

**Received:** 04 March, 2026

**Accepted:** 25 May, 2026

**Published:** 03 June, 2026

# Challenges in Developing Mathematical Competence in Primary School Pupils: A Case Study Based on Teachers' Views

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**Cite this article:**

Yanbiyik, S., & Güder, S. (2026). Challenges in developing mathematical competence in primary school pupils: A case study based on teachers' views. *Cultura Científica*, (24): 509–516.

## Abstract

The purpose of the current study was to analyse the difficulties experienced in the development of mathematical competence among primary school students from the perspective of teachers. This study employed a qualitative research paradigm with the use of the case study methodology. In this research, the sample comprised 18 teachers teaching at the primary school level. Semi-structured interviews were used for collecting data, and an interview form designed by the researcher was implemented. For designing the interview form, expert opinion and piloting were utilized. In order to interpret data, descriptive analysis was applied. According to the findings, students face major difficulties in mathematical competence development in relation to the four sub-dimensions. Regarding problem solving, the most common issue reported by teachers is a lack of understanding the meaning of the problem after reading it. Cognitive developmental limits, problems with separating problem into smaller tasks, and determining the best strategy for finding its solu-

tion are the primary concerns for the sub-dimension of mathematical reasoning. For mathematical representation, the key issues include abstract-concrete conceptualisation, graph-reading, table-reading, and symbol interpretation, and when talking about mathematical communication, the main problems involve comprehension of mathematical terms, using them properly, and explaining. Based on the research results, it should be stated that such difficulties are not only related to student achievement but also to language, symbols, previous experiences, psychological, and contextual elements that should be taken into account in the assessment. As far as the practical implications are concerned, the research provides a practice-oriented problem map covering four dimensions of mathematical competence development in primary school mathematics education.

**Keywords:** Mathematical Competence; Problem Solving; Mathematical Reasoning; Mathematical Representation; Mathematical Communication; Teachers' Views

## 1. INTRODUCTION

Mathematical competence is a layered concept in the field of primary school mathematics education, which cannot be explained only through the correctness of calculations. Mathematical competence is defined as the capability of children to comprehend mathematical situations, identify the relationships among them, reason, make transitions between various representations, and communicate their ideas through mathematical language [1]. The definition of mathematical competence that has been emphasized in the mathematical competence framework in the Turkish curriculum in 2018 requires considering problem solving, reasoning, use of mathematical representations, and mathematical communication together. Primary school years, which can be called the first systematic encounter with mathematics for pupils, appear as a special period of interrelatedness between verbal, visual, and symbolic structures.

Challenges faced in primary school mathematics education are generally interpreted in terms of one single variable. For instance, reading comprehension skills, mathematical anxiety, use of representations, and problem-solving success have been discussed in various studies as independent factors. However, as revealed in practical experience, there is no such phenomenon in this respect. As shown in previous research, the significant relation between Year 4 pupils' self-efficacy perceptions about reading comprehension and their metacognitive awareness with their problem-solving success shows that success in mathematics cannot be attributed solely to the technical aspect of problem solving [2]. Also, the significant relationship established between reading attitude, level of reading comprehension, and success in solving non-routine problems of Year 4 primary school pupils reveals the linguistic dimension of the problems of mathematical education [3]. Additionally, the opinions of teachers about PISA-like mathematics problems included in the LGS test confirm the importance of reading comprehension and analysis of real-life context [4]. Moreover, primary school mathematics education does not solely consist of difficulties caused by the students. Program intensity, differences in prior knowledge, abstractness of concepts, and teaching environment restrictions also influence this process. Current studies that focus on the difficulties of classroom teachers in mathematics education show that the process cannot be evaluated without consideration of the features of the students and the environment in the classroom [5, 6]. Therefore, it appears to be insufficient to explain the difficulties encountered in the development of mathematical competence just by looking at student success.

