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Examination of Problems in Middle School Mathematics Textbooks in Relation to the PISA Mathematical Literacy Framework

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Abstract

This research examines the extent to which mathematics problems in middle school textbooks for grades 5 through 8 align with the PISA mathematical literacy framework. The analysis emphasizes key dimensions, including content, context, cognitive processes, proficiency levels, and problem types. Utilizing document and descriptive analyses, the research evaluates textbooks published by Türkiye's Ministry of National Education for the 2023–2024 academic year. Results reveal significant imbalances in the distribution of content areas, with "change and relationships" dominating, while "quantity" is underrepresented. Contextual analysis shows a predominance of "personal" contexts, with limited occupational, social, and scientific scenarios, which restrict students' engagement with real-world applications. Regarding mathematical processes, the emphasis is on procedural tasks, while higher-order cognitive skills are insufficiently represented. Furthermore, the majority of problems correspond to PISA proficiency levels 2 and 3, with minimal representation of levels 5 and 6, highlighting a scarcity of tasks designed to foster advanced mathematical competencies. These findings underscore the necessity for a more equitable integration of content areas, a broader spectrum of real-life contexts, and tasks targeting higher proficiency levels. Recommendations propose a redesign of textbooks to incorporate a wider range of cognitive demands and contextual scenarios, with the aim of enhancing students' mathematical literacy and preparedness for international assessments such as PISA.

Keywords: PISA, matematical literacy, middle school textbook, problem types.

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Introduction

Mathematical literacy (ML) is widely acknowledged as a critical competency in the contemporary era of information and technology, occupying a central role in modern education systems. As Altun (2020) notes, ML serves not only to integrate mathematical knowledge into everyday life but also to enhance cognitive abilities. It involves applying mathematical concepts to real-world situations, thereby fostering critical thinking and problem-solving skills (Höfer & Beckmann, 2009). The importance of ML in educational discourse is closely tied to the Programme for International Student Assessment (PISA), which evaluates and compares the effectiveness of global education systems (Altun et al., 2022; Kabael, 2019). Beyond theoretical constructs, ML empowers individuals to formulate, apply, and interpret mathematics across diverse contexts (Ministry of National Education [MoNE], 2019; Organisation for Economic Co-operation and Development [OECD], 2013). This broad conceptualization underscores ML's critical role in tackling complex societal challenges and emphasizes the need for educational policies and curricula that prioritize its development. Consequently, the primary goal of mathematics education is to equip students with these essential competencies by creating learning environments that nurture their growth as mathematically literate individuals (MoNE, 2023; OECD, 2019).

In numerous countries, ML is developed through structured educational resources, with textbooks playing a foundational role. Textbooks significantly influence the mathematical competencies students acquire, guiding them toward achieving learning objectives aligned with curricular standards (Alajmi, 2012; Fan et al., 2021; Herbel-Eisenmann, 2007; Valverde et al., 2002). Research highlights their substantial impact on teaching practices and student outcomes (Pepin & Haggarty, 2001; Sevimli, Çelik & Kul, 2022). Notably, aligning textbook content with international benchmarks like PISA enhances the quality of mathematics education, as seen in nations where textbooks effectively incorporate PISA's problem contexts and cognitive demands (Hopkins et al., 2008; Incikabi, Sadak & İncikabı, 2023; Son, 2012; Törnroos, 2005). Recent studies stress the importance of assessing textbooks against the ML framework to ensure students encounter problems and cognitive challenges akin to those in international assessments (Korkmaz, Çelik Demirci & Kul, 2024; Tarim & Tarku, 2022; Wu et al., 2020). Comparative analyses show that textbooks in high-performing education systems feature complex, contextually rich, and cognitively demanding tasks (Bozkurt & Yılmaz, 2020; Çelik Demirci & Kul, 2021). In contrast, textbooks in countries like Türkiye often present a limited range of proficiency levels and problem contexts, potentially contributing to lower PISA performance (OECD, 2023a; MoNE, 2023).

Despite the recognized importance of textbooks in fostering ML, comprehensive evaluations of Turkish mathematics textbooks for grades 5–8 against the PISA framework are scarce. In the 2022 PISA, Türkiye scored 453 in mathematics, ranking 39th out of 81 countries and 32nd out of 37 OECD nations above the global average of 438 but below the OECD average of 472. While 61.3% of students achieved the minimum proficiency level, only 5.4% reached the top level (MoNE, 2023). These results signal an urgent need to better align educational materials with globally recognized ML standards and to implement strategies to boost students' mathematical competencies. Thus, this study aims to analyze and classify problems in mathematics textbooks for grades 5 through 8 using the PISA ML framework, examining their distribution across content areas, contexts, processes, proficiency levels, and structures to assess how well they support ML development.

