



Functionally Oriented Mathematics Instruction: From Learning Outcomes to Task Selection and Assessment

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Abstract

The paper focuses on possibilities for improving mathematics instruction through the development of functional mathematical knowledge, that is, knowledge that students can understand, connect, and apply in different situations. Based on considerations of learning outcomes, the cognitive demands of tasks, assessment, problem solving, and mathematical modelling, a framework for the selection and analysis of mathematical tasks aimed at developing functional knowledge is proposed. The framework integrates learning outcomes, mathematical content, cognitive demands, strategy selection and justification, the functional component, and the role of context and modelling. Its application is illustrated through the analysis of selected tasks. Particular emphasis is placed on the fact that the functional potential of a task depends not only on its content or real-life context but also on how it is formulated and implemented in instruction.

Keywords: functional mathematical knowledge, mathematics instruction, learning outcomes, mathematical tasks, problem solving.

MSC2020: 97D30, 97D40, 97D50, 97D60

1. Introduction

One of the important goals of contemporary mathematics education is to enable students not only to reproduce acquired knowledge, but also to understand it, make connections, provide justification, and apply it in different situations. Understanding mathematics implies that students make sense of the knowledge and procedures they have acquired, establish connections among mathematical ideas, and apply them to solve a range of tasks and problems (Hiebert et al., 1997). Achieving such an approach largely depends on how teachers plan and implement instruction. It is particularly important that the intended learning outcomes be aligned with instructional activities and with the tasks used to assess student achievement. If students are predominantly required, both during instruction and assessment, to reproduce facts and apply practised procedures, they cannot be expected to sufficiently develop more complex forms of mathematical reasoning or to apply their knowledge independently in new situations. Functionally oriented mathematics instruction, therefore, is not limited to the occasional introduction of tasks based on everyday-life situations. Rather, it involves aligning learning outcomes, instructional activities, and assessment methods,

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selecting tasks that promote understanding, application, reasoning, and justification, and using feedback to guide further learning (Black & Wiliam, 1998; NCTM, 2014; Wiggins & McTighe, 2005).

Based on the theoretical considerations outlined above, this paper proposes a framework for selecting and analyzing mathematical tasks to develop functional mathematical knowledge. The framework integrates learning outcomes, mathematical content, the cognitive demands of tasks, the functional component of knowledge, the need for strategy selection and justification, as well as the role of context and mathematical modelling. Its application is illustrated through the analysis of selected mathematical tasks.

The aim of the paper is to examine possibilities for improving functionally oriented mathematics instruction, with particular emphasis on mathematical tasks that promote understanding, reasoning, justification, and the application of knowledge. Particular attention is devoted to the revised Bloom's taxonomy, written assessments, different types of tasks, Pólya's approach to problem solving, and the role of context and mathematical modelling.

2. Functional mathematical knowledge and outcome-oriented mathematics instruction

Functional mathematical knowledge refers to students' ability to use acquired knowledge in new situations, connect mathematical concepts and representations, select appropriate procedures, justify their solutions, and evaluate their validity. It is not determined by the amount of content students have acquired, but rather by how they can use that knowledge. This concept is closely related to mathematical literacy, which refers to an individual's ability to formulate problems mathematically across a variety of contexts, apply mathematical knowledge, and interpret the results. It includes mathematical reasoning and the use of concepts, procedures, facts, and tools to describe, explain, and predict various phenomena (OECD, 2019). This does not mean that factual and procedural knowledge lose their importance; they provide an essential foundation. However, the functionality of knowledge depends on whether students are able to select, connect, and apply such knowledge in appropriate situations. The functionality of mathematics instruction cannot be assessed solely on the basis of the presence of a real-life context. A task situated in an everyday-life context is not necessarily functional if students are merely required to recognize and mechanically apply a familiar procedure. Conversely, a task without an everyday-life context may contribute to the development of functional mathematical knowledge if it requires students to connect concepts, select an appropriate strategy, and justify their reasoning. Recent research indicates that the relationship between mathematical knowledge and mathematical literacy is complex and that solving contextual tasks requires students not only to possess relevant mathematical knowledge but also to recognize the mathematical content embedded in the situation and apply appropriate knowledge and procedures (Manfreda Kolar & Hodnik, 2021).