Similarly, the domain of mathematical reasoning and mathematical communication is multidimensional. It is indicated that a significant relation has occurred between mathematical anxiety and mathematical self-efficacy of Year 3 and 4 pupils; hence, it cannot be ignored that emotional factors also play a role in the reasoning and expression process of children [7]. Moreover, studies that analyze textbooks and questions included in examinations concerning representational competence emphasize the significance of qualities and diversification of representations for pupil's comprehension processes [8]. As it is obvious, since the three skills are very closely related, the difficulties faced by primary school pupils should be analyzed in a holistic way rather than fragmentation of the problems.

Even though there are many studies in the literature about the difficulties encountered in problem-solving, reading comprehension, anxiety, or general problems in mathematics education, it is obvious that few studies exist concerning the development of mathematical competence through its four dimensions. Especially, it is expected that qualitative data obtained from teachers' observations will enable understanding what kind of difficulties occur, where these difficulties occur with regards to the concepts or languages, and in which ways these difficulties reflect themselves in the process of mathematics education. The purpose of this study is to explore difficulties in developing mathematical competence in primary school pupils according to teacher observations. Within this scope, this study seeks to answer the following questions: What are the difficulties of primary school pupils in the process of problem solving? What kinds of difficulties occur in mathematical reasoning? What kinds of difficulty points emerge while using mathematical representations? And what difficulties occur in mathematical communication?

In this context, it aims to reveal a practical "map of difficulties" in primary school mathematics education by considering the sub-dimensions of mathematical competence together.

## 2. METHOD

This study adopted a qualitative case study method. Case studies allow for deep explorations of phenomena within their experiences, contextual features, and meanings [9, 10]. The case to be studied in this paper is the difficulties identified by the teachers in the process of developing mathematical competence among pupils. Rather than measuring those difficulties individually and numerically, this study sought to identify how these difficulties were expressed and clustered within the various dimensions of mathematical competence.

Participants of the study were chosen among 18 classroom teachers in primary schools. For selecting participants, the maximal variation method was utilized. Professional experience years were selected as the diversity criteria for participants. The teaching experience of participants ranged between 3 and 15 years. The selection of such participants was regarded important in that it would allow observation of the same phenomenon of educational science by teachers of different levels of professional experience. To ensure the anonymity of participants, the codes K1-K18 were assigned to participants.

The data was gathered with the help of semi-structured interview forms that were developed by the researchers. There were four questions in the interview form, with each question covering one of the sub-dimensions of mathematical competence: problem-solving, mathematical reasoning, use of mathematical representations, and mathematical communication. The data gathering tool was prepared based on literature review and then revised with expert opinion. Five experts were consulted for reviewing the data gathering tool, and five classroom teachers underwent pilot application. As a result of the expert review and pilot application, the last form was prepared by the researchers.

While conducting the interviews, audio and hand-written recordings were made upon the consent and preference of the participants. Interviews were made on the direct questions that are asked in order to gather information about the difficulties faced by pupils in various aspects of mathematical competence. In this way, a data set for comparison purposes regarding the problem-solving, reasoning, representation, and communication difficulties could be obtained.

Qualitative data gathered by means of interviews were analyzed by employing the method of descriptive analysis. For this purpose, codes and frequencies were determined according to predefined categories. Quotations from teachers' statements were used for supporting interpretations and ensuring credibility of the analysis. Categories and codes found for the dimensions of problem-solving, mathematical reasoning, mathematical representations, and mathematical communication became the grounds of the analysis.

### 3. FINDINGS

#### 3.1. DIFFICULTIES ENCOUNTERED IN THE PROBLEM-SOLVING PROCESS

Frequency and percentage distribution of difficulties relating to this sub-dimension are given in Table 1.

**Table 1.** *Prominent difficulties in the problem-solving process*

Prominent difficulty	f	%
Difficulty in understanding the problem	6	33
Problems arising from a lack of information	3	16
Failure to select an appropriate strategy for the problem	4	22
Lack of developed logical thinking skills	3	16
Underdeveloped analytical and synthesis skills	2	12

The opinion of the teachers regarding problem solving may be grouped into two categories: difficulties related to understanding the problem, and the absence of analytical and strategic abilities. As for the 'difficulties related to understanding the problem,' one of the most frequent problems pointed out was the students' inability to understand the nature of the problem given and what they were asked to do. The frequency of occurrence of this code was stated to be 6, accounting for 33 percent of the codes in total. Difficulties caused by the absence of knowledge have been cited by 3 teachers and account for 16 percent of the total. The analysis of the teacher statements reveals that there is some interconnection between the above mentioned difficulties. That is, students often fail to analyze the textual content of the problem and are unable to start its solving because of the lack of understanding of the mathematical language or the relations involved.

