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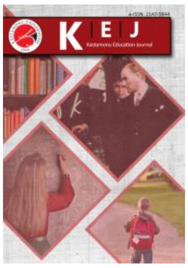

| Research Article / Araştırma Makalesi |

Investigation of SACs High School Mathematics Material Based on PISA Proficiency Levels and Contexts[1]

BİLSEM Lise Matematik Materyalinin PISA Yeterlik Düzeyleri ve Bağlamlarına Göre İncelenmesi

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Keywords

1. Mathematical Literacy
2. Mathematics Proficiency Levels
3. Mathematical Literacy Contexts
4. SAC
5. Gifted Students

Anahtar Kelimeler

1. Matematiksel Okuryazarlık
2. Matematik Yeterlilik Düzeyleri
3. Matematiksel Okuryazarlık Bağlamları
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Abstract

Purpose: This study's primary aim is to categorize questions from the activity forms of the algebra and number theory module in the High School Mathematics Auxiliary Course Material, published by the Ministry of National Education (MoNE) in 2021 for SACs. This categorization was based on the PISA mathematics proficiency levels and mathematical literacy contexts.

Design/Methodology/Approach: The document analysis technique, a qualitative research method, was employed for this investigation. A cumulative count of 199 questions from the activity forms of 19 activities within the auxiliary course material were examined.

Findings: Based on the PISA Mathematics proficiency levels, the majority of the questions were at Level 2 (41.11%), while the fewest were at Level 5 (8.12%). Regarding context, the fewest questions were in the societal context (1.01%), and the vast majority were in the scientific context (90.80%).

Highlights: The study concluded that the levels and contexts of questions in the course material were not evenly distributed, even though questions from every level and context were present. It is recommended that future course materials intended for gifted students should place a greater emphasis on ensuring a balanced distribution and include a higher number of questions that demand advanced skills.

Öz

Çalışmanın amacı: Bu çalışmanın temel amacı, MEB tarafından 2021 yılında BİLSEM'ler için yayınlanan Lise Matematik Yardımcı Ders Materyalinde yer alan cebir ve sayılar teorisi modülünün etkinlik formlarında yer alan soruları kategorize etmektir. Bu kategorilendirme PISA matematik yeterlik düzeyleri ve matematik okuryazarlığı bağlamları temel alınarak yapılmıştır.

Materyal ve Yöntem: Bu araştırma için nitel bir araştırma yöntemi olan doküman analizi tekniği kullanılmıştır. Yardımcı ders materyalinde yer alan 19 etkinliğe ait etkinlik formlarındaki toplam 199 soru incelenmiştir.

Bulgular: PISA Matematik yeterlilik düzeylerine göre, soruların çoğunluğu 2. Düzeyde (%41,11), en azı ise 5. Düzeyde (%8,12) yer almaktadır. Bağlam açısından, en az soru toplumsal bağlamda (%1,01), büyük çoğunluk ise bilimsel bağlamda (%90,80) yer almıştır.

Önemli Vurgular: Çalışma, her düzey ve bağlamdan sorular bulunmasına rağmen, ders materyalindeki soruların düzey ve bağlamlarının eşit dağılmadığı sonucuna varmıştır. Üstün yetenekli öğrencilere yönelik gelecekteki ders materyallerinin dengeli bir dağılım sağlamaya daha fazla önem vermesi ve ileri beceri gerektiren daha fazla sayıda soru içermesi önerilmektedir.

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INTRODUCTION

The Organization for Economic Co-Operation and Development (OECD, 2013) defines mathematical literacy as the capacity to employ decision-making and mathematical thinking processes to address challenges people confront today and will encounter in the future. Another perspective posits that mathematical literacy embodies an individual's ability to reason, analyze, formulate and tackle problems within real-world settings (Martin, 2007). Given this context, it is widely acknowledged that possessing foundational mathematical literacy enables individuals to effectively navigate the complexities of contemporary life (Steen et al., 2007). Therefore, the overarching objective of mathematics education should be the cultivation of mathematically literate individuals. Educational systems worldwide aim to enhance mathematical literacy through varied curricula that integrate practical and theoretical mathematical education, preparing students not only for academic pursuits but also for informed and competent participation in a rapidly advancing society. With this in mind, the Ministry of National Education (2018) is committed to fostering robust mathematical literacy skills in everyone, emphasizing the understanding and pragmatic application of mathematical notions in daily life. Since 2003, Turkey has been an active participant in the Program for International Student Assessment (PISA), which shares these educational objectives.

PISA, conducted by OECD, is a triennial survey designed to gauge the ability of 15-year-old students to apply the knowledge and skills they've acquired in school to real-world situations (MoNE, 2020). Essentially, PISA aims to assess the degree to which students can contextualize classroom learning in real-world settings. This research assesses participating countries' educational efficacy in reading proficiency, science literacy, and mathematical literacy based on student performance. Participating countries utilize these evaluation findings to shape their educational strategies (Baştürk Şahin and Altun, 2019). PISA analyzes mathematical literacy in three aspects: mathematical processes and the underlying abilities, mathematical content, and contexts (OECD, 2019a). Among these, the aspect of context is particularly significant because it ensures that mathematical tasks are relevant to real-world settings, which enhances students' ability to apply mathematical concepts practically and meaningfully. The contexts defined by PISA include personal, societal, occupational, and scientific settings, each tailored to test students' skills in varying real-life situations. Besides, in 2012, PISA developed specific definitions of mathematical literacy levels tailored to each student level, detailing the six levels of proficiency. These levels range from basic numerical tasks to complex mathematical reasoning and problem-solving, highlighting the importance of accurately assessing and subsequently fostering a student's progression in mathematical understanding and application. In this framework, PISA has defined the essential skills and knowledge required for individuals to be educated as mathematically literate. Levels and contexts are key variables in this study, as they provide insights into students' mathematical development and illustrate how effectively they can integrate mathematics into various aspects of their lives and the wider world. Understanding levels and contexts in mathematical literacy is particularly critical in gifted education, as it helps tailor teaching methods and materials to challenge gifted students and meet their advanced learning needs effectively.