Theoretical Framework

PISA Mathematical Literacy

The 2018 PISA assessment highlights four key components; content, context, process, and proficiency as essential for evaluating ML. The PISA framework identifies four main mathematical content categories: change and relationships, space and shape, quantity, and uncertainty and data. These categories reflect broad areas of mathematical thinking and align closely with international curricular standards (OECD, 2023a). Consistent across recent PISA cycles, such as 2018 and 2022, these categories provide robust indicators for evaluating the scope and depth of textbook content. The category of change and relationships emphasizes modeling and understanding mathematical changes through the use of equations, functions, and algebraic expressions. Tools such as equations, inequalities, and graphical representations are utilized to describe, interpret, and model dynamic relationships, while data representation and numerical values are significant for illustrating these connections. The space and shape category encompasses real-world phenomena such as perspective drawing, navigation, and geometric representation. Within this framework, PISA underscores the importance of creating representations, interpreting three-dimensional objects from various perspectives, and understanding maps as vital to fostering ML. The quantity category focuses on quantifying objects and scenarios in the environment, including measurement, dimensions, numbers, units, and numerical trends. Quantitative reasoning within this domain involves interpreting numbers in various forms, predicting outcomes, and evaluating results. Finally, the uncertainty and data category addresses uncertainties encountered in everyday life as well as in scientific and technological contexts. This area incorporates probability, statistical theory, and data identification techniques, while emphasizing skills such as interpreting and presenting data to manage uncertainties effectively. Each content category plays an integral role in understanding and applying mathematical concepts. The problems included in the PISA assessments were carefully designed to ensure a balanced representation across these four categories, with each allocated 25%. This equitable distribution is essential for promoting students' mathematical thinking skills and fostering the development of constructive and reflective thinkers (OECD, 2023b). By encompassing a range of mathematical areas, these categories enable the acquisition of comprehensive knowledge and skills. The contexts in which mathematical problems are presented also play a critical role in determining appropriate problem-solving strategies and representations. In the PISA assessment, these contexts are classified into four groups: personal, occupational, social, and scientific. The personal context includes scenarios related to individual, familial, or social activities such as personal planning, transportation, health, food preparation, shopping, recreation, sports, and travel. Occupational contexts focus on scenarios relevant to work environments across various sectors, emphasizing situations relatable to 15-year-olds. The social context addresses issues within the individual's community, including voting systems, public transportation, government policies, demography, and economics. The scientific context involves problems that apply mathematics to real-world scientific and technological scenarios, such as meteorology, climate science, the medical field, space science, and genetics. The balanced distribution of these context categories, with each allocated 25% in the PISA assessments, prevents dominance by any single context. This ensures that students engage with diverse problem scenarios, preparing them to address real-world challenges effectively while nurturing mathematical thinking in a variety of situations.

In the PISA 2018, the problems were structured into three categories of mathematical processes, each with specific weightings that illustrate the connection between real-world problems and mathematical reasoning. The first process, formulating situations mathematically, accounts for 25% of the assessment. This process involves translating real-world problems into mathematical terms by creating models and expressions that render everyday challenges solvable. The second process, using mathematical concepts, facts, procedures, and reasoning, constitutes the largest portion of the assessment, with an allocation of 50%. During this stage, students apply their mathematical knowledge and skills to analyze situations, draw conclusions, and solve problems using a comprehensive set of tools and techniques. The third process, interpreting, applying, and evaluating mathematical results, is also allocated 25% and requires students to assess the relevance and validity of solutions within the context of the original problem. Together, these processes represent a balanced approach to mathematical engagement, bridging theoretical understanding with practical application. In addition to the processes, the PISA framework categorizes problems into six distinct levels of mathematical proficiency. These levels indicate the depth and breadth of students' mathematical knowledge and their ability to solve increasingly complex problems. The hierarchical structure of proficiency levels provides valuable insights into the progression of mathematical competence, reflecting how students' skills develop over time. The primary objective of this study is to analyze the distribution of problems in middle school mathematics textbooks with respect to content, context, process, proficiency level, and problem structure. Understanding this distribution is crucial for evaluating how effectively textbook problems contribute to the development of students' ML.

Role and Importance of Textbooks

Fan, Zhu and Miao (2013) highlight that textbooks in contemporary education systems serve as essential guides integrating both general and specific teaching objectives, enabling consistent learning outcomes by providing a unified framework for course delivery. Textbooks are crucial in the teaching and learning process as they reflect the curriculum's content, a notion supported by Haggarty and Pepin (2002) and Stein, Remillard and Smith (2007). Brousseau (1986) emphasizes that textbooks are vital resources that significantly influence both students' self-regulation of learning and teachers' design of course content. According to Erbaş, Alacacı and Bulut (2012), an effective textbook should be crafted with a reader-centric approach to facilitate meaningful engagement with the content. Işık (2008) notes that, similar to their global counterparts, teachers in Türkiye heavily rely on textbooks in their teaching processes. The standards for these textbooks, set by the Board of Education and Guidance, direct teachers on the scope and depth of the subjects to be taught in the classroom. Huang et al. (2022) argue that a quality textbook is beneficial to students and holds a significant place in education, thus underscoring the need for careful analysis and evaluation of textbooks to enhance their effectiveness. Mathematical competencies, aligned with frameworks like PISA, can be developed through well-designed textbook tasks (Yılmaz, Ay & Aydın, 2021). Valverde et al. (2002) describe textbooks as the "de-facto national curriculum," shaping teaching practices and bridging curriculum with classroom implementation. Real-life contexts in textbook problems, as emphasized by Zhu and Fan (2006), enhance learning by engaging students in practical applications of mathematics. However, many textbooks prioritize basic cognitive tasks, offering limited opportunities to interpret and evaluate mathematical solutions in real-world contexts (Incikabi, Sadak and İncikabi, 2023). OECD (2019) stress the need for tasks that cover the full cycle of mathematical literacy—formulating, employing, and interpreting—to prepare students for complex problem-solving. The alignment of textbooks with frameworks like PISA is critical for equipping students with relevant skills.