When planning instruction, teachers should begin with students' existing knowledge and difficulties, because new mathematical knowledge is constructed by connecting it with previously acquired concepts and experiences. Effective instruction therefore also involves gathering information about what students already know, what they misunderstand, and what kind of support they need. The teaching programme, or curriculum, is not limited to the selection and sequencing of instructional content, but also includes clearly defined goals and learning outcomes, methods for assessing their achievement, and the planning of appropriate learning activities. In this regard, the backward design approach begins by identifying the desired learning results, followed by determining the evidence that will be used to assess whether those results have been achieved, and then planning instructional activities, learning experiences, and procedures that lead towards those results (Wiggins & McTighe, 2005). Instructional content is not neglected in this process; rather, it provides the foundation on which students' knowledge, skills, and competencies are developed. General and subject-specific competencies indicate what students will be able to apply from what they have learned in further learning and in life. Achievement standards also play an important role

in instructional planning, as national educational documents define the knowledge and skills that students are expected to demonstrate at the end of particular levels of education. The current achievement standards for mathematics in Serbia are defined for the end of the first cycle of primary education, the end of primary education, and the end of secondary education ([Ministry of Education of the Republic of Serbia, 2024a, 2024b](#)). Learning outcomes and standards are related, but they are not identical. Learning outcomes more directly guide instructional planning and ongoing assessment, whereas standards provide a framework for expected achievement, most often at the end of an educational cycle. Standards may be used as a reference point when selecting and designing tasks, but they are not measurement instruments in themselves. Tasks, tests, and other assessment procedures are the means used to determine the extent to which learning outcomes and standards have been achieved.

High-quality instructional planning requires that learning outcomes, instructional activities, and assessment methods be aligned not only in content but also in the cognitive processes they require of students. If a learning outcome involves analysis, justification, or the application of knowledge in a new situation, its achievement cannot be fully assessed by a task that requires only the recall of a fact or the mechanical application of a practised procedure.

3. Cognitive demands of tasks and the assessment of student achievement

When planning instruction and assessment, it is not sufficient to determine only the content that will be covered by the tasks. It is also necessary to consider what students are expected to do with that content: recognize it, explain it, apply it, analyze it, evaluate it, or use it to create a new solution. The revised Bloom's taxonomy can be used as a framework for aligning learning outcomes, instructional activities, and assessment methods. Its two-dimensional structure enables the simultaneous classification of a learning outcome or task by both the type of knowledge involved and the cognitive process students are expected to apply ([Anderson & Krathwohl, 2001](#); [Krathwohl, 2002](#)). The knowledge dimension encompasses factual, conceptual, procedural, and metacognitive knowledge, while the cognitive process dimension encompasses remembering, understanding, applying, analyzing, evaluating, and creating. These categories are arranged approximately in order of increasing complexity, but they are not regarded as a completely rigid hierarchy, since some cognitive processes may overlap. The same mathematical content can serve as the basis for tasks with different cognitive demands. For example, students may be asked to state the formula for the area of a rectangle, apply it to given dimensions, analyze how the area changes as the length of one side changes, or determine the dimensions of a rectangle that satisfies given conditions. The content remains the same, but the cognitive processes involved differ. Classifying instructional activities and assessment tasks into the appropriate cells of the taxonomy table, where types of knowledge and cognitive processes intersect, makes it easier to identify the demands placed on students. In this way, inconsistencies between intended learning outcomes and the methods used to assess their achievement can also be identified ([Krathwohl, 2002](#)). It is also important to distinguish cognitive complexity from task difficulty. The cognitive complexity of a task refers to the type and level of cognitive processes required to solve it, whereas task difficulty is an empirical indicator of students' success in solving the task. Therefore, cognitive complexity and difficulty do not represent the same characteristic of a task ([Daniel & Embretson, 2010](#); [Schneider et al., 2013](#)). A remembering task may be difficult if a student lacks the required knowledge, while an application or analysis task may be relatively easy if the situation is familiar to the student. Task difficulty also depends on students' age, prior knowledge, experience, and the way in which the task is formulated.