Gifted individuals, characterized by superior cognitive, emotional, and behavioral traits compared to their peers, possess above-average creative thinking abilities and a penchant for undertaking challenging tasks. They also demonstrate a remarkable aptitude for managing and organizing data, and an ability to transpose mathematical principles across different domains (Sisk, 1987). Their advanced cognitive abilities uniquely position them to excel in mathematical literacy, which involves not just computational skills but also the ability to reason, solve complex problems, and effectively communicate using mathematical concepts (Hardianti & Zulkardi, 2019). This form of literacy is crucial as it enables gifted students to engage deeply with mathematical ideas and to apply these skills across various domains, enhancing both their academic performance and future opportunities (Kurnaz, 2018). Despite their high levels of mathematical ability, gifted students may still encounter challenges in metacognition and problem-solving, underscoring that mathematical literacy involves more than innate ability; it requires the development of advanced planning, monitoring, and evaluative skills concerning one's own thinking processes (Sihotang et al., 2020). Therefore, equipping gifted individuals with robust mathematical literacy is fundamental not only for their personal fulfillment but also for leveraging their potential to contribute significantly to societal advancement. In this light, it is crucial for educational systems to incorporate comprehensive strategies that foster these skills, ensuring that gifted students can navigate and excel in a complex, rapidly evolving global landscape.

In Turkey, gifted students have the opportunity to enhance their education at Science and Art Centers (SACs), which are specialized institutions offering supplemental education to cultivate and maximize their unique talents (Karabulut et al., 2023). SACs' primary objectives include raising awareness of individual talents, fostering their growth to maximize potential, and honing their problem-solving skills (MoNE, 2019). In line with their advanced cognitive characteristics, students are supported by project-based, interdisciplinary, enriched, and differentiated education programs. Complementary course materials are also provided to aid them in producing original works, projects, and productions that match their abilities (MoNE, 2019). The "SACs High School Mathematics Auxiliary Course Material," published by the Ministry of National Education's General Directorate of Special Education and Guidance, is tailored for students specializing in mathematics at SACs. This material provides a differentiated and enriched educational resource, supporting an in-depth education in mathematics for students in the 7th and 8th grades. The SAC program, tailored for these students, offers students an in-depth education in their chosen disciplines and emphasizes interdisciplinary connections to equip them with comprehensive knowledge, advanced skills, and relevant behaviors, ultimately encouraging them to make significant contributions in their respective fields (Karaaslan et al., 2021). This specialized resource is designed to cater to the higher cognitive capabilities of these students, providing them with a rigorous mathematical curriculum that challenges and extends their abilities beyond the standard educational offerings. It strategically emphasizes the importance of interdisciplinary connections and advanced problem-solving skills, essential for gifted students to fully exploit their potential and excel in complex mathematical concepts and applications.

The "SACs High School Mathematics Auxiliary Course Material," includes 39 activities designed for educators, incorporating lectures, sample questions, student activity examples, additional project suggestions, measurement and evaluation tools, and "Activity Forms" all aligned with curriculum objectives. Organized modularly, the book is divided into four key modules: analysis, finite mathematics, geometry, and algebra with number theory. In this study, we have focused on evaluating the questions in the algebra module in terms of level and context because previous research indicates that students often struggle with algebra due to its abstract nature and the low level of challenge provided by the questions in existing educational resources (Şaban, 2019; Akkaya & Durmuş, 2006). These issues are largely attributed to the questions' lack of complexity and their failure to effectively connect with real-world applications, underscoring the need for a more rigorous and contextually relevant approach in educational materials.

In our study, we analyze the complexity and real-world applicability of algebra questions within textbooks, aiming to provide insights that curriculum developers and textbook authors can use to better align educational materials with the cognitive needs of gifted students. By focusing on the levels and contexts of algebra questions, we highlight the essential role that textbooks play as primary educational tools that shape learning environments and influence the development of mathematical literacy, as noted by France et al. (2023). Bernardino (2023) further supports this, noting that the effectiveness of textbooks in fostering mathematical literacy is contingent upon their alignment with educational goals and teaching practices. Our analysis is intended to guide the enhancement of textbooks by demonstrating how well-tailored content can nurture gifted students' abilities to apply mathematical reasoning in varied, practical scenarios, thus preparing them for advanced problem-solving and innovation in their future endeavors. By providing these insights, we aim to assist in the creation of textbooks that are not only more responsive to the needs of gifted learners but also instrumental in their advanced academic and professional preparation.

