, who reached the maximum score of 4, maintained both their scores and performance levels. An increase was observed in the scores of the remaining students. This increase is considered to be associated with the development of students' ability to relate problems to previously encountered problems.

The evaluation results indicated that Ahmet and Öznur were not able to fully demonstrate this indicator. However, it is noteworthy that these students showed improvement compared to their initial levels. Indeed, although they were able to recall previously encountered problems related to the task, they were insufficient in explaining the relationship between those problems and the current one.

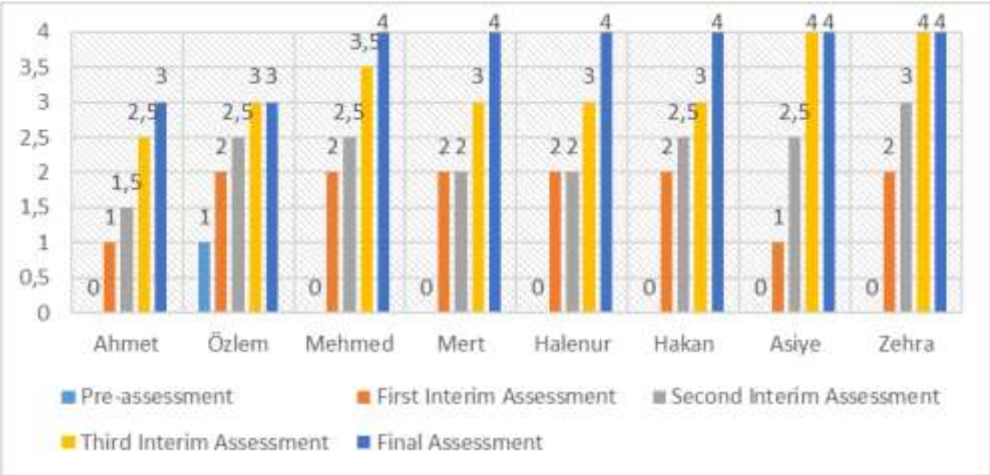
One of the students who fully demonstrated the "reflecting on the problem" indicator, Hakan, expressed his thinking as follows:

> *"In previous problems, we were comparing the heights of mountains. We were finding them by subtracting the differences. Those problems were easy, teacher. Here we are thinking. There are not many operations either. I need to find the height that two children can climb together. In this respect, it is different from those problems."*

The scores obtained by the students during the implementation process are presented in Figure 2.

**Figure 2.**

*Students' Scores Obtained in the Study*




According to Figure 2, students increased their performance scores related to the metacognitive knowledge dimension during the problem-solving process. This finding indicates a positive development in metacognitive knowledge skills.

When the interim assessment and final evaluation findings are examined together, it is observed that the first indicators acquired by the students belong to the "awareness of problem understanding" dimension. One of the indicators related to the "reflecting on the problem" dimension, namely relating the problem to prior knowledge, began to be demonstrated by students starting from the first action cycle. In contrast, the acquisition of the indicator related to relating the problem to previously encountered problems occurred at a later stage of the process. This indicator was first demonstrated by Zehra and Asiye in the third interim assessment. Examination of the evaluation results shows that this indicator was eventually acquired by all students except these two initially demonstrating students. This finding suggests that as the process progressed, students were able to relate problem situations not only to their existing knowledge but also to their previous problem-solving experiences.

## Discussion, Conclusion, and Recommendations

The findings of the study indicate that the Realistic Mathematics Education (RME) approach supports the development of primary school students' metacognitive knowledge skills. At the beginning of the instructional process, students were found to approach problem solving in a procedure-oriented manner, to experience difficulties in establishing relationships between given and required information, and to be insufficient in explaining the solution strategies they used. However, with the implementation of the action plans, significant changes were observed in students' approaches to problem solving. By the end of the process, a notable improvement was observed in both awareness of problem understanding and reflecting on the problem dimensions.

It was found that indicators related to metacognitive knowledge emerged gradually throughout the implementation process. The first observed indicator was awareness of problem understanding, which appeared in the first interim assessment. The "relating the problem to prior knowledge" indicator within the reflecting on the problem dimension began to be demonstrated by students starting from the second interim assessment. The "relating to previously encountered problems" indicator, which is also part of this dimension, was demonstrated by only two students in the third interim assessment, whereas in the final assessment it was exhibited by six students. This finding indicates that students developed the ability to relate problem-solving experiences to new problem situations as the process progressed. In particular, students' increasing tendency to connect problem situations with prior knowledge and, over time, with previously encountered problems suggests an improvement in metacognitive knowledge skills. These findings are consistent with research indicating that metacognitive awareness is a skill that can be developed through appropriate instructional arrangements and learning environments (Brown, 1987; Schoenfeld, 1985; Veenman, 2017; Zohar & Barzilai, 2013).