Research investigating the alignment of mathematics textbooks with the PISA ML framework is relatively scarce, particularly in the context of Turkish educational materials. Existing studies have highlighted significant deficiencies in the depth and complexity of problems presented in these textbooks, especially at higher PISA proficiency levels. For example, İskenderoğlu and Baki (2011) examined an 8th-grade mathematics textbook and found that while it included problems corresponding to PISA proficiency levels 1 through 4, it lacked tasks at levels 5 and 6, which represent advanced problem-solving and reasoning skills. Similarly, Yıldırım (2019) analyzed textbooks from grades 5 through 8, focusing exclusively on the 'change and relationships' content category within the algebra domain. This study revealed a complete absence of tasks at proficiency levels 4, 5, and 6, indicating a notable gap in challenging algebraic content. More recently, Tarim and Tarku (2022) evaluated the grade 8 textbook's alignment with the PISA ML framework across multiple dimensions: content, context, and process. Their findings showed that the 'quantity' category contained the highest number of problems, while 'uncertainty and data' had the fewest. In terms of context, 'scientific' scenarios predominated, with 'social' contexts being the least represented. The process of 'using mathematical concepts and procedures' was most frequently employed, whereas 'formulating situations mathematically' was the least emphasized. Additionally, their analysis identified a significant shortfall in higher proficiency level problems, with no tasks at levels 5 and 6, limited representation at level 4, and some inclusion of open-ended problems. Collectively, these studies underscore a critical limitation in Turkish middle school mathematics textbooks: a lack of complex, higher-level tasks that align with the PISA framework's emphasis on applying mathematical knowledge in real-world contexts.

Despite these insights, prior research has been narrow in scope, often focusing on specific grade levels or content areas rather than providing a holistic view of textbook alignment across all middle school grades (5–8). For instance, İskenderoğlu and Baki (2011) and Tarim and Tarku (2022) concentrated solely on grade 8, while Yıldırım (2019), although broader in grade coverage, limited its analysis to a single content category. This fragmented approach has left a gap in understanding how well Turkish mathematics textbooks, as a whole, prepare students for the demands of the PISA assessment and, more broadly, for mathematical literacy in practical settings. To address this, the current study undertakes a comprehensive analysis of problems from mathematics textbooks across grades 5 through 8, classifying them according to the PISA ML framework's key dimensions: content, context, process, proficiency level, and problem structure. This systematic evaluation aims to provide a detailed picture of the textbooks' strengths and weaknesses, offering insights into their alignment with international standards. By doing so, it seeks to inform curriculum developers about necessary enhancements to better equip students with the advanced problem-solving skills required for PISA and real-life applications, ultimately contributing to the improvement of students' ML.

Method

This study adopted a qualitative document analysis approach to examine the mathematics problems presented in middle school textbooks through the lens of the PISA ML framework. Document analysis is widely used in educational research to investigate written materials and official documents, including curricula and textbooks, as it allows researchers to systematically identify, interpret, and evaluate patterns within the text (Patton, 2014; Yıldırım & Şimşek, 2008).

Selection of Textbooks and Data Collection

This study focused on official mathematics textbooks for grades 5, 6, 7, and 8, published by the Ministry of National Education (MoNE) for the 2023–2024 academic year, with the aim of determining the alignment of textbook problems with PISA's ML framework. These specific grade levels were selected to capture the educational trajectory leading to age 15, which is the target age group for PISA assessments. The mathematics textbooks for middle school are publicly accessible through the MONE's official website. Following a Board of Education decision, these textbooks have been officially approved for use over a five-year period from their publication date. They are widely recommended for teaching in Turkish public schools, ensuring broad distribution and usage among students. The study's analytical foundation was the complete set of mathematical problems extracted from the chosen textbooks, which are comprehensively detailed in the accompanying Table 1. Each textbook is organized into units and includes sections such as "Are We Ready?", "Let's Remember", "Let's Learn Together", "Let's Research and Think", "Your Turn", and "Unit Evaluation." These sections encompass various problem formats (e.g., gap-filling, matching, multiple-choice, true-false, example solutions, and open-ended problems) designed to address curricular goals. The textbooks were purposefully selected based on three key criteria: (a) official curriculum representation, ensuring nationwide instructional content consistency; (b) relevance to the PISA age group, covering learning progressions for students approaching age 15; and (c) potential for comparative analysis to identify alignment strengths and weaknesses with international mathematical education standards. Brief contextual information about the textbooks is provided in Table 1, including authorship and total number of problems.

Table 1.
Mathematics Textbooks Used in the Research

Class	Textbooks	Authors	Number of Problems
5. grade	Mathematics Textbooks 5 (2023)	Betül Korkmaz, Didem Yiğit Meşe, Hayriye Tuğçe Arslan	346
6. grade	Mathematics Textbooks 6 (2021)	Neziha Çağlayan, Aybike Dağıstan, Betül Korkmaz	804
7. grade	Mathematics Textbooks 7 (2023)	Avni Külköylüoğlu, Mehmet Güneş, Mustafa Selçuk, Yunus Tuğrul	506
8. grade	Mathematics Textbooks 8 (2021)	Hadi Böge, Ramazan Akıllı	455