In the academic field, numerous studies have focused on mathematical literacy, with several specifically addressing the mathematical literacy of gifted students (Albayrak et al., 2023; Karaduman et al., 2023; Leikin, 2021; McAllister & Plourde, 2008; Weiner & Robinson, 1986; Zedan & Bitar, 2017). A significant portion of this research involves textbook analysis, adopting various approaches: some researchers have gathered insights from educators or students who have used these materials (Genç & Erbaş, 2017; Nicol & Crespo, 2006), while others have conducted cross-country textbook comparisons (Conklin, 2004; Charalambous et al., 2010; Yeğit, 2020). Additionally, some studies have analyzed central exam questions (Mutlu & Akgün, 2016; Öztürk, 2020), and a considerable number have scrutinized course materials through the lens of PISA mathematical literacy (Al Cihan, 2023; İskenderoğlu & Baki, 2011; Karataş, 2019; Şaban, 2019; Şirin, 2019; Tarım & Tarku, 2022; Tarku, 2022; Yıldırım, 2019). For example, İskenderoğlu and Baki (2011) found that an 8th grade mathematics textbook predominantly featured questions at levels 1 through 4, with Level 2 being the most common at 47%, leading to a recommendation for the inclusion of higher-level questions. Similarly, Tarım and Tarku (2022) noted a majority of questions set in a "scientific context" and at Level 2, and they recommended a more balanced distribution of question levels in future editions. However, a noticeable gap remains in the literature: there is a lack of studies that specifically examine materials designed for gifted students through the framework of PISA mathematical literacy.

Given the alignment of educational objectives for gifted students with PISA's definition of mathematical literacy, a rigorous evaluation of course materials tailored for these students within the PISA framework of mathematical literacy competencies and domains is imperative. This alignment necessitates a thorough assessment of the course materials to ensure they meet both the advanced cognitive needs of gifted students and the international educational standards. Such evaluations are crucial as they not only verify that the educational content fulfills the complex cognitive requirements of gifted students but also prepare them for future challenges by enhancing their mathematical reasoning and application skills. Considering these factors, the primary goal of this study is to systematically analyze and categorize questions from the "algebra and number theory" module of the High School Mathematics Auxiliary Course Material designed for Science and Art Centers (SACs), aligning them with PISA’s mathematical proficiency levels and literacy contexts. This systematic approach aims to ensure that these educational tools effectively contribute to the development of mathematical literacy among gifted students.

To address this central objective, the study seeks answers to the subsequent sub-questions:

1. How are the questions from the "algebra and number theory" module's activity forms in the High School Mathematics Auxiliary Course Material for SACs classified according to PISA's mathematical proficiency levels?
2. How are the questions from the "algebra and number theory" module's activity forms in the High School Mathematics Auxiliary Course Material for SACs categorized based on PISA's mathematical literacy contexts?

METHOD/MATERIALS

In this study, the document analysis technique, a qualitative research method, was employed. Document analysis refers to the systematic examination of written materials (Wach, 2013). Specifically, the questions within the activity forms of the "algebra and number theory" module from the High School Mathematics Auxiliary Course Material for SACs were scrutinized. Initially, the questions in the material were explored and coded. Subsequently, these coded questions were categorized based on the PISA mathematical proficiency levels and mathematical literacy contexts.

Selection of Course Material

In Turkey, the "High School Mathematics Auxiliary Course Material for SACs" was prepared by the General Directorate of Special Education Services and approved by the Board of Education in 2021. This material was specifically designed to guide mathematics teachers in educating students enrolled in SACs and those channeled towards mathematical fields. Given its significance in the education of gifted individuals, this book was chosen for examination to classify its content according to the PISA mathematics proficiency levels and mathematical literacy contexts.

Data Collection

For this study, we examined the questions in the activity forms within the algebra and number theory module of the "SACs High School Mathematics Auxiliary Course Material" used in Turkey. Before initiating the research, we sought and obtained ethical approval from the Çukurova University Ethics Committee Commission.

Data Coding

Researchers independently coded questions pertaining to the subject areas of algebra and number theory within the material. In this coding approach, identifiers were assigned based on the activity number, page number, and question number to ensure clarity in the analysis. For instance, a question marked as number 5 on page 233, stemming from the sixteenth activity, was coded as 16-233-5. This uniform coding method was applied to all 199 questions in the material for the study. After completing the coding, the two researchers compared and analyzed their coding to ensure consistency.

Tools Used for Document Analysis Classification

PISA Mathematics Proficiency Levels: PISA developed a comprehensive six-level proficiency scale that distills data gathered from mathematics test materials. This scale facilitates international comparisons by allowing students' mathematical proficiency to be assessed and grouped into one of these six levels (EARGED, 2010). The levels as determined by PISA in 2003 are detailed in Table 1.

Table 1. PISA Mathematics Proficiency Levels

Proficiency Level	What can a student who has reached this level do?
6	Students at level six can independently derive, generalize, and apply concepts to tackle intricate problems using knowledge from their research and modeling. They seamlessly connect various information sources and representations. These students exhibit advanced mathematical thinking and reasoning. When confronted with novel problems, they strategically approach solutions, showcasing a deep understanding and mastery over symbolic and formal mathematical operations. Furthermore, they can articulate their discoveries, interpretations, and perspectives effectively, highlighting their applicability to specific scenarios.
5	Students at level five can create models for intricate situations, recognizing their boundaries and underlying assumptions. They can select and assess strategies for complex problems related to these models. These students work strategically, utilizing robust thinking, reasoning skills, and relevant mathematical representations. They can introspect, articulate their interpretations, and convey their reasoning to others.
4	Students at level four can effectively use models for complex scenarios, even when needing to make assumptions. They adeptly choose and merge various representations, linking them to real-world situations. They think adaptably with foresight, formulating explanations based on their interpretations. They can communicate their viewpoints and findings to others.
3	Students at level three can execute specific operations, even those involving sequential decisions. They can choose and apply basic problem-solving techniques. These students can decipher and utilize information from various sources, reasoning directly from them. They're capable of creating concise reports detailing their findings and reasoning.
2	Students at level two can interpret straightforward situations without needing skills beyond direct inference. They gather information from a single source and use one representation form. These students can apply basic algorithms, formulas, and procedures. Their reasoning is direct, and their interpretations are based solely on observable results.
1	Students at level one can address questions within familiar contexts, where problems are clearly defined and all required information is provided. They can discern information and execute routine tasks based on clear instructions. They can also carry out operations that follow a singular, straightforward stimulus.