To evaluate the quality of a written assessment, it is not sufficient to analyze individual tasks; it is also necessary to consider the test as a whole, particularly the extent to which it covers the content and cognitive processes specified in the learning outcomes. Written assessments make it possible to assess a larger number of students within a relatively short period of time and to provide more standardized assessment conditions. However, assessment should not be viewed solely as a final

measurement of achievement. When the results are used to identify students' difficulties, adapt instruction, and provide feedback, assessment also serves a formative function (Black & Wiliam, 1998). When constructing a written assessment, it is important that tasks be clearly and unambiguously formulated, linguistically appropriate for students, and focused on the knowledge or ability being assessed. Unclear or unnecessarily complex wording may introduce difficulties that are unrelated to the construct being measured (Haladyna et al., 2002; Nitko & Brookhart, 2011). In addition, tasks should adequately represent the content and learning outcomes being assessed, while scoring procedures and criteria for evaluating responses should be determined in advance. If a test covers only a limited portion of the content or consists predominantly of tasks that assess the reproduction of knowledge, its results do not provide a sufficient basis for drawing conclusions about the achievement of more complex learning outcomes (Nitko & Brookhart, 2011). Whenever possible, task difficulty should also be evaluated based on students' responses rather than solely on the teacher's impression. For a written assessment to contribute to learning, it is not sufficient to provide students only with a score or grade. Feedback should indicate what the student has done successfully, identify difficulties and errors, and suggest steps the student can take to improve their knowledge and further learning. It should focus not only on the accuracy of the final answer but also on the procedures and strategies the student used to solve the task (Black & Wiliam, 1998; Hattie & Timperley, 2007).

Written assessments may include both closed-ended and open-ended tasks. Closed-ended tasks allow for greater coverage of content within a limited period of time and enable simpler, more objective scoring, but they provide more limited insight into students' reasoning processes and may invite guessing. They include, among others, true–false items, multiple-choice items, and matching tasks. In multiple-choice items, it is particularly important that the incorrect options be plausible, and typical student errors may be used when constructing them (Haladyna et al., 2002). Open-ended tasks require students to formulate their own responses and can provide more information about their choice of strategy, the solution process, and the quality of their justification. Their assessment, however, requires clearly defined criteria. Because different task formats have distinct advantages and limitations, their selection and combination should align with the learning outcomes being assessed (Nitko & Brookhart, 2011). The distinction between open-ended and closed-ended tasks should not be equated with the distinction between lower- and higher-level cognitive tasks. A closed-ended task may require analysis or evaluation, while an open-ended task may assess only simple recall. The cognitive demand of a task depends on the cognitive processes students need to use to arrive at an answer, rather than solely on the task's format.

The above considerations indicate that a mathematical task cannot be evaluated solely by its content, form, or estimated difficulty. Assessing its potential to foster functional mathematical knowledge requires simultaneous consideration of the learning outcome it is intended to address, the cognitive processes it activates, the degree of student autonomy in selecting a solution strategy, the need to make connections and provide justification, as well as the role of context and the way in which the task is implemented.

4. Mathematical problem solving and the functional application of knowledge

One of the prerequisites for developing mathematical literacy is an appropriate approach to problem solving. Problem solving involves not only obtaining the correct result but also understanding the problem's conditions, selecting a strategy, carrying out the procedure, providing justification, and checking the solution. George Pólya identifies four basic stages of solving a mathematical problem: understanding the problem, devising a plan, carrying out the plan, and looking back at the solution (Pólya, 1973). In the first stage, the student identifies what is unknown, what information is given, and what relationships and conditions exist among the given elements. When devising a plan, the student looks for a connection between the given information and the unknown, recalls related or previously solved problems, and considers a procedure that might lead

to a solution. While carrying out the plan, the student follows the intended steps and checks their correctness. In the final stage, the student checks the result and its justification, considers whether the problem could be solved differently, and examines whether the result or the procedure used can be applied to another problem. Although the stages are presented in a particular sequence, individual steps may overlap during the problem-solving process (Pólya, 1973).

Example. A rhombus is given with the measurements shown in the figure (Fig. 1). Determine the values of the unknowns and the rhombus's perimeter. Show your work.

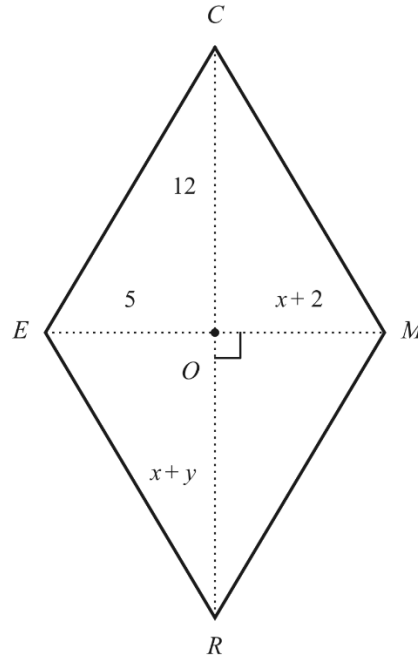


Fig. 1. Rhombus with the given measurements.