Data Analysis

A systematic content analysis was performed according to the PISA ML framework to ensure a structured examination of textbook problems. Content analysis, a well-established qualitative research method, involves systematically categorizing textual units based on predefined codes and themes, thereby enabling the identification of patterns and underlying meanings. Prior to initating the analysis, each textbook included in the sample was thoroughly reviewed. This preparatory phase allowed the two researchers—who each possess specialized expertise in analyzing PISA mathematics items—to gain a comprehensive understanding of the textbooks' content and organization. The PISA ML framework functioned as the principal data collection instrument and was operationalized in this study as a two-dimensional matrix encompassing content categories, mathematical processes, contexts of ML, and PISA proficiency levels. These proficiency levels are defined as follows: *Level 1*: Students handle familiar problems with all information readily available. They follow instructions and perform basic, routine procedures. *Level 2:* Students interpret straightforward contexts, extract relevant information from one source, and apply basic algorithms, formulas, or rules. They provide simple, direct interpretations of results. *Level 3:* Students follow established procedures, make simple models, and apply basic strategies. They interpret information from multiple sources and demonstrate foundational reasoning skills. *Level 4:* Students handle explicit models in concrete yet complex situations, integrate multiple representations, and connect these to real-life contexts. They produce coherent explanations and reason insightfully. *Level 5:* Students model complex situations, identify constraints, and evaluate solution strategies. They think strategically, reflect on their approaches, and articulate clear interpretations. *Level 6:* Students apply advanced mathematical knowledge to complex, often unfamiliar problems. They integrate various representations, develop new strategies, and communicate thorough justifications. The content dimension encompasses four domains: change and relationships, space and shape, quantity, and uncertainty and data. The mathematical processes are categorized into three groups—formulating situations mathematically, using mathematical concepts and processes, and interpreting/applying/evaluating mathematical outcomes—while the contexts of ML are classified as personal, professional, social, and scientific. In addition, problem structure types (e.g., gap-filling, matching, example solution, multiple choice, true/false, open-ended) were also examined to capture the breadth of problem formats.

Coding Procedures

To ensure systematic and consistent coding, two researchers with demonstrated expertise in mathematics education and educational measurement collaboratively analyzed 10% of the identified problems from the complete set of textbooks. This approach guaranteed that every textbook and each problem within it was examined by both coders. The coding process was initially guided by the criteria established through the PISA ML framework and a predefined coding scheme. Following the first round of independent coding, the percentage agreement between the coders was calculated by dividing the number of instances where all coders concurred by the total number of coding instances. This calculation resulted in an initial agreement rate of approximately 89% for content, context, and process classifications, and 91% for PISA proficiency levels and problem types. These percentages reflect the ratio of matched codes to the total coding decisions. For instances of initial disagreement, a standardized evaluation table was prepared. This table documented each problematic coding instance along with the differing perspectives of the coders. Subsequently, the coders engaged in a structured discussion, revisiting and deliberating on the disputed items until a consensus exceeding 95% was achieved. This iterative negotiation process served not only to resolve discrepancies but also to refine the coding scheme, enhancing its clarity and applicability.

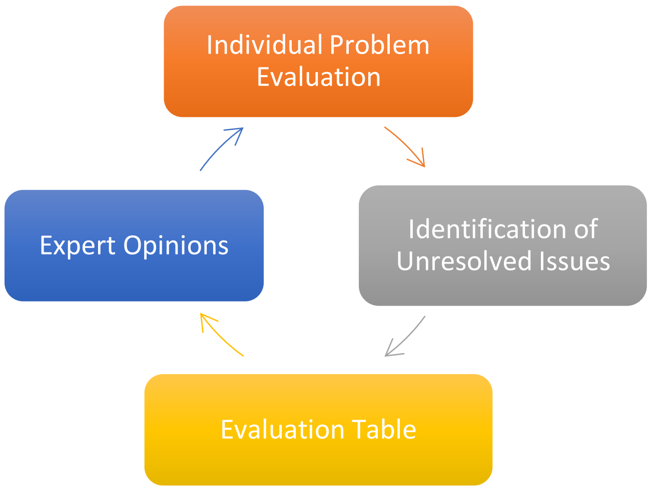

Figure 1. Classification Process Of Problems In Mathematics Textbooks

Sample codes

The content areas covered within the PISA mathematical literacy framework, which serves as the primary data collection tool for the study, are coded as follows: change and relationships as C1, space and shapes as C2, quantity as C3, and uncertainty and data as C4. Situations categorized under mathematical processes are coded as mathematical formulation as P1, using mathematical concepts, facts, procedures, and reasoning as P2, and interpreting, applying, and evaluating mathematical results as P3. Situations unrelated to any classification under ML contexts are coded as NC (No Context), while personal context is coded as C1, occupational context as C2, societal context as C3, and scientific context as C4. Competency levels under the PISA framework are coded sequentially from Level 1 to Level 6 as L1, L2, L3, L4, L5, and L6, respectively.

Table 2.
An Example of Problems Analysis (Coding) (Külköylüoğlu et al., 2023, p. 108)

Problem: Furkan's age is 5 less than twice Feray's age. The sum of their ages is 16. Write an equation that represents Feray's age. Solution: Let Feray's age be x. Then, Furkan's age is $2x - 5$. The sum of their ages is: $2x - 5 + x = 16$ $3x - 5 = 16$
Content *Change and Relationships* (Code: C1). The category of change and relationships encompasses algebraic expressions, equations, inequalities, and the functions and algebra topics represented through tables and graphs. Since the question provided is related to algebraic expressions and equations, it has been coded as C1.
Process *Mathematical Formulation of Situations* (Code: P1). The mathematical formulation of situations in the process category refers to individuals' ability to demonstrate fundamental mathematical knowledge and skills in understanding, analyzing, and solving problems. The given question involves understanding, analyzing, and solving problems using basic knowledge and skills; therefore, it has been coded as P1.
Context *No Context* (Code: NC). This question cannot be associated with any of the personal, occupational, societal, or scientific contexts categorized under context. Thus, it has been coded as NC to indicate the absence of any contextual relationship.
Level *Level 2* (Code: L2). Students at this level are capable of solving simple problems by using fundamental mathematical concepts and procedures. Since the given question involves the use of basic mathematical procedures to solve a simple problem, it has been coded as L2.