It can be seen from the teacher statement K2 that "They do not produce a solution because they do not understand the problem". It can also be said that K14 and K6 show the teachers' belief that mathematical language and symbols represent obstacles on the way to problem-solving. This proves that problem solving does not consist only of operational actions, but requires thorough linguistic analysis. Furthermore, according to the teachers, the educational environment, along with the limited conceptual vocabulary, often cause the problem mentioned.

The second cluster of codes refers to difficulties related to problem solving skills, such as strategy selection and analytical and logical thinking. Thus, in the problem solving stage, the most frequent problem is the inability of the students to choose a proper strategy in dealing with the problem. The frequency of occurrence is 4, whereas the percentage is 22%. Lack of analytical skills, along with the development of logic thinking has been cited by 3 teachers and accounts for 16%, while the underdeveloped ability of synthesis has been cited by 2 teachers and is 12% percent of the total codes in this cluster. The findings show that the students often have a good idea of what the problem is about but find themselves unable to decide upon the ways and strategies to solve the problem. The teacher's K12 remark that "To formulate effective strategies, it is necessary to analyze the problem, consider various ways to solve the problem, and use these ways" shows that the teachers believe that the problem lies in the students' inability to think properly and take corresponding mental actions.

Consequently, the analysis of teachers' opinions regarding problem solving shows that the difficulties related to the lack of reading comprehension and problem solving skills enhance each other. On the one hand, if the students cannot solve the problem due to the difficulty to comprehend it, they will also find it difficult to choose an appropriate strategy. On the other hand, due to the absence of such strategies in their repertoire, the students will not be able to continue working with

the problem even if they have comprehended it well enough.

### 3.2. DIFFICULTIES ENCOUNTERED IN THE MATHEMATICAL REASONING PROCESS

The frequency and percentage distribution of difficulties related to this sub-dimension are provided in Table 2.

**Table 2.** *Prominent difficulties in the mathematical reasoning process*

Prominent difficulty	f	%
Inability to break the problem down into parts	4	22
Inability to conceptualise abstract mathematical concepts	3	16
Inability to think logically	2	11
Prejudice and lack of self-confidence	3	16
Stress and anxiety	2	11
Inability to determine a solution strategy	4	22

Three distinct clusters can be identified in relation to mathematical reasoning. They are as follows: cognitive development issues, problems connected with psychosocial factors, and difficulties that arise due to an inability to formulate solution strategies. Cognitive development-related issues form the most prevalent cluster. As many as 47 percent of teachers stated that they observed cognitive development-related problems in terms of reasoning ability. By analyzing the sub-codes of this cluster, one can say that an inability to divide problems into components has been indicated by 4 teachers (22%), an inability to concretize abstract mathematical notions by 3 teachers (16%), and an inability to think logically by 2 teachers (11%).

It is important to note that K2 believes that students are currently at a stage when they are 'transitioning from the concrete to the abstract', and that the system is pushing them to find a solution quickly. At the same time, K15 emphasizes that, considering students' age group, their logical thinking has not yet developed completely, thus leading to challenges in analyzing complex situations. One should pay attention to the fact that teachers connect reasoning abilities with both achievement levels and cognitive readiness of students, as well as with their particular thinking styles. In addition, it is widely stated that it is difficult for students to break down problems into component parts, especially in case of problems requiring a multi-stage solution.