In this example, the student first needs to identify the given information and the quantities that must be determined. The solution is based on connecting the properties of the diagonals of a rhombus with the Pythagorean theorem. Since the diagonals bisect each other and intersect at right angles, the relevant diagonal segments can first be determined and then used to calculate the side length and, subsequently, the perimeter of the rhombus. Finally, the student checks the obtained values and justifies the procedure. In addition to carrying out the individual steps of the solution, the task requires the student to recognize which properties of the rhombus relate the given quantities to the unknowns, determine an appropriate sequence for applying them, and observe that the half-diagonals and a side of the rhombus form a right triangle. In this way, the student connects the properties of a rhombus's diagonals to the Pythagorean theorem and selects a solution strategy that yields the required perimeter.

The cognitive demand of the task can be further increased by how it is implemented. Rather than stating in advance which properties should be applied, the teacher can ask students to justify their choices, compare different solution sequences, or verify the obtained result. Justification is an integral part of mathematical thinking. When students explain why a particular procedure is correct, compare different strategies, and discuss mathematical ideas and solutions, they develop and strengthen their mathematical understanding and their ability to construct arguments (NCTM, 2000).

Functional applications of mathematics are often associated with real-life problems, but mathematical modelling involves more than placing a familiar mathematical procedure within an everyday context. It includes understanding and structuring a real-world situation, identifying relevant quantities and relationships, translating them into a mathematical model, working mathematically with the model, and interpreting the obtained result in relation to the original real-world context (Blum & Leiss, 2007). For a real-life context to have instructional value, it should be

relevant to the problem-solving process. If the context can be disregarded and the task reduced to the direct application of a formula, students do not have the opportunity to mathematize the situation independently or to evaluate the reasonableness of the result. Interpreting the solution in relation to the initial situation is an important part of the functional application of mathematics.

Project-based and investigative tasks can also promote functional knowledge. For example, students may analyze a sequence of geometric figures, calculate their perimeters, predict the next figure, and express the relationship between the perimeter and the position of the figure in the sequence using a formula. Such a task integrates pattern recognition, geometry, algebraic representation, and generalization.

Tasks that promote functional knowledge should require more than the direct recognition of a formula and the application of a practised procedure. They should encourage students to connect different representations, select appropriate strategies, analyze conditions, and justify their conclusions. However, simply selecting a cognitively demanding task is not sufficient, as the task's cognitive demand may change during classroom implementation. The way in which the teacher introduces and guides students' work on the task, as well as the type of support provided, can help maintain a high level of mathematical thinking, but may also reduce the task to procedural execution without connections to mathematical meaning (Stein, Grover, & Henningsen, 1996). Recent research on mathematical modelling has likewise emphasized the need to consider both task design and classroom implementation. Geiger et al. (2022) developed a framework that integrates principles for modelling task design with a pedagogical architecture for implementation and specifies the knowledge and capabilities required of teachers and students. Tasks that allow for the use of different solution strategies are particularly valuable. Considering different student approaches provides an opportunity to compare strategies and identify the mathematical connections among them. The teacher's role is not merely to confirm whether an answer is correct, but also to carefully select, organize, and connect students' solutions in order to guide the discussion toward important mathematical ideas (Smith & Stein, 2011).

Based on the theoretical considerations discussed above, a set of criteria can be identified to assist teachers in selecting, analysing, and adapting mathematical tasks aimed at developing functional mathematical knowledge. The purpose of this framework is not to require every task to meet all the criteria simultaneously, but rather to enable a more systematic consideration of its instructional potential.

When analysing a task, the following questions may be considered: which learning outcome the task is intended to achieve or assess; which mathematical knowledge and representations the student needs to connect; which cognitive processes are required for solving the task; whether the procedure is directly provided or the student is expected to select a strategy independently; whether the task requires justification, verification, or comparison of solutions; and whether the context, if present, plays an essential role in the solution process. In tasks based on real-life situations, it is also important to consider the extent to which the student is expected to mathematise the situation, construct or use a mathematical model, and interpret the obtained result.