Validity and Reliability of Data

Ensuring the validity and reliability of the data was fundamental to this study. Validity was bolstered by aligning the coding criteria with the comprehensive dimensions of the PISA Mathematical literacy framework and by obtaining expert reviews to confirm appropriate coverage and construct representation. Reliability was assessed through percentage agreement and statistical indices such as Cohen's kappa and Krippendorff's alpha, which account for chance agreement. The high initial agreement rates, combined with stable reliability coefficients (e.g., Krippendorff's $\alpha > .80$), indicated the consistency of the coding process (Cohen, 1960; Krippendorff, 2019). Additionally, the reliability coefficient proposed by Miles and Huberman (1994) was calculated, resulting in a value of .84, reflecting the acceptability of coding decisions. Iterative refinement and expert reviews further strengthened the overall validity and reliability of the findings, ensuring that the study's results are grounded in a robust and methodologically sound coding framework.

Findings

Findings for Analysing the Problems in the Fifth Grade Textbook

After analyzing the problems in the fifth-grade textbook according to content, mathematical processes, context categories, and PISA proficiency levels, the structure of the problems was also examined. The findings from this comprehensive analysis are detailed below.

Table 3.

Distribution of Problems in the Fifth Grade Textbook According to Content, Process and Context Categories and Proficiency Levels

Category	Proficiency Levels						
	1.level	2. level	3. level	4. level	5. level	6. level	Total
Content							
Change and Relations	14	60	25	16	0	0	115
Space and Shapes	4	17	18	14	0	0	53
Quantity	17	61	40	9	1	0	128
Uncertainty and Data	4	8	25	13	0	0	50
Total	39	146	108	52	1	0	346
Process							
Mathematical formulation of situations	20	87	9	8	0	0	124
Using mathematical concepts, facts, procedures & reasoning	21	44	63	27	0	0	156
Interpretation, implementation and evaluation	1	12	36	17	1	0	66
Total	42	143	108	52	1	0	346
Context							
No Context	58	124	43	0	0	0	225
Personal	7	35	30	11	1	0	84
Occupational	0	0	4	0	0	0	4
Social	1	6	12	4	0	0	23
Scientific	2	5	2	1	0	0	10
Total	68	170	91	16	1	0	346

An analysis of Table 3 reveals that Level 2 problems predominate across the categories of content, mathematical process, and context. Consequently, when analyzing the fifth-grade mathematics textbook as a whole, it is evident that the majority of problems fall into Levels 2 and 3. A notable finding of this study is the scarcity of Level 5 problems and the complete absence of Level 6 problems. Below is an example of a Level 5 problem from the fifth-grade mathematics textbook.

Using the data provided below, posing a problem involving addition and subtraction of fractions and solve it.

a) $\frac{2}{5}, \frac{4}{15}$, Turkish, Mathematics, English b) $\frac{3}{14}$, Pizza

Figure 2. Example of a Level 5 Type Problem in the Fifth Grade Mathematics Textbook

When analyzing the problems in the fifth-grade mathematics textbook according to the categories of content, mathematical process, and context, significant disparities were observed in the number of problems among some subcategories. For instance, within the content category, subcategories such as ‘space and shapes’ and ‘uncertainty and data’ contained fewer problems compared to others. In terms of mathematical processes, there was a notable scarcity of problems involving ‘interpretation, application, and evaluation.’ Additionally, within the context category, the rarity of problems in the ‘professional’ context and the prevalence of non-contextual problems were particularly striking. The findings regarding the structure of the problems in the fifth grade mathematics textbook are shown in Table 4.

Table 4.
Distribution of the Problems in the Fifth Grade Mathematics Textbook According to Their Structure

Problem Type	Frequency	Percentage
Fill in the blank	73	21.1

Table 4 continuing

Matching	12	3.46
Example Problem	39	11.26
Multiple Choice	36	10.43
True-False	12	3.46
Open-ended	174	50.29
Total	346	100

As can be seen in Table 4, the problems in the fifth grade mathematics textbook consist of more open-ended problems. On the other hand, matching and true/false problems were found to be less common than the other problem types.

Findings for Analysing the Problems in the Sixth Grade Textbook

After analyzing the problems in the sixth-grade mathematics textbook according to content, mathematical process, context categories, and PISA proficiency levels, the structure of the problems was also examined. The findings from this comprehensive analysis are detailed below.

Table 5.
Distribution of Problems in the Sixth Grade Textbook According to Content, Process and Context Categories and Proficiency Levels

Category	Proficiency Levels						
	1.level	2. level	3. level	4. level	5. level	6. level	Total
Content							
Change and Relations	35	71	59	2	0	0	167
Space and Shapes	18	60	57	33	1	0	169
Quantity	83	143	52	8	0	0	286
Uncertainty and Data	59	57	54	10	2	0	182
Total	195	331	222	53	3	0	804
Process							
Mathematical formulation of situations	128	115	39	3	0	0	285
Using mathematical concepts, facts, procedures & reasoning	57	182	88	37	0	0	364
Interpretation, implementation and evaluation	10	34	95	13	3	0	155
Total	195	331	222	53	3	0	804
Context							
No context	181	287	175	46	3	0	692
Personal	5	18	25	1	0	0	49
Occupational	6	5	2	0	0	0	13
Social	1	21	14	6	0	0	42
Scientific	2	0	6	0	0	0	8
Total	195	331	222	53	3	0	804

According to Table 5, it is evident that unlike the fifth grade, the sixth grade mathematics textbooks do not contain any problems of the sixth level. Additionally, there is a higher concentration of problems at the second and third levels. An analysis of the problems within the subcategories of content, mathematical process, and context categories shows a similar distribution overall. However, it was noted that problems involving the mathematical formulation of situations are more prevalent at the first and second levels within the mathematical process category. Upon further analysis of the mathematical process category, it was observed that problems requiring the use of mathematical concepts, facts, procedures, and reasoning were more common than others. In the content category, 'multiplicity' emerged as the most frequently addressed area, whereas 'change and relationships' and 'space and shapes' were less commonly featured. Similar to the fifth grade, the sixth grade mathematics textbooks also exhibited a high number of problems lacking specific context. Among the context-inclusive problems, those related to personal and social issues were more prevalent, and problems associated with scientific subjects were also notably frequent. This distribution highlights the focus areas and potential gaps in contextual application within the sixth grade curriculum, suggesting areas for further enhancement to align with broader educational goals. The results concerning the structure of the problems in the sixth grade mathematics textbook are shown in Table 6.