PISA Mathematical Literacy Contexts: PISA organizes the contexts in which mathematical problems are framed into four distinct categories: personal, occupational, societal, and scientific. In the 2018 PISA evaluation, the distribution of mathematical items was evenly spread among these contexts, with each one accounting for 25% of the total. This uniform distribution ensures no single context type overshadows the others (OECD, 2019a). The aforementioned "Contexts" categorization of mathematical literacy as defined by PISA can be seen in Table 2 (OECD, 2010).

Table 2. PISA Mathematical Literacy Contexts and Scopes

Contexts	Scopes	Examples
Personal	This context category encompasses items related to an individual's personal experiences.	It includes situations involving one's family, friends, travels, and recreational activities like games, shopping experiences, and more.
Occupational	This context category pertains to items that individuals might encounter in their occupational lives.	This can range from tasks involving accounting, measurement, managing one's time, calculating costs, to activities related to construction and buildings.
Societal	This context category involves items relevant to community and societal interactions.	Examples include processes like elections, public policies, population strategies, aspects of the national economy, and systems like public transportation.
Scientific	This context involves mathematical applications pertinent to various scientific fields.	It encompasses areas like basic sciences, medicine, studies on climate, space exploration, and more. Additionally, concepts intrinsic to the realm of mathematics itself also fall under this category.

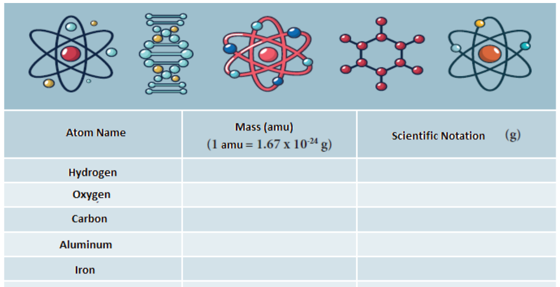
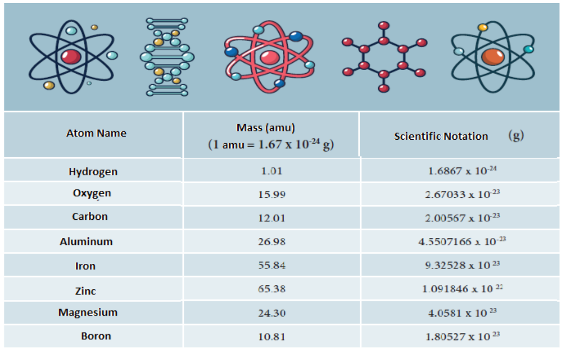
Data Analysis

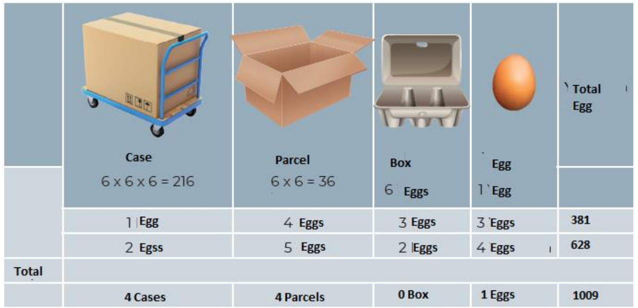
The questions in the activity forms of the algebra and number theory module of the book were firstly solved and then it was determined which skills could be used to reach a solution. These skills were compared with PISA mathematics proficiency levels and the questions were categorized by determining which level they were at. Then, all coded questions were analyzed and classified according to the explanations of PISA mathematics literacy contexts.

In the study, the questions in the textbooks were classified according to PISA mathematics literacy competency levels and contexts by researchers and three experts who have completed their master's degrees in mathematics education and received training in mathematics literacy. Initially, the researchers classified all the questions according to level and context categories. Following this, tables classified by the researchers and experts were compared, and a meeting was held with the experts and researchers where consensus was reached on questions that were evaluated differently by the researchers in terms of PISA mathematics literacy competency levels and contexts. In this regard, examples and detailed explanations of questions where there was disagreement regarding the PISA mathematics literacy context and level are provided in the Findings section. Additionally, it is explained in detail that two questions were excluded from the evaluation due to their inherent structure preventing the determination of their context and levels. Apart from these two questions, there were no disagreements in classifying the remaining questions in terms of mathematics literacy competency levels. The disagreements occurred in the scientific context category of mathematics literacy contexts. The reason for the disagreements is that some questions were not evaluated within the context of mathematical literacy, but were directly related to the nature of mathematics. A consensus was reached among the researchers and experts, taking into account previous studies (Tarım & Tarku, 2022; Küçükgençay et al., 2021), to include questions directly concerning the nature of mathematics in the scientific context. This decision and its rationale are also discussed in detail in the Findings section.

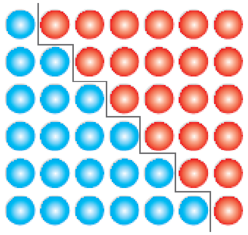
Analysis of sample questions, coded within the context of PISA mathematical proficiency levels and literacy contexts, along with their solutions are detailed in Table 3.

