

Trends in Cognitive Demands Levels of Mathematical Tasks in Turkish Middle School Mathematics Textbooks: Algebra Learning Domain

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This study reports a small part of a large-scale study. In this vein, trends in cognitive demand levels of mathematical tasks in the Algebra Learning Domain of 5 mathematics textbooks prepared according to four middle school mathematics curricula that have been updated since the beginning of the 2000s in Turkey were determined. This study is a document review, and the criterion sampling method was used to select textbooks. The cognitive demand levels of the mathematical tasks in the examined books were analysed according to the content analysis. The study revealed that the tasks in the middle school mathematics textbooks written according to the updated mathematics curriculum in Turkey in the 2000s are generally low cognitive demand tasks. Also, some suggestions are made for further research according to the findings.

Keywords: Mathematics Curriculum, Mathematics Textbooks, Mathematical Tasks, Cognitive Demand Levels, Algebra Learning Domain

Introduction

The Fourth Industrial Revolution and the 21st century offer us a world of interconnected and rapidly changing intricate relationships (Toh & Kaur, 2016). Because the 21st century and the Fourth Industrial Revolution include accelerated technological innovations such as cyber-physical technology, social media, artificial intelligence, robotics, the Internet of Things, and 3-D printing (The Organization for Economic Co-operation and Development [OECD], 2021), this century has made it necessary for individuals to acquire several competencies to respond to challenging and different demands of the 21st century, and individuals equipped with only factual knowledge stay away from meeting these demands. In this context, individuals in this new century must know how to use their cognitive, affective, and psychomotor skills and activate them to produce solutions for complex tasks and situations (Longworth, 2003). This rapid and great knowledge acquisition and transfer and technological developments in this century naturally necessitated the revision of the education environment in general, and mathematics, and processes, curricula, and textbooks to meet the century's needs. The current study focuses on the cognitive demand levels of mathematical tasks in middle school mathematics textbooks written according to Turkey's updated mathematics curriculum (2005, 2009, 2013, and 2018) since the beginning of the 2000s. The textbooks reveal "a reflection of the current education policy as an indicator of the concrete steps of teaching and learning" (Valverde, Bianchi & Wolfe, 2002, p. vii) and establish a relationship between the aims of the curriculum and the classroom practices designed by the teachers (Schmidt, McKnight, & Raizen, 2002; Törnroos, 2005).

For this reason, textbooks are seen as an in-class curriculum implementation and provide a framework for students' learning situations to organize their learning experiences (Demirel, 2017). This framework creates a strong tendency in teaching environments and processes to think mathematically, search and discover patterns to understand mathematical structures and their underlying relationships and use available resources effectively and appropriately to formulate and solve problems. This tendency also includes making sense of mathematical ideas, predicting, generalizing, justifying, communicating, and deciding

whether mathematical results make sense (Schoenfeld, 1992). In this context, if this mathematical tendency can be formed in students, then it can be expected that students will be more involved in dynamic mathematical activities based on rich and valuable mathematical tasks (see National Council of Teachers of Mathematics [NCTM], 2000; Schoenfeld, 1994).

Background

Turkish Education System and Turkish Middle School Mathematics Curriculum in the 21st Century

Today -as mentioned before- the rapid change brought about by the developments in information and technology has also affected teaching philosophies to a certain extent. Accordingly, the teaching environment and processes naturally transform rapidly (Trilling & Fadel, 2009; Heilio, 2004). In this context, education experts try reorganizing the factors affecting the teaching environment and processes (for example, curriculum, education, and training methods) by considering these changes (Carney, 2008; Levin, 1997; Lundberg, 2019; Ramsey, 1993).

In the Turkish Education System, which adopts the centralized education approach, the curriculum is quite decisive on the education system. In this context, since 2005, the curriculum has been reviewed by the Ministry of National Education (Ministry of National Education of Turkey) [in Turkish: MEB] in light of developments in the world and contemporary educational philosophies (Board of Education [in Turkish: TTKB], 2009). Underneath these renovation works, besides the idea of meeting the needs of the age and reflecting the educational practices that are at the forefront of the academic environment and processes (TTKB, 2004), the low scores of Turkish students in the comparative exams in international organizations such as the Third International Mathematics and Science Study [TIMSS] and the Program for International Student Assessment [PISA] also lie behind it (see Mullis, Martin, Foy, Kelly, & Fishbein, 2020).

In this context, reform movements were initiated in Turkey in 2005 to change the traditional understanding of mathematics education in Turkey, and the curriculum of almost all disciplines was updated in this process. Turkey's primary education mathematics curriculum, based on the student-centered teaching approach, was also updated in 2005 and has been implemented in all primary schools gradually since the 2005-2006 academic year. Likewise, in 2009, 2013, and 2018, updates were made in all curricula in general and mathematics curricula in particular, based on the same philosophical approach.