Table 6.
Distribution of the Problems in the Sixth Grade Mathematics Textbook According to Their Structure

Problem Type	Frequency	Percentage
Fill in the blank	53	6.59
Matching	12	1.50
Example Problem	1	0.12
Multiple Choice	239	29.72
True-False	16	2
Open-ended	483	60.07
Total	804	100

As indicated in Table 6, the problems in the sixth-grade mathematics textbook are predominantly multiple-choice. Matching and true/false problems are less common, and it was noted that the number of problems providing sample solutions is particularly limited.

Findings for Analysing the Problems in the Seventh Grade Textbook

After analyzing the problems in the seventh-grade mathematics textbook according to content, mathematical process, context categories, and PISA proficiency levels, the structure of the problems was also examined. The findings from this comprehensive analysis are detailed below.

Table 7.
Distribution of Problems in the Seventh Grade Textbook According to Content, Mathematical Process and Context Categories and Proficiency Levels

Category	Proficiency Levels						
	1.level	2. level	3. level	4. level	5. level	6. level	Total
Content							
Change and Relations	55	175	57	7	1	0	295
Space and Shapes	33	47	32	7	0	0	119
Quantity	2	7	6	3	1	1	20
Uncertainty and Data	4	30	19	16	3	0	72
Total	94	259	114	33	5	1	506
Process							
Mathematical formulation of situations	27	44	15	5	0	0	91
Using mathematical concepts, facts, procedures & reasoning	61	174	43	6	3	0	287
Interpretation, implementation and evaluation	6	41	56	22	2	1	128
Total	94	259	114	33	5	1	506
Context							
No context	50	187	90	26	0	0	353
Personal	5	53	26	9	3	1	97
Occupational	1	9	5	5	0	0	20
Social	0	18	5	5	0	0	28
Scientific	0	5	1	1	1	0	8
Total	56	292	127	46	4	1	506

An analysis of Table 7 reveals that the fifth and sixth grade mathematics textbooks predominantly contain problems at the second and third proficiency levels. However, a notable distinction is that the seventh grade mathematics textbook includes problems at the sixth level, which differentiates it from the textbooks for the fifth and sixth grades. An example of a problem from the sixth level in the seventh grade mathematics textbook is provided below. On page 263 (see in detail), there is a problem:

What is the minimum number of unit cubes that could have been used in the structure shown above?

Figure 3. Example of a Level 6 Type Problem in the Seventh Grade Mathematics Textbook

When analyzing the problems within the subcategories of content, mathematical process, and context, it is evident that problems categorized at the second and third proficiency levels are more prevalent. Specifically, within the content category, there was a higher number of problems related to ‘change and relationships’ and fewer problems concerning ‘quantity’. Upon examining the subcategories of the mathematical process category, it was noted that there was a predominance of problems that required the use of mathematical concepts, facts, procedures, and reasoning over other types. Similarly, the seventh-grade mathematics textbooks, like those for fifth and sixth grades, contained a higher number of problems that lacked specific contexts. Among the contextually based problems, those related to personal subjects were more frequent, whereas problems related to scientific subjects were less common.

Table 8.
Distribution of the Problems in the Seventh Grade Mathematics Textbook According to Their Structure

Problem Type	Frequency	Percentage
Fill in the blank	31	6.12
Matching	6	1.18
Example Problem	191	37.78
Multiple Choice	254	50.19
True-False	5	0.98
Open-ended	19	3.75
Total	506	100

As shown in Table 8, the problems in the seventh-grade mathematics textbook primarily consist of multiple-choice problems and problems with model solutions. It was observed that matching and true/false problems are less common compared to other types of problems.

Findings for Analysing the Problems in the Eight Grade Textbook

After analysing the problems in the eighth grade mathematics textbook according to content, mathematical process and context categories and PISA proficiency levels, the structure of the problems was examined. The results of this analysis are presented below.

Table 9.
Distribution of Problems in the Eight Grade Textbook According to Content, Mathematical Process and Context Categories and Proficiency Levels

Category	Proficiency Levels						
	1.level	2. level	3. level	4. level	5. level	6. level	Total
Content							
Change and Relations	48	85	70	68	0	1	272
Space and Shapes	4	14	37	16	0	1	72
Quantity	3	0	0	7	2	2	14
Uncertainty and Data	6	43	31	16	0	1	97
Total	61	142	138	107	2	5	455
Process							
Mathematical formulation of situations	55	129	56	26	1	0	267
Using mathematical concepts, facts, procedures & reasoning	2	5	37	25	0	0	69

Table 9 continuing

Interpretation, implementation and evaluation	4	8	45	56	1	5	119
Total	61	142	138	107	2	5	455
Context							
No context	29	79	92	65	0	1	266
Personal	8	16	35	29	2	0	90
Occupational	24	47	0	2	0	0	73
Social	0	0	9	8	0	0	17
Scientific	0	0	2	3	0	4	9
Total	61	142	138	107	2	5	455