Table 3. Sample Analysis Explanations in the Framework of PISA Mathematics Proficiency Levels and Mathematical Literacy Contexts, Coded Questions and Solutions

<table>
<tr><th>Level</th><th>Sample Question</th><th>Solution</th><th>Level Explanation of the Question</th><th>Context</th></tr>
<tr><td>1</td><td>13-57-1
Examine whether the following communities indicate a cluster.
a. The most beautiful cities in Turkey
b. Provinces in Turkey with altitudes exceeding 1000 meters
c. The most successful students in our school</td><td>A cluster is defined as 'a well-defined collection of varied objects'. The term 'well-defined' implies that we can clearly identify the said objects through our perception, intuition, and reasoning. Essentially, the composition of this collection should remain consistent and not vary from person to person. Everyone should agree on its constituents. As such, while the collections in items a and c don't represent a well-defined set, the collection in item b does.</td><td>In this question, the student is tasked with determining whether the groups in the provided items are well-defined. The student is expected to discern information about familiar situations based on given instructions. Given its open-ended nature and the fact that it requires operations based on a single data point, this question falls under the PISA Mathematics proficiency level 1.</td><td>Societal</td></tr>
<tr><td>2</td><td>8-132-15

<table>
<tr><th>Atom Name</th><th>Mass (amu)
(1 amu = 1.67 x 10^{-24} g)</th><th>Scientific Notation (g)</th></tr>
<tr><td>Hydrogen</td><td></td><td></td></tr>
<tr><td>Oxygen</td><td></td><td></td></tr>
<tr><td>Carbon</td><td></td><td></td></tr>
<tr><td>Aluminum</td><td></td><td></td></tr>
<tr><td>Iron</td><td></td><td></td></tr>
</table></td><td>
<table>
<tr><th>Atom Name</th><th>Mass (amu)
(1 amu = 1.67 x 10^{-24} g)</th><th>Scientific Notation (g)</th></tr>
<tr><td>Hydrogen</td><td>1.01</td><td>1.6867 x 10^{-24}</td></tr>
<tr><td>Oxygen</td><td>15.99</td><td>2.67033 x 10^{-23}</td></tr>
<tr><td>Carbon</td><td>12.01</td><td>2.00567 x 10^{-23}</td></tr>
<tr><td>Aluminum</td><td>26.98</td><td>4.5507166 x 10^{-23}</td></tr>
<tr><td>Iron</td><td>55.84</td><td>9.32528 x 10^{23}</td></tr>
<tr><td>Zinc</td><td>65.38</td><td>1.091846 x 10^{22}</td></tr>
<tr><td>Magnesium</td><td>24.30</td><td>4.0581 x 10^{23}</td></tr>
<tr><td>Boron</td><td>10.81</td><td>1.80527 x 10^{23}</td></tr>
</table></td><td>In this question, the student is instructed to research the mass of atoms and then convert it into grams using the unit provided in the query. During this conversion to grams, the student needs to arrange the exponents and format them into scientific notation. The task necessitates sourcing information from a singular reference, representing this information in a specific notation, and employing basic calculations. Consequently, this question aligns with the PISA Mathematics proficiency level 2.</td><td>Scientific</td></tr>
</table>

Level	Sample Question	Solution	Level Explanation of the Question	Context
3	14-215-14 1 case, 4 parcels and 3 boxes of packaged and 3 unpackaged eggs in the hen house and 2 crates, 5 parcels and 2 boxes of packaged and 4 unpackaged eggs, eggs from the first coop with eggs will be combined. How many crates, parcels and boxes in total used? What is the number of unpacked eggs?		In this question, the student is asked to be able to make addition in different bases. When the student adds the number of eggs and obtains a number greater than 6, the student is asked to transfer them to the packing unit to the student' s left, write the remainder and multiply it by the digit value to find the total number of eggs. In the question, students are expected to make sequential decisions, interpret, use and reason about representations based on different sources of information. Therefore, the PISA Mathematics proficiency level for this question is 3.	Occupational
4	5-90-7 Gökay can climb a 12-step ladder 1 or 2 steps at a time. How many different ways can he step out?	1 option for step 1 (1) 2 options for step 2 (1+1, 2) 3 options for step 3 (1+1+1, 2+1+1, 1+2) 5 options for step 4 (1+1+1+1+1, 2+1+1+1, 1+2+1, 2+2) 8 options for step 5 (1 step from step 4 and 2 steps from step 3) 13 options for step 6 (1 step from step 5 and 2 steps from step 4) ... There are 233 different options for 12 digits.	In this question, the student must use correct counting techniques per the instructions and correlate the results with the Fibonacci sequence. The question demands the student to integrate different representations and link them to real-world scenarios. Hence, the PISA Mathematics proficiency level for this question is 4.	Personal

	Case 6 x 6 x 6 = 216	Parcel 6 x 6 = 36	Box 6 Eggs	Egg 1 Egg	Total Egg
	1 Egg	4 Eggs	3 Eggs	3 Eggs	381
	2 Egss	5 Eggs	2 Eggs	4 Eggs	628
Total					
	4 Cases	4 Parcels	0 Box	1 Eggs	1009

Level	Sample Question	Solution	Level Explanation of the Question	Context
5	17-215-13 Create a number system with base 16. Determine the numbers and symbols you need to use and express the equivalent of the numbers given below in different bases in base 16 with the symbols in the number system you have created. a. 300 = b. 12303 = c. $(100111001110101)_2$ =	In bases greater than 10, special symbols are used instead of values greater than or equal to 10. In base 16, A is usually used instead of 10, B instead of 11, C instead of 12, D instead of 13, E instead of 14 and F instead of 15. a. 300 = $(12C)_{16}$ b. 12303 =$(300F)_{16}$ c. $(100111001110101)_2 = (4E75)_{16}$	In this question, the student is tasked with devising a base system other than base 10. Following this, they must convert both base 10 and base 2 into base 16. The question necessitates the student to construct models for intricate situations, select an appropriate strategy, and relate mathematical representations. As such, the PISA Mathematics proficiency level for this question is 5.	Scientific
6	2-39-5 Write and prove the statement whose proof without words is given as follows. 	Proposition: $1 + 3 + 5 + 7 + ... + (2n - 1) = (2n^2)/4 = n^2$ Proof by induction: 1. This proposition becomes $1 = 1^2$ for n = 1. It is trivial. 2. $\forall k \geq 1, S_k \Rightarrow S_{k+1}$ S_k: $1 + 3 + 5 + 7 + ... + (2k – 1)=k^2$ S_{k+1}: $1 + 3 + 5 + 7 + ... + (2k – 1) + (2k+1)$ $= k^2+(2k+1)=(k+1)^2$	In this question, the student must algebraically represent the expression provided through a visual proof and inductively validate it. The student should effectively link various information sources and representations, transitioning seamlessly between them, while showcasing expertise in symbolic operations and mathematical correlations. Consequently, the PISA Mathematics proficiency level for this question is 6.	Scientific