In general, the specific aims of mathematics curriculums are formed around critical features such as conceptual understanding, awareness of the relationship between mathematics and daily life, individual ideas being at the forefront of the problem-solving process and being able to be managed. The conceptual approach adopted is aimed at helping students form mathematical meanings and make abstractions based on their concrete experiences and intuitions. All these programs include an approach that prioritizes developing students' mathematical process skills (for example, problem-solving, connection, communication, modeling, and reasoning) (see MEB and 2013, 2018). This new approach to curriculum preparation has naturally started the process of re-preparing the textbooks (Jones & Tarr, 2007), which is a reflection of the curriculum and one of the main factors that come to mind with the students and teachers in the teaching environments (Jones & Tarr, 2007). Because textbooks are an effective teaching tool in determining the subjects and making sense of them (Ball & Cohen, 1996), they are the most crucial critical part of what kind of lesson the teachers will teach (Fan & Kaeley, 2000).

Textbooks, Teaching Mathematics and Algebra Teaching

Since textbooks are an important teaching material (Grouws, Tarr, Chavez, Sears, Soria, & Taylan, 2013; Harwood, 2016) that teachers refer to in the planning and implementation of a lesson, the teachers' determination of the course content and the choice of the strategies they will use in their lessons generally differ from the textbooks. (Freeman & Porter, 1989; Reys, Reys & Chavez, 2004). In this context, textbooks play an important role in providing learning opportunities to students (Törnroos, 2005), being a strong determinant of what and how students learn (Kim, 2013), and creating teaching opportunities for teachers. In this context, it is expected that the mathematics teaching curricula in general and the textbooks written in the domain of learning algebra focus on developing students' mathematical content and process skills.

Algebra and algebraic thinking are thinking and reasoning domains that prepare students for mathematical reasoning in other mathematics subjects (see Kaput, 2000; Kieran, 1992; Usiskin, 1999). Algebra and algebraic thinking, important disciplines in raising individuals suitable for 21st-century skills and revealing the functionality of mathematics in daily life, are frequently noted in the literature (Brumbaugh & Rock, 2012; Van de Walle et al., 2014). NCTM (2000) states that investigating algebraic concepts provides a solid basis for developing students' higher-order thinking and problem-solving skills. In this way, students can have the opportunity to make sense of the nature of mathematical processes, concepts, and relationships through various mathematical tasks (Stein, Smith, Henningsen, & Silver, 2000). Forming these opportunities through mathematical tasks also includes preparing curricula that support the algebraic development of students (Cai & Knuth, 2005). Because mathematical tasks reveal both what students learn, how they look at mathematics, and how they use and make sense of mathematics (Stein, Grover, & Henningsen, 1996, p. 459), in this context, tasks allow students to think conceptually and encourage them to make connections between concepts (Stein & Smith, 1998) and enable them to focus on a specific mathematical idea (Stein et al., 1996).

Tasks and Mathematical Tasks

Although there is no agreed definition of what the concept of a task is, it is seen that some researchers use the idea of a task in a similar sense to any problem or question presented to students (see Sáiz & Figueras, 2009). Brousseau (1997) also established a relationship between the concepts of task and problem but also put forward some limitations here. According to him, for a problem to be a task, it must first consist of more than one step, or the problem must not be solved immediately by applying a previously known algorithm. In other words, according to Brousseau (1997), a task can be considered a problem(s) with complex content for discovery purposes. Doyle's (1983, 1986, and 1988) approach to mathematical tasks expressed as product-oriented pursuits in the teaching environment and processes of mathematics forms the basis for Herbst's (2008) notions that a task should be handled with a particular social group (for example, teachers and students) and that this group should be evaluated with a holistic view regarding behavior and communication styles.

Thus, mathematical tasks have central importance in student learning and thinking, as they provide students with the opportunity to think about the subject/subjects because they carry messages about what individuals/students dealing with mathematics are doing (NCTM, 1991), present information that can be organized mathematically to students, allow students to use their experience and knowledge (Van den Heuvel-Panhuizen, 2005), and provides content in which students will engage (Doyle, 1983). Additionally, different task types lead students to different ways of thinking (Doyle, 1983; Hiebert & Wearne, 1993). Since students can have authentic experiences with mathematics with the tasks set in the classroom environment (see Schonfeld, 1992), the tasks act as an important bridge between the classroom practices and

the student's learning process by determining the content in which the students will engage (Arbaugh & Brown, 2002) and can structure and influence students' thinking styles (Henningsen & Stein, 1997).