An analysis of Table 9 indicates that the eighth-grade mathematics textbook has a higher proportion of problems at the second and third proficiency levels compared to other grades. Notably, there are very few problems at the fifth and sixth levels, although the number of problems at the sixth level is slightly higher in the eighth-grade textbooks than in those of other grades. When examining the problems within the subcategories of content, mathematical process, and context, a similar distribution pattern is evident across these categories. However, the distribution within the subcategories of the context category appears to be different. Additionally, like in other grade levels, the seventh-grade mathematics textbooks contain a high number of context-free problems. The prevalence of problems relating to personal contexts is higher, while those pertaining to scientific contexts are fewer, mirroring the pattern observed in the seventh-grade textbooks. In terms of content, the analysis reveals a dominance of problems pertaining to ‘change and relationships’, with ‘quantity’ being the least addressed area. Examples of this can be seen in Table 9. On page 110 of the 8th grade textbook and page 312 of the 6th grade textbook, there are two problems as follows:

Table 10.
Example for the Mathematical Content

Content	Examples
Change ve Relations	Ancient Egypt is regarded as the birthplace of mathematics. Today, it is agreed that Egyptian mathematicians were required to master mathematics to carry out their daily governmental tasks. Every year, the Nile River would overflow, flooding the lands with water and mud. After the waters receded, the previously flooded lands had to be measured to determine the boundaries for irrigation. These surveys helped to reestablish the borders that had been erased by the floodwaters. Because landowners, who held land equal to their state duties, were mathematicians, the tasks at hand often involved mathematical calculations. However, the calculations and solutions developed by mathematicians also served various purposes, from agricultural areas to the construction of pyramids. For instance, we know that some of the tools found in the ancient Egyptian city of Alexandria are still in the British Museum today. Here is a problem from that period: A rectangular pool of water from an unknown source weighs approximately 19 kg more than it would if it were empty. What is the volume of the pool? Think about it.
Quantity	As a teacher, Ayşe wants to reward Ali and Ahmet, who performed well on the mathematics exam, with the pencils in her possession. She wants to give more pencils to Ali, who scored higher. Explain how you would distribute a total of 18 pencils between Ali and Ahmet.

When analyzing the problems within the subcategories of the mathematical process category, it was observed that the number of problems related to the mathematical formulation of situations is higher than in other subcategories. This represents a divergence from textbooks at other grade levels. Additionally, within this category, there were fewer problems focused on the use of mathematical concepts, facts, procedures, and reasoning compared to the other subcategories.

Table 11.
Distribution of the Problems in the Eight Grade Mathematics Textbook According to Their Structure

Problem Type	Frequency	Percentage
Fill in the blank	110	24.1
Matching	5	1.3
Example Problem	8	1.7
Multiple Choice	172	37.8

Table 11 continuing

True-False	6	1.3
Open-ended	154	33.8
Total	455	100

As indicated in Table 11, the majority of problems in the eighth-grade mathematics textbook are multiple-choice. There are fewer matching and true/false problems compared to other types. Additionally, one of the most notable findings from the study is the scarcity of problems that provide sample solutions.

Discussion, Conclusion and Suggestions

The primary objective of this study was to examine the extent to which middle school mathematics textbooks align with the PISA ML framework in terms of content, context, processes, proficiency levels, and problem types. The findings highlight several key issues that may limit the development of students' ML and their preparedness for international assessments such as PISA. Firstly, an imbalance in the distribution of content areas was observed. While the PISA framework assigns equal weight (25%) to each content category (OECD, 2019), one category- 'change and relationships'- tended to dominate. This suggests that textbooks do not present a fully representative cross-section of mathematical domains. Such imbalances can restrict students' exposure to a broad range of concepts and hinder the development of a well-rounded mathematical understanding. Although periodic curriculum updates and textbook revisions occur, these changes may inadvertently reinforce certain emphases while neglecting others, reducing students' opportunities to engage with a diverse set of mathematical ideas. This discrepancy highlights the need for a more balanced distribution of content in textbooks, especially when aiming to succeed in international assessments. Furthermore, this variation in content distribution across grade levels may stem from the differing number of objectives assigned to each content area in the middle school curricula. Notably, Tarim and Tarku (2022) identified that in mathematics textbooks, the 'quantity' category had the most problems, while 'uncertainty and data' had the fewest. Conversely, in our study, the 'change and relationships' category featured predominantly, with 'quantity' receiving the least focus in textbooks. These disparities might be attributed to the analysis of different textbooks or editions, as curriculum changes could alter content distribution in newer editions. These findings suggest the need for a more uniform distribution of content areas in textbook development to foster students' mathematical thinking and problem-solving skills effectively.

The findings of this study highlight the limited variety of real-life contexts presented in Turkish middle school mathematics textbooks. Although there is a predominant focus on "personal" contexts, the lack of diversity in contexts, particularly those related to occupational, social, and scientific domain may restrict students' ability to engage with a broader spectrum of real-world problems. Bingölbali and Özdiner (2022) similarly emphasizes that mathematics textbooks often fail to include a rich spectrum of real-life applications, thereby limiting opportunities for students to tackle complex, contextually rich tasks. Incikabi, Sadak and İncikabi (2023) further observed that mathematics textbooks from Türkiye, Singapore, and Australia include only a limited proportion of problems grounded in real-life scenarios, reinforcing the evidence for the scarcity of real-life opportunities in mathematics textbook tasks. To promote ML effectively, it is essential for textbooks to integrate a broader range of real-life contexts, encompassing professional, social, and scientific domains, alongside personal contexts. Such an approach would enable students to perceive mathematics as a versatile and transferable tool applicable across various aspects of life (Gravemeijer & Doorman, 1999). While personal contexts, such as daily planning or recreation, help students solve familiar problems, occupational, social, and scientific contexts prepare them to tackle unfamiliar and complex challenges, such as those related to work, societal issues, or scientific advancements. The underrepresentation of these contexts hampers the development of adaptable problem-solving skills. A more balanced inclusion of all four context categories, as outlined in the PISA framework, would ensure that students are well-prepared to apply mathematics in both familiar and novel scenarios. This balance fosters comprehensive mathematical thinking and enhances students' readiness to navigate real-world challenges, ultimately contributing to their overall problem-solving competency and real-world preparedness.

The analysis of middle school mathematics textbooks in this study reveals a strong focus on procedural skills, such as using mathematical concepts, facts, and procedures, but also demonstrates a balanced inclusion of higher-level cognitive tasks, aligning more closely with the expectations of the PISA 2018 mathematics framework. This finding contrasts with Incikabi, Sadak & İncikabı (2023), who reported that textbooks from three countries predominantly emphasize formulating and employing mathematical processes, while offering only a small proportion of tasks requiring interpretation, evaluation, or decision-making in real-life contexts. The broader inclusion of higher-order cognitive tasks observed in this study highlights the potential for fostering advanced problem-solving skills and mathematical thinking at a critical stage in students' education. The PISA 2018 mathematics framework advocates a balanced approach, allocating equal weight (25%) to formulating and interpreting/applying tasks and 50% to procedural skills. This balance emphasizes the integration of real-world scenarios with mathematical models and the critical assessment of solutions. While Incikabi, Sadak & İncikabı (2023) found that textbooks fall short of this vision, the results of this study suggest that textbooks can indeed align with PISA's framework by incorporating diverse contexts and cognitive demands. These findings challenge prior research on the underrepresentation of cognitively demanding tasks in educational materials (O'Keeffe & O'Donoghue, 2015; Zhu & Fan, 2006) and support the need for textbooks that promote mathematical reasoning and real-world application, as emphasized in national and international standards (NCTM, 2000). To further bridge the gap, future efforts should focus on refining textbook content to ensure consistent alignment with frameworks like PISA, fostering a generation capable of tackling complex academic and real-world challenges in an increasingly quantitative world.

When evaluating middle school mathematics textbooks against the PISA mathematics proficiency levels, a notable absence of sixth-level problems—the highest proficiency level—was observed. Problems at the fifth and fourth levels were also rarely included, with the majority of tasks corresponding to the second level, the most common proficiency level among students in Türkiye as reflected in the PISA 2018 assessment. This aligns with prior research, which consistently highlights the scarcity of higher-level proficiency problems in Turkish mathematics textbooks. Studies by İskenderoğlu and Baki (2011) and Yıldırım (2019) underscore this trend, identifying a lack of advanced problems that challenge students' cognitive skills. Similarly, Tarım and Tarku (2022) found that fifth and sixth-level PISA problems were absent, with fourth-level problems being infrequent and lower-level open-ended tasks dominating textbook content. Erkoç Özçetin (2022) further noted a predominance of low-level problems in eighth-grade textbooks and supplementary materials like EBA, highlighting a systemic gap in the inclusion of high-level mathematical challenges. Addressing this gap requires a deliberate effort to enrich textbook content with a broader range of problem difficulties. Kul, Sevimli and Aksu (2018) advocate for incorporating more high-proficiency-level problems to foster the development of advanced mathematical thinking skills among students. Enhancing the cognitive rigor of textbooks is critical not only for improving performance on international assessments like PISA but also for deepening students' overall mathematical understanding and problem-solving abilities. To achieve these goals, diversifying the complexity of problems in textbooks is essential. A well-balanced inclusion of tasks across all proficiency levels will better prepare students to tackle diverse mathematical challenges, support the development of higher-order cognitive skills, and ensure a more comprehensive and effective mathematics education. Such an approach will ultimately contribute to a more competitive and adaptable generation of learners equipped to excel in both academic and real-world contexts.

Finally, our research highlights the variation in problem structures within mathematics textbooks. While open-ended problems are initially prevalent, multiple-choice problems become dominant in later grades, accompanied by a noticeable scarcity of gap-filling problems. Findings by Kul, Sevimli and Aksu (2018) reveal that Turkish middle school textbooks primarily feature multiple-choice problems, whereas Canadian textbooks emphasize open-ended problems that require higher cognitive skills. In both contexts, matching and true/false problems are less common. This distribution may limit the development of students' mathematical thinking skills. Open-ended problems and those offering model solutions promote comprehensive reasoning and problem-solving abilities, fostering critical thinking and deeper understanding. To address this, we recommend increasing the presence of open-ended and model-solution problems in textbooks. Such changes could significantly enhance students' critical thinking, problem-solving skills, and readiness for real-world challenges, ultimately contributing to a more effective and globally competitive mathematics curriculum.

The study emphasizes the need to address students' insufficient practice with real-life problems, which limits their problem-solving abilities. It recommends enhancing the balance of ML contexts, processes, and content in textbooks and increasing tasks that foster higher-order cognitive skills. Drawing on high-performing countries like Singapore, textbooks should include problems aligned with the full PISA ML Framework, featuring real-world contexts and higher-level (levels 5 and 6) open-ended tasks. Balancing contexts such as personal, social, and scientific scenarios will help students relate to familiar experiences while developing critical skills. Supporting teachers' professional development and revising textbooks to reflect these changes will strengthen students' mathematical foundation and improve international assessment performance.

Limitations

This study focused solely on the content of textbooks from one academic year and did not investigate classroom implementation, teacher interpretations, or supplementary materials. Future research could explore longitudinal changes in textbook design, the role of teacher professional development in improving task quality, or cross-country comparisons to identify international best practices that could guide local reforms.

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