FINDINGS

The primary aim of this research was to classify questions from the activity forms within the algebra and number theory module of the "High School Mathematics Auxiliary Course Material," specifically designed for the Science and Arts Centers. This classification was based on the PISA mathematics proficiency level and mathematical literacy contexts. Table 4 provides a detailed breakdown of the activities present in the algebra and number theory module of the studied material. Additionally, it enumerates the quantity of questions associated with the activity forms of each respective activity.

Table 4. Activity Names and Question Numbers in the Algebra and Number Theory Module of SACs' High School Mathematics Material

Activity Name	Number of Questions
1. Mathematical Logic	5
2. Mathematical Proof Methods	7
3. Clusters	13
4. Relation and Function	10
5. Fibonacci Numbers and the Golden Ratio	9
6. Special Numbers	13
7. Polygonal Numbers	12
8. Exponents	15
9. Rooted Numbers	15
10. Prime Numbers	9
11. Fundamental Theorem of Arithmetic	9
12. Euclidean Algorithm and GCD-LCM	18
13. Divisibility Rules	13
14. Operations on Different Bases	17
15. Language of Computers	-
16. Modular Arithmetic	14
17. Linear Equivalence Systems	12
18. Encryption Techniques	-
19. Equations and Inequalities	8
Total	199

In Table 4, it is evident that the algebra and number theory module of the book comprises 19 activities, with a cumulative total of 199 questions in the activity forms that follow these activities. Among these, the "Euclidean Algorithm and GCD-LCM" activity boasts the most questions, whereas the "Mathematical Logic" activity features the fewest. Notably, the "Language of Computers" and "Encryption Techniques" activities contain sample applications within the activity, but lack any associated activity form. A glance at Table 4 reveals that the distribution of questions in the activity forms varies, suggesting it is not proportionally aligned with the activities.

The first sub-goal of this study aims to categorize questions from the activity forms on algebra and number theory topics within the High School Mathematics Auxiliary Course Material for SACs, based on PISA mathematics proficiency levels. To achieve this, the questions, as outlined in Table 4, were coded and classified in accordance with PISA levels. Table 5 presents the resulting frequency and percentage distributions of the questions across these levels.

Table 5. Frequency and percentage distributions of questions according to PISA mathematics proficiency scale levels

PISA Mathematics Proficiency Levels	f	%
Level 1	10	5.07
Level 2	81	41.11
Level 3	53	26.90
Level 4	18	9.13
Level 5	16	8.12
Level 6	19	9.64
Total	197	100

Upon examining Table 5, it's evident that the distribution of questions in the High School Mathematics Auxiliary Course Material, based on PISA Mathematics proficiency levels, is as follows: first level comprises 10 questions (5.07%), second level has 81 questions (41.11%), third level contains 53 questions (26.88%), fourth level consists of 18 questions (9.13%), fifth level includes

16 questions (8.12%), and sixth level features 19 questions (9.64%). In the book under analysis, level 2 questions are the most prevalent, constituting 41.11%, while level 5 questions are the least common at 8.12%. Despite the presence of questions from all levels in the book, the distribution among the levels is not even.

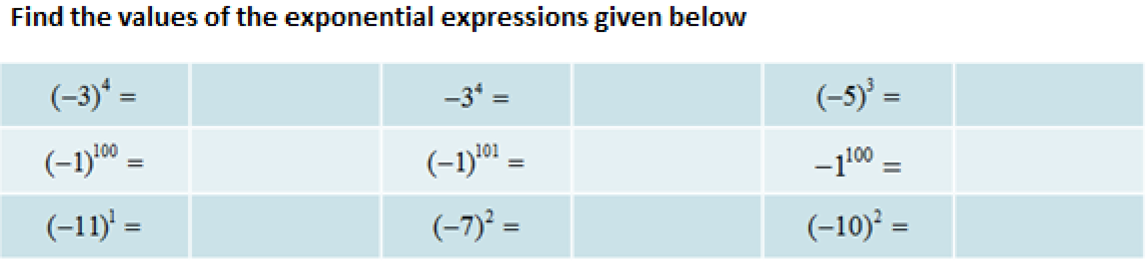
The second sub-objective of this study aims to categorize the questions in the activity forms related to algebra and number theory topics in the High School Mathematics Auxiliary Course Material for SACs based on PISA mathematical literacy contexts. To achieve this, questions outlined in Table 4 were coded and sorted according to PISA mathematical literacy contexts. Table 6 subsequently presents the frequency and percentage distributions of these questions by context.