Another important cluster in regard to reasoning skills is associated with psychosocial factors. As many as 3 teachers (16%) mentioned prejudice and a lack of self-confidence among students. Additionally, stress and anxiety are stated by 2 teachers (11%). It has been said that students' negative experience in mathematics classes and expectations of failure adversely affect their reasoning abilities. Statement K1, "A student with a prejudice against mathematics may struggle with mathematical reasoning skills," directly shows this relationship between the affective dimension and reasoning. At the same time, K4 emphasized that students only focus on one possible solution path and experience stress because of this. Thus, reasoning is viewed as a skill that is dependent not only on cognitive capacity but also on psychological ones.

An inability to formulate a solution strategy belongs to the third cluster that is under discussion. This code has been mentioned by 4 teachers (22%). K3 and K14 believe that students are unable to apply techniques such as decomposition of the problem, generation of alternative solution paths, and modelling. A significant observation in this connection is that this particular cluster overlaps with the lack of strategy code in the problem-solving dimension. Thus, one can conclude that this means that there is no sharp distinction between the two dimensions; they rely on common cognitive and affective factors.

### 3.3. DIFFICULTIES ENCOUNTERED IN THE USE OF MATHEMATICAL REPRESENTATIONS

Table 3 presents the frequency and percentage distribution of difficulties in this sub-dimension.

**Table 3.** *Prominent difficulties in the use of mathematical representations*

Prominent difficulty	f	%
Difficulties in transferring from abstract to concrete	7	38
Students finding it difficult and complex to read graphs and tables	6	33
Symbols seeming complex and difficulty in making connections	5	27

Findings about mathematical representation have been categorised into three types: problems in translation from abstract concepts to concrete concepts, problems in reading graphs and tables, and problems in understanding symbols. The frequency of the first type of problems is higher than other types, and this type includes 7 teachers' statements with a rate of 38%. As it is seen from teachers' comments, pupils had problems in relation to connecting mathematical concepts with concrete objects or actual events. K13 indicated that numbers, operations and geometric figures might be very abstract to pupils, while K14 mentioned the difficulty of connecting abstract concepts with real life situations. From the above

findings, it can be inferred that the use of mathematical representations does not mean merely changing representations for pupils, but reconstructing their representations of the concept.

Problems in interpretation of graphs and tables was observed in 6 teachers' comments, which accounted for 33% of the total number of codes. Problems in this regard were mainly attributed to the underdevelopment of students' literacy in interpreting graphs and tables. K6 indicated that students could not establish logical connections between numerical, graphical, and symbolic representations, and K17 believed that constructing and interpreting graphs, tables and diagrams was difficult for students. K18 linked this kind of problems to the lack of visual literacy and prior knowledge. It can be said that difficulties that have occurred in this context have not just been in relation to the process of 'reading' tables and graphs, but also the inability to create logical connections among them.

Thirdly, there were some difficulties about understanding symbols. The frequency of this kind of difficulties was 5, while the percentage was 27%. Teachers pointed out that pupils experienced problems in memorising symbols, distinguishing between similar symbols, and creating connections between symbols. In particular, K10 mentioned that pupils could confuse symbols having a similar appearance like ">" and "<". On the other hand, K11 commented that since the multiplication sign was written as a point, pupils could read the symbol "2.3" as "23". From the above findings, it can be inferred that even small formal differences in the symbolic language used by mathematicians may lead to problems of interpretation of symbols.

Therefore, based on the above findings, it can be said that pupils need more concretization of mathematical notions, strong prior knowledge, and training for working with different representations in order to understand mathematical visual and symbolic systems.

### 3.4. DIFFICULTIES ENCOUNTERED IN THE MATHEMATICAL COMMUNICATION PROCESS

The frequency and percentage distribution of difficulties related to this sub-dimension are presented in Table 4.

**Table 4.** *Prominent difficulties in the mathematical communication process*

Prominent difficulty	f	%
Difficulty in understanding and correctly expressing mathematical terms	8	44
Difficulties in expressing and explaining correctly	5	27
Lack of attention, lack of motivation, lack of self-confidence, lack of knowledge and misconceptions	5	27

The code with the highest frequency among the results related to the mathematical communication dimension is the difficulty in understanding and expressing mathematical terms. The mentioned code has been mentioned by 8 teachers and constituted 44% of all results. The teachers pointed out that not only memorizing mathematical terms but also comprehending and using them is difficult for pupils. For instance, according to K3, pupils sometimes have trouble with terms such as greater than, less than and equal to; whereas, K13 said that addition, subtraction and multiplication terms were sometimes confusing for pupils. It is evident that K10's statement about the confusion of terms such as bar chart, object graph and frequency table proves the relationship between conceptual knowledge and mathematical communication.