The fact that RME activities are grounded in real-life contexts enabled students to actively participate in the learning process, explore problem situations, and make their thinking processes visible. During this process, students had the opportunity to relate mathematical situations to real-life experiences and to discuss different solution strategies through group interactions, thereby engaging in the questioning and evaluation of their own thinking processes. This is considered to have supported the development of their metacognitive knowledge skills. Indeed, studies demonstrating that RME enhances students' abilities to justify solution strategies, reason mathematically, and explain their mathematical thinking (Freudenthal, 1991; Gravemeijer, 1994; Van den Heuvel-Panhuizen, 2000) support this finding. Therefore, the results of the study indicate that RME is an effective approach not only for improving mathematical achievement but also for developing students' metacognitive awareness and metacognitive knowledge skills.

The instructional prompts, classroom discussions, group work, and researcher feedback implemented throughout the action plans aimed to enhance students' cognitive awareness. These practices contributed to students' more conscious and inquiry-based engagement in problem-solving processes. Moreover, the cyclical nature of action research enabled systematic observation, evaluation, and improvement processes, allowing developmental changes in students to be monitored in a structured way. The findings are consistent with those of Özsoy & Ataman (2009), who reported that increases in metacognitive knowledge support students' problem understanding and strategy development skills. Similarly, Artzt & Armour-Thomas (1992) identified the use of prior experiences as an important metacognitive indicator in problem solving. In this study, students' increasing ability to recall and relate previously encountered problems to new situations supports these findings. In addition, Işık (2015) emphasized that structured classroom activities within a design-based research framework contribute to the development of students' metacognitive skills. In this respect, the present study demonstrates that planned instructional interventions and learning environments that promote active student participation play a significant role in developing metacognitive awareness and metacognitive knowledge skills.

The study reveals that the RME approach is an effective instructional method for improving primary school students' metacognitive knowledge skills. At the end of the research process, students' awareness of problem-solving increased, they analyzed problem situations more consciously, and their ability to articulate their thinking processes improved. However, the fact that two students did not fully demonstrate the "relating to previously encountered problems" indicator suggests that some metacognitive knowledge skills require longer-term and more systematic instructional support. This finding indicates that students need rich learning experiences, diverse problem situations, and sustained reflective thinking activities in order to transfer prior problem-solving experiences to new contexts. Therefore, while RME appears to be an effective approach for developing metacognitive knowledge skills, long-term implementation is essential for ensuring more stable and comprehensive development of these skills.

Gençer (2025) found that integrating metacognitive strategies into realistic problem-solving improved students' understanding in probability by enabling deeper learning. Değirmenci (2025) demonstrated that metacognition-oriented mathematics learning environments enhance primary school students' metacognitive skills. Similarly, Akış (2022), in a meta-analysis study conducted with third-grade students, reported that students in experimental groups experienced improvement in metacognitive skills when realistic mathematics instruction was supported with metacognitive strategies. Overall, the findings suggest that metacognitive skills can be associated with RME and that this approach contributes positively to students' problem-solving processes. However, studies with larger samples and different grade levels are needed to strengthen the generalizability of the findings.

This study shows that RME is a holistic approach that focuses not only on academic achievement but also on thinking processes. Therefore, systematically supporting metacognitive skills at early ages is expected to make a significant contribution to students' later mathematics learning experiences. Based on these findings, it is recommended that teachers include more real-life-based, discussion-oriented, and strategy-focused activities in mathematics lessons, provide regular opportunities for students to express their solution processes verbally or in writing, and explicitly teach metacognitive strategies to all students regardless of academic achievement. In addition, problem-solving and metacognitive strategies, which are treated separately in curricula, should be integrated, and teacher education programs should incorporate RME-like meaning-making approaches in practice-oriented ways.

**Disclosure Statements**

**Contribution rate statement of the researchers:**

Both authors contributed equally to this study.

**Conflict of interest statement:**

The authors declare that there is no conflict of interest.

**CRediT Authorship Contribution Statement**

Yeşim BAYRAK, Esin ACAR: Conceptualization, methodology, data collection, data analysis, writing – review & editing.

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**Ethical Declaration and Committee Approval**

In this research, the principles of scientific research and publication ethics were followed.