Table 6. Frequency and percentage distributions of questions according to PISA mathematical literacy contexts

Contexts Category	f	%
Personal	9	4.56
Occupational	7	3.55
Societal	2	1.01
Scientific	179	90.80
Total	197	100

Upon examining Table 6, it is observed that there are 9 questions (4.56%) in the personal context, 7 questions (3.55%) in the occupational context, 2 questions (1.01%) in the societal context, and 179 questions (90.80%) in the scientific context. While the book contains the fewest questions in the societal context (1.01%), it is heavily dominated by questions in the scientific context (90.80%). Although questions from all contexts are present in the book, their distribution across these contexts is not even.

There are exceptions to the general categorization of contexts. Specifically, in the unique scenario where a unit solely encompasses mathematical structures and doesn't reference any context outside of mathematics, it is categorized under the scientific context (OECD, 2019a). In this research, questions within the scientific context were assessed from two distinct angles: first, as questions that genuinely pertain to a scientific context, and second, as questions that don't explicitly reference any particular context. These latter questions, due to the mathematical structures they embody, are classified as being within the scientific context by default. Out of these, 40 questions can be deemed to be truly situated within a scientific context as they encompass elements tied to scientific and technological mathematical applications. However, the remaining 139 questions solely draw from the realm of mathematical science. A review of the literature reveals that Tarım and Tarku (2022) also bifurcated the scientific context in their research. Conversely, Küçükgençay et al. (2021) labeled questions that solely integrated mathematical structures and excluded scientific or technological mathematical applications as having "no context" in their study. Figure 1 illustrates examples of questions that exclusively derive from the domain of mathematics yet are classified under the scientific context.



Find the values of the exponential expressions given below

$(-3)^4 =$		$-3^4 =$		$(-5)^3 =$	
$(-1)^{100} =$		$(-1)^{101} =$		$-1^{100} =$	
$(-11)^1 =$		$(-7)^2 =$		$(-10)^2 =$	

Figure 1. Example of a question classified in a scientific context and containing only mathematical expressions (8-128-3) (Karaaslan ve ark., 2021)

As illustrated in Figure 1, the sample question does not encompass elements related to mathematical practices tied to science and technology. Nevertheless, in this study, such questions were categorized under the scientific context due to their intrinsic alignment with the nature of mathematical science.

In the distribution presented in Table 4, there are 199 questions. Yet, Table 5 and Table 6 indicate that only 197 of them can be classified according to PISA mathematics literacy contexts and PISA mathematics proficiency levels. This discrepancy arises because the context and level of two questions, coded as 16-233-7 and 17-245-10 from Activity 16, Modular Arithmetic, and Activity 17, Linear Equivalence Systems, respectively, could not be pinpointed. Both of these questions pertain to equivalences and are identical, reading: "Devise and resolve a real-life problem where equivalences will be utilized." Given that the resolution to this question is left to the student's discretion, its context would naturally fluctuate based on the student's choice. Furthermore, the question's level might also change depending on the student's interpretation. However, since students are prompted to formulate the question themselves, it might be classified as Level 5. This is attributed to the student's required skills like creativity, the generation of unique solutions, model development and application in intricate situations, and understanding the respective limitations and assumptions.

In alignment with the primary objective of this study, questions from the activity forms pertaining to algebra and number theory in the High School Mathematics Auxiliary Course Material were categorized based on PISA mathematics proficiency levels and PISA mathematics literacy contexts. Beyond the primary findings, the study further explored if the distribution of questions in the book, as reviewed in the scope of this research, aligned proportionally with the PISA mathematics proficiency levels in relation to the PISA mathematics literacy contexts. In this regard, Table 7 presents the distribution of questions from Table 4, categorized by PISA mathematics literacy contexts and proficiency scale levels.

Table 7. Distribution of PISA mathematics proficiency levels of the questions in the course material according to PISA mathematics literacy contexts

Contexts Category	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Total
Personal	1	-	7	1	-	-	9
Occupational	-	3	4	-	-	-	7
Societal	1	-	1	-	-	-	2
Scientific	8	78	41	17	16	19	179
Total	10	81	53	18	16	19	199

In Table 7, the classification of PISA mathematics literacy contexts alongside the PISA mathematics proficiency scale levels reveals specific trends. Within the personal context, only questions from the first, third, and fourth levels are present. The occupational context has questions solely from the second and third levels. The societal context encompasses only the first and fourth level questions. In contrast, the scientific context features questions from all levels. Notably, the fifth and sixth level questions are exclusive to the scientific context, with none found in the personal, Occupational, or Societal contexts. Additionally, the distribution of the questions across the first through fourth levels is not evenly spread among the contexts.

DISCUSSION

In this research, questions from the activity forms within the algebra and number theory module of the High School Mathematics Auxiliary Course Material—developed for SACs—were categorized by PISA mathematics proficiency level and mathematical literacy contexts. A total of 199 questions spanning 19 activities were assessed.

Upon classifying by the PISA mathematics proficiency levels, it was determined that there were 10 questions (5.07%) at level 1, 81 questions (41.11%) at level 2, 53 questions (5.07%) at level 3, 18 questions (9.13%) at level 4, 16 questions (8.12%) at level 5, and 19 questions (9.64%) at level 6. The minimal representation is observed at level 5, while level 2 contains the maximum number of questions. This skew towards level 2 questions aligns with prior research. İskenderoğlu and Baki (2011) analyzed the 8th-grade mathematics textbook and found that nearly 47% of the questions were at level 2. In his study, Şaban (2019) analyzed 954 questions related to the algebra sub-learning area in mathematics and mathematics application textbooks for grades 6-8 according to the PISA mathematics competency scale. He noted that the majority of the questions were at level 2. Similarly, Tarım and Tarku (2022) found that the 8th grade textbooks they reviewed in 2022 predominantly featured questions of the 2nd level. Furthermore, this trend corresponds with Turkey's PISA 2018 mathematics score average (OECD, 2019b). Given that the High School Mathematics Auxiliary Course Material for SACs is intended to provide differentiated and enriched content (Karaaslan et al., 2011), the frequent inclusion of level 2 questions ensures students grasp these nuanced topics comprehensively.