In addition to the characteristics of the task itself, the way in which it is implemented should also be taken into account. The same task may have different cognitive and functional potential depending on whether the teacher provides the procedure in advance, directs the student towards a single strategy, or, conversely, encourages independent exploration, comparison of different solutions, justification, and verification of the results obtained.

The proposed criteria for analyzing the instructional potential of mathematical tasks are summarized in Table 1.

Table 1. Criteria for analyzing the instructional potential of mathematical tasks

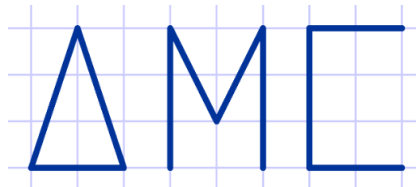
Criterion	Question for Task Analysis
Learning outcome	What should the student demonstrate or develop by solving the task?
Mathematical content and connections	Which knowledge, concepts, or representations does the student need to connect?
Cognitive demand	Does the task require remembering, understanding, applying, analyzing, evaluating, or creating?
Strategy selection and justification	Does the student independently select a solution strategy, and is justification or verification of the solution required?
Functional component	In what way is mathematical knowledge applied, connected, or used in a new situation?
Context/modelling	Is the context essential to the task, and does the student need to mathematize and interpret the situation?

To illustrate the proposed framework, twelve tasks differing in mathematical content, form, and context were selected. The intention was not to present a collection of tasks of a single type, but rather to include examples that allow for the analysis of different aspects of functional mathematical knowledge: application in real-life contexts, mathematical modelling, connections between different mathematical domains and representations, strategy selection, systematic exploration of possibilities, justification, and verification of solutions. The diversity of the examples also makes it possible to demonstrate that the functional potential of a task does not depend solely on its topic or on the presence of a real-life context.

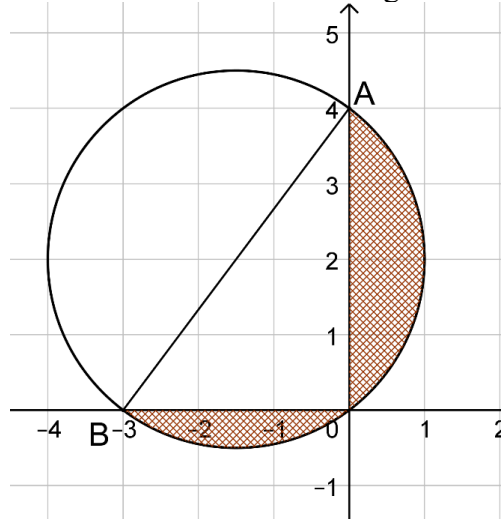
1. Can the diamond, heart, and club symbols in the given table be uniquely replaced by real numbers so that the sum of the first three numbers in each column is equal to the given number in the fourth row of that column?

♠	♦	♥
♥	♠	♦
♥	♥	♠
7	6	6

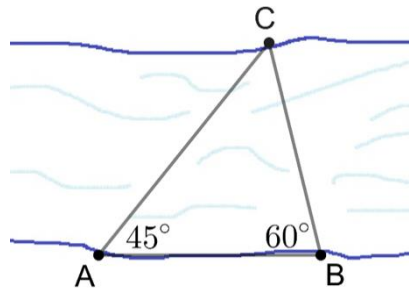
2. Ana deposited 100,000 dinars in a bank account at an annual interest rate of 3.5%. How much money will Ana have in the account after 2 years?
3. Calculate the total length of the line segments used to form the Cyrillic letters ДМC on the square grid, if the unit distance is 1 cm.



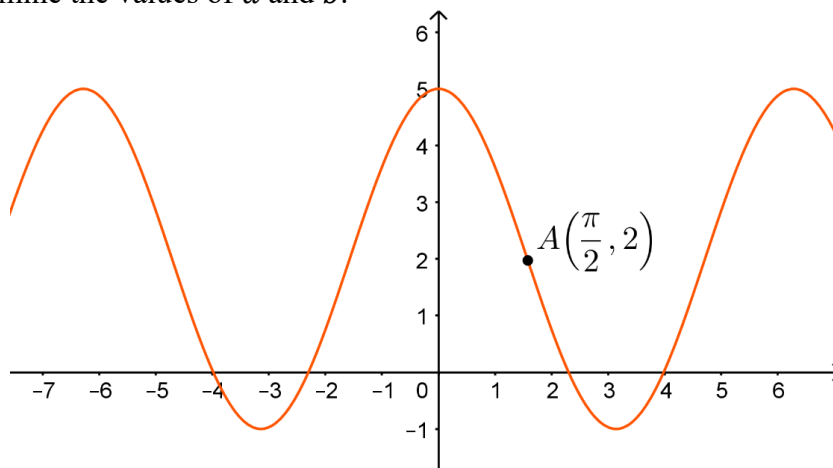
4. Calculate the sum of the areas of the shaded circular segments shown in the figure.