Tasks and Cognitive Demand Levels in Mathematics Textbooks

The cognitive domain refers to an understanding characterized by understanding (Grønmo, Lindquist, Arora & Mullis, 2015) and the ability to use mathematics effectively (Schoenfeld, 2004). Mathematics textbooks are an essential tool that affects students' cognitive learning success (Hadar, 2017; Polat, 2021). Thus, it is expected that the textbooks will include tasks for the development of student's cognitive processes beyond routine mathematical operations, and it is stated that only in this way it is possible to develop students' cognitive learning and thus enrich and deepen student learning (Hadar & Ruby, 2019). Schoenfeld (2004) drew attention to the importance of the cognitive domain in mathematics education and stated that the content-oriented approach in the textbooks should not be adhered to. He particularly emphasized the need to develop mathematical thinking skills for students, such as understanding and solving problems in different contexts, reasoning, making connections, and using other problem-solving strategies. Therefore, there is an intense emphasis on supporting teaching with different task types in mathematics education programs (see MEB, 2005; 2009).

The use and selection of tasks and task types to be used in mathematics lessons naturally require the cognitive demand levels of these tasks to be considered because cognitive demand shows the effort a student should spend to think about a problem (Candela, 2016). The cognitive demand level of a task expresses the type of cognitive processes required to complete the task (Doyle, 1988). Since learning outcomes are also related to the cognitive processes that enable students to perform the tasks they encounter in the classroom (Estrella, Zakaryan, Olfos, & Espinoza, 2020), the importance of cognitive processes increases even more. The cognitive processes expressed here are expressed at different levels, from memorization and implementing rules and algorithms to using complex thinking and reasoning strategies. In particular, when we consider the cognitive processes involved in mathematical tasks, it is seen that cognitive demand levels are categorized into two levels low and high cognitive demand (Candela, 2016; Henningsen & Stein, 1997). Tasks that require high-level cognitive demand require interpretation, involve more complex representations, use different methods and strategies, and encourage justification, discussion, and explanation.

Conversely, tasks requiring low-level cognitive demand include remembering information and directly applying previously learned algorithms or rules (Stein et al., 1996). Proposing an analysis framework for examining cognitive demand levels, Stein et al. (2000), on the other hand, subdivided high cognitive demand levels into procedures with connections (High-P) and doing math (High-P), and low cognitive demand levels as memorizing (Low-M) and procedures without connections (Low-P). Memorization includes remembering previously known rules, information, and definitions. In contrast, the level of operations not based on association requires algorithmic operations. While associative operations include conceptual understanding, mathematical relationships, and different representations, doing mathematics includes tasks with a complex structure and requires more cognitive effort (Stein et al., 2000).

Some Studies On Mathematical Tasks And Cognitive Demand Levels In Mathematics Textbooks

Studies on mathematical tasks and the cognitive demand levels are founded upon textbook analysis (Kwon & Kim, 2013; Park, 2011; Wijaya, Van den Heuvel-Panhuizen & Doorman, 2015) and classroom practices (Stein et al., 1996; Smith & Stein, 1998; Stylianides & Stylianides, 2008). Numerous studies examine the cognitive demand levels of mathematical tasks in international textbooks (for example, Barcelos Amaral & Hollebrands, 2017; Hadar &

Ruby, 2019; Hong & Choi, 2014; Hong & Kim, 2012; Maonga, 2020; Park, 2011). For example, Maonga (2020) examined the cognitive demand levels of the tasks on quadratic equations in Malawian mathematics textbooks and determined that the tasks in the books generally contain a low level of cognitive demand, while the tasks that require high cognitive demand are given little space. Similarly, in the study examining the cognitive demand levels of the tasks related to the function subject in the middle school mathematics textbook, it was determined that 95% of the tasks had a low demand level, and the rest had a high demand level (Hong & Kim, 2012). In a study conducted in the context of similarity in Brazilian and American mathematics textbooks, context-based tasks and cognitive demand levels of these tasks were examined. It was determined that context-based tasks were generally at a low cognitive demand level (Barcelos Amaral & Hollebrands, 2017).

On the other hand, a limited number of studies have been conducted in Turkish mathematics textbooks on mathematical tasks and on determining the cognitive demand levels of these tasks. In this context, for example, Karakuzu (2017) analyzed the tasks in the geometry domain in mathematics textbooks according to type (activity, solution example, problem), context, representation style, and cognitive demand levels and found that mathematical tasks are concentrated at the level of operations, not based on connection and operations based on connection. Sarpkaya (2011) compared the mathematical tasks of the algebra learning domain in middle school mathematics textbooks with the algebraic tasks applied by four middle school mathematics teachers in their classes regarding cognitive demands. It was determined that the tasks in the textbooks are generally tasks related to the connection. However, it has also been observed that teachers prefer tasks with low cognitive demand levels in their classroom practices. They typically use mathematical tasks not based on the connection in their lessons. Similarly, Özgeldi and Esen