The second group of findings consists of the difficulty with accurate expression and explanation. The difficulty with expression and explanation was observed by 5 teachers (27%). The difficulty with expression and explanation occurred particularly with foreign-born students, language-deficient students, and because of communication barriers due to difference in the mother tongue of pupils in certain regions. According to K9, the process of concretizing mathematical concepts may be complicated because of language difficulties. Moreover, K15 noted that pupils could not express their thoughts and steps for a solution; hence, they have difficulties with translating mathematical terms into language. The mentioned finding indicates that mathematical communication implies not only expressing the right answers, but also the ability of pupils to express mathematical relations and concepts verbally and symbolically.

The third cluster includes attention deficits, lack of motivation, lack of self-confidence, lack of knowledge and conceptual misunderstandings. The mentioned codes were pointed by 5 teachers (27%) and are referred to as other codes. K4 explained that the communication of pupils is based on their attentiveness to mathematical problems and the absence of attention weakens their mathematical communication skills. On the contrary, K16 argued that a pupil without knowledge of mathematical terms could not even communicate in a mathematical way since knowledge is the basis for communication. The described situation shows that mathematical communication is not the final stage of the learning process, but it is one of the foundations of learning.

From the findings concerning the mathematical communication dimension, it can be concluded that linguistic, conceptual and affective factors are tightly connected in classroom mathematics. Pupils cannot explain the solution to a problem if they do not understand a concept. If pupils cannot explain their solution, it is impossible to reconstruct the concept. This is why mathematical communication should not be viewed as a skill, but rather as a foundation of the learning process.

#### 4. DISCUSSION

The evaluation of the results together shows that the difficulties with the development of mathematical competence in primary school pupils under four headings are related to four fundamental and interconnected axes. These are reading comprehension and mathematical language, conceptual and symbolic analysis, developmental and affective readiness, and context-specific limitations. The aforementioned view suggests looking for the way of addressing the issue of mathematical competence as a holistic teaching challenge, rather than an issue itself.

The finding regarding the most crucial problem in the problem-solving dimension, i.e., difficulty with reading comprehension and comprehending what the problem asks, coincides with the modern research. For instance, according to Boz and Ulusoy [3], there are statistically significant correlations between reading attitudes and comprehension abilities of Year 4 pupils and their problem-solving skills. On the other hand, the findings of Bayraktar and Özçakır Sümen [2] demonstrate that the problem-solving competencies of students depend on their self-efficacy and metacognitive awareness in reading comprehension. Thus, the results of this study prove that the linguistic aspect of mathematical problems is a vital element in teaching that should be paid enough attention. In addition, Şıvkın et al. [4] point out that reading comprehension and analysis are decisive for solving problems of PISA-like type. Therefore, problem-solving instruction at the primary school should include teaching students how to analyse texts and establish key relations between words.

It can be concluded that teachers evaluate reasoning abilities of pupils taking into account cognitive development, existence of strategies, and psychosocial factors. For example, Altuntaş and Deringöl [7] discovered a statistically significant correlation between pupils' mathematical anxiety and self-efficacy. In this regard, the findings of the study indicate that pupils' reasoning processes are influenced by self-confidence issues, preconceptions, stress and anxiety. Therefore, it can be claimed that reasoning skills not only depend on cognitive maturation of a child, but also on their psychological characteristics and learning environment. The teachers' perception that some pupils are prone to rushing to a solution implies that answer-focused approaches to teaching prevent the development of pupils' reasoning skills.