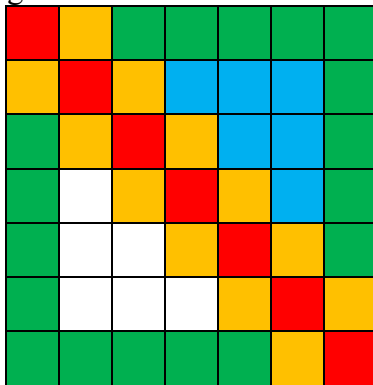
5. For 5 euros (EUR), 625 Serbian dinars (RSD) can be purchased, while for 2 Kuwaiti dinars (KWD), 750 Serbian dinars (RSD) can be purchased. How many euros (EUR) are needed to purchase 100 Kuwaiti dinars (KWD)?
6. To measure the width of a river, surveyors identified two points on one bank of the river (the bank on which they were standing) and one point on the opposite bank. They then measured the corresponding interior angles of the triangle, as shown in the figure. If $AB = 50$ m, what is the width of the river?



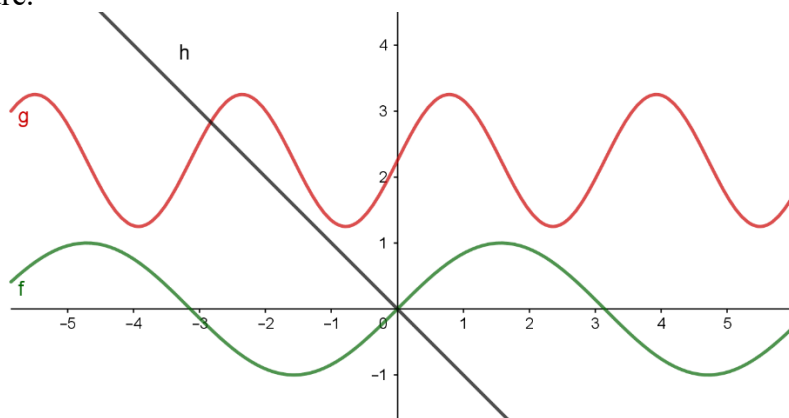
7. Three houses are located at pairwise distances of 13 m, 14 m, and 15 m. At what distance from the houses should a well be dug so that it is equally distant from all three houses?
8. The captain of a ship spotted a lighthouse located on the coast at the ship's destination. He sees the top of the lighthouse at an angle of elevation of 20° . He found online that the lighthouse is 10 m high. How far is the ship from the shore at that moment?
9. The graph of the function $f(x) = a \cos x + b$ is given. Based on the information shown in the graph, determine the values of a and b .



10. The figure shows a square. Its cells are colored using one of five colors: white, green, blue, orange, and red. What is the probability that a randomly selected point in the square lies in:
- a white region;
 - a green region;
 - a red or blue region;
 - a region that is not orange?



11. Pera likes making fruit smoothies. He has four types of fruit available: apples, bananas, lemons, and raspberries. A smoothie can be made using at least two types of fruit. How many different smoothie flavors can Pera make from these fruits?
12. The graphs of the functions $f(x) = \sin x$, $g(x) = \sin 2x + \frac{9}{4}$ and $h(x) = -x$ are shown in the following figure.



- How many zeros does the function $f(x)$ have in the interval $[-\pi, \pi]$?
- How many zeros does the function $g(x)$ have in the interval $[-2\pi, 2\pi]$?
- How many solutions does the equation $\sin x = \sin 2x + \frac{9}{4}$ have?
- How many solutions does the equation $\sin 2x + \frac{9}{4} = -x$ have?

Tasks 1 and 11 require students to consider possibilities systematically and to select an appropriate way of organizing them. Their functional potential does not arise from a real-life context, but from the need to identify relationships, organize cases systematically, and justify that all possibilities have been considered. Depending on how the tasks are implemented, the teacher may encourage students to compare different strategies, evaluate their efficiency, and explain why a particular approach ensures that the solution is complete.