Despite the literature indicating a lack of fifth and sixth-level questions in previously examined books (İskenderoğlu & Baki, 2011; Şaban 2019; Tarım & Tarku 2022), the High School Mathematics Auxiliary Course Material tailored for SACs revealed a significant 17.76% presence of these higher-level questions. Similarly, in their study, Sarıkaya & Yenilmez (2022), when 149 questions and sub-questions in the Secondary School Mathematics Applications textbooks were examined, it was seen that there were 62 questions from the 5th level and 33 questions from the 6th level. Furthermore, Özyaprak (2016) mentioned that when gifted students face questions commensurate with their cognitive capabilities, it promotes active engagement, curiosity, and exploration in mathematics. Wheatley (1983) underscored the importance of striking a balance between computation skills and higher-order thinking for textbooks designed for gifted students. Given that objectives crafted for gifted students are anticipated to be differentiated and enriched, there exists an expectation of a linear association between the question levels and objectives. The inclusion of level 5 and 6 questions in textbooks for gifted students is essential due to their advanced cognitive abilities and the need for challenging educational content. Research highlights the importance of a differentiated curriculum to keep these students engaged and motivated, as the lack of challenging material significantly risks underachievement (Kahveci & Akgül, 2014; Kanapathy et al., 2022). While specific studies on creating high-level questions for gifted students are scarce, the consensus supports their integration to meet unique educational needs and fully realize learning potential (He et al., 2022). Therefore, it is crucial for textbooks for gifted students to include a significant number of level 5 and 6 questions. Consequently, the presence of levels 5 and 6 questions in this particular book, devised as a guiding tool for instructors of gifted students, aligns seamlessly with the book's mission: facilitating students' mastery of comprehensive, advanced mathematical knowledge, skills, and behaviors, and empowering them to produce correspondingly.

Based on the PISA-defined context categories, it's evident that the majority of questions fall within the scientific context, accounting for 179 (90.80%), while the societal context sees the least representation with only 2 questions (1.01%). The personal and occupational contexts follow with 9 (4.56%) and 7 (3.55%) questions, respectively. This aligns with Tarku's (2022) findings, where the scientific context dominated with 80.6% of the questions, and the societal context was minimally represented at 1.5%. Contrastingly, Küçükgençay et al. (2021) adopted a distinct categorization technique. In their analysis, questions that lacked any discernible links to science and technology-related mathematical applications were labeled as 'no context'. They observed that the majority of the questions fell into this 'no context' category. In our study, a significant 139 questions (70.55%) were bracketed within the scientific context solely due to their affiliation with mathematical science, devoid of any concrete ties to actual science and technology. Conversely, the remaining 40 questions (21.31%) directly connected to scientific and technological themes, solidifying the dominance of the scientific context in our study, a trend that mirrors the broader literature. The majority of questions in the scientific context of the textbook primarily focus on the abstract nature of mathematics (Altun et al., 2004). This focus can lead to a disconnect between the questions and real-life applications, as they often do not align with practical scenarios found in societal, personal, or professional contexts. Therefore, it is advisable to revise these questions to better integrate real-life applications within the scientific framework. Additionally, it is essential to heed PISA's recommendation for a balanced distribution of questions across various contexts (OECD, 2019a), reflecting the diverse problem situations students are likely to encounter in real life. Furthermore, studies by Coştu et al. (2009) and Mutlu & Akgün (2016) have highlighted a significant gap in teachers' understanding of mathematical contexts and their tendency to undervalue these contexts. This gap can hinder students' ability to effectively connect mathematical concepts with real-world problems. To address these challenges, it is crucial for the High School Mathematics Auxiliary Course Material designed for SACs to provide a more equitable distribution of questions across all contexts, ensuring that students receive a well-rounded exposure to diverse mathematical applications. This approach will not only enhance their learning experience but also better prepare them to apply mathematical skills in various real-life scenarios.

CONCLUSION AND RECOMMENDATIONS

When analyzing the distribution of question levels according to their contexts, it becomes apparent that questions at the fifth and sixth levels are solely in the scientific context. Only one question at the fourth level falls under the personal context, with the remainder situated within the scientific domain. This distribution is believed to be because fifth and sixth-level questions inherently embody elements from the realm of pure mathematics. Nonetheless, the presence of merely two questions in the societal context, the absence of questions from each context at every level, and the disproportionate distribution of contexts relative to levels indicate that the course material doesn't align with PISA's emphasized distribution. It seems that while the course material's authors prioritized high-level skills for gifted students, they overlooked the importance of a balanced distribution across contexts. Given these observations, it's advisable for mathematics textbooks, crafted to assist teachers of gifted students, to ensure a balanced question distribution across all levels. Additionally, during textbook creation, there should be a focus on including an adequate number of questions from each context. This ensures that students hone their problem-solving skills by relating mathematics to everyday scenarios. For future course materials tailored for gifted students, an emphasis should be on increasing high-level skill questions while ensuring distribution equilibrium. Additionally, it is suggested that questions in other modules of the High School Mathematics Auxiliary Course Material for SACs be analyzed in light of PISA mathematical literacy components.

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Statements of publication ethics

We hereby declare that the study has not unethical issues and that research and publication ethics have been observed carefully.

Researchers’ contribution rate

The study was conducted and reported with equal collaboration of the researchers.

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Ethics Committee Approval Document of this research was provided by Çukurova University in 24.05.2023 by Ethics Committee for Education and Humanities with number 706949.

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