The findings related to mathematical representation indicate that difficulties in converting concepts into concrete terms, interpreting graphs and tables, and understanding symbols occur together. The mentioned results suggest that transitioning between types of representation cannot happen automatically and needs to be systematically trained. For instance, Ayyıldız and Cansız Aktaş [8] highlight the role of representational competence in the process of mathematical understanding while conducting a study of textbooks and exam problems. Similarly, the findings of Balaban [5] and Guler et al. [6], who examined the challenges faced by classroom teachers in mathematics lessons, indicate that teaching mathematics in the fields, where abstractions and representation are involved, is problematic. The results of this study show that difficulties with understanding graphs cannot be considered only at their surface but should be looked for in deeper roots caused by a lack of links between graphs, tables, symbols and verbal representation. From the perspective mentioned above, it is necessary to pay closer attention to representing various representations and using visual literacy and concretization methods in classroom instructions.

In the mathematical communication dimension, the dominant difficulties with mathematical language, expression and explanation remind of the importance of this aspect of mathematics education. The teachers pointed out that pupils struggle with a range of concepts from simple operations to terminology of graphs and tables. The findings indicate that the difficulty with language and the fact that some students are foreigners and live in specific regions make mathematics teaching dependent on linguistic aspects. Similar conclusions can be made based on studies devoted to the challenges faced by teachers in classroom instruction [5, 6]. It is necessary to pay attention not only to defining concepts verbally, but also to their use in the process of communicating.

Among the contributions of this study, the demonstration of the relationship between problem-solving, reasoning, representation and communication as connected dimensions is important. For instance, it was revealed that problem-solving difficulties are usually associated with difficulties with communication and reading comprehension; reasoning and strategy development and self-confidence. On the other hand, difficulties in mathematical representation depend on symbolic language and conceptual knowledge. Therefore, it cannot be said that improvements in the field of mathematical education in primary school will suffice if they focus on one particular dimension.

The connection between mathematics and external factors is one more significant contribution. Such difficulties as lack of knowledge, language barriers, insufficient access to education, and limited experience of students were revealed. Researching the challenges faced by classroom teachers in the process of teaching mathematics shows that many aspects of teaching, such as the student him/herself, the context, and the nature of the material taught, influence the process [5]. Thus, it cannot be claimed that the difficulties experienced by students in mathematics classes only depend on their performances. The findings suggest that, especially in the context of social inequality, mathematical language and representation require special attention.

In terms of practical implications, the results indicate the necessity of the teacher not to limit his/her functions to delivering knowledge, but to facilitate the process of structuring mathematical language, connecting different forms of

representations, and revealing pupils' mathematical thinking. Problem-solving involves the stages of analysing texts, generating alternatives, representing visualized images and justifying the solution through communication; and these stages can be considered in the course of one class. Hence, it can be suggested that teachers place more emphasis on short activities aimed at analysing texts, verbalizing solutions, using different forms of representations, and mapping concepts and words.

## 5. CONCLUSION

The present study clearly shows that, from teachers' point of view, problems encountered within the development process of mathematical competence among primary school students are clustered in four essential aspects. Namely, within problem solving, reading and strategic competence; within reasoning, cognitive competence and self-confidence/avoidance of anxiety; within mathematical representation, abstraction-concretization competence, graphs, tables and symbols competence; and finally within mathematical communication, terminology competence and explaining. From the results, one can conclude that the described difficulties cannot be considered exclusively as student failure; instead, linguistic, conceptual, affective and context-related variables should all be taken into account. In this way, the three priorities regarding primary school math teaching become obvious. First, teaching problem solving cannot be dissociated from teaching reading and language of mathematics. Second, an atmosphere needs to be established where students can find several ways of solving the problem, where students can switch between graphical and verbal and symbolic representations and where the errors in solving can serve as a valuable learning opportunity. Third, students' mathematical communication should not reduce to saying the right answer but to the processes of correctly naming, explaining and justifying the concept in question.

The research has shown through teachers' opinions and observations the essential areas in which mathematical competence faces challenges at the primary school level. The most important practical lesson from the research findings concerns the multidimensional nature of mathematical competence, as a result of the combination of the four related sub-aspects.

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