Tasks 3, 4, 7, and 10 illustrate the importance of connecting different mathematical knowledge and representations. In Tasks 3 and 4, students need to recognize the geometric structure of a complex representation and connect it with appropriate procedures for calculating lengths or areas. Task 7 requires students to connect the situation involving three houses with the property of the circumcenter, while Task 10 connects a geometric representation with the concept of probability. In these tasks, the functionality of knowledge is reflected in recognizing relevant mathematical relationships and connecting them in situations where the procedure is not given directly.

Tasks 2, 5, 6, and 8 are situated in real-life contexts, but their functional potential differs. In Tasks 2 and 5, students mainly apply familiar percentage or proportional relationships, so the cognitive demand is primarily at the application level, particularly if the relevant procedure is already familiar to them. By contrast, Tasks 6 and 8 require students to connect a real-world situation with an appropriate geometric or trigonometric model and to interpret the obtained result in relation to the original context. These examples show that the presence of a real-life context alone does not determine the functionality of a task; the degree to which students must mathematize the situation, select a model, and independently choose a procedure is also important.

Tasks 9 and 12 are based on connecting graphical and symbolic representations of functions. In Task 9, students are expected to infer parameter values in an algebraic representation of a function from the characteristics of its graph, whereas in Task 12, they use graphical representations to determine the zeros of functions and the number of solutions to equations. In both cases, the emphasis is not on the mechanical application of a formula, but on interpreting graphical information, recognizing relationships, and moving between different mathematical representations.

Task 2 can also illustrate how a task's functional potential can be increased through modification. In its present formulation, students are required to apply a familiar procedure for calculating interest in a specific financial situation, which shows that a real-life context does not automatically make a task functionally oriented. However, the task can be modified to require more complex cognitive activity. For example, students could be presented with the conditions offered by two banks and asked to determine which option is more advantageous after a given period, justify their choice, and examine whether the decision would change for a different initial deposit or savings period. Such a formulation requires comparison, strategy selection, decision-making, and justification, thereby giving the same mathematical content greater potential for developing functional mathematical knowledge.

The conceptual analysis of the selected tasks shows that their potential for developing functional mathematical knowledge cannot be assessed solely on the basis of their content, format, or the presence of a real-life context. It is more important to consider what students are actually required to do while solving a task: whether they merely apply a familiar procedure or independently select and connect relevant knowledge, choose a strategy, justify their procedure, verify the result, and, when working in a real-life context, interpret it in relation to the original situation. At the same time, the teacher can significantly increase or reduce the cognitive and functional potential of the same task through the way questions are posed, the degree of support provided, and the requirements for justification and comparison of solutions. The proposed framework can therefore serve as a practical guideline for teachers in selecting, analyzing, and adapting mathematical tasks in classroom instruction.

5. Conclusion

The development of functional mathematical knowledge depends on the alignment of learning outcomes, instructional activities, and assessment methods, as well as on the selection and implementation of tasks that promote reasoning, justification, connections between mathematical ideas, and the application of knowledge. The quality of a task cannot be assessed solely on the basis of its content, format, difficulty, or the presence of a real-life context, but also on the cognitive processes it requires of students and the degree of independence it allows in selecting and justifying a solution strategy. The instructional potential of the same task may also change depending on how it is implemented, including the questions the teacher poses, the support provided, the opportunities to compare different approaches, and the feedback given to students. Functionally oriented mathematics instruction therefore represents an approach in which learning outcomes, activities, tasks, assessment, and feedback are systematically directed towards the development of meaningful, connected, and applicable mathematical knowledge.

Based on the theoretical considerations discussed in this paper, a framework for selecting, analyzing, and adapting mathematical tasks to develop functional mathematical knowledge is proposed. The framework integrates learning outcomes, mathematical content, cognitive demands, strategy selection and justification, the functional application of knowledge, and, where relevant, context and mathematical modelling. Its application to the selected tasks illustrates how these criteria can be used to systematically consider the instructional potential of mathematical tasks. The proposed framework can therefore serve as a practical guideline for teachers when selecting and adapting tasks that encourage students to connect relevant knowledge, independently choose strategies, justify and verify their solutions, and apply mathematics in new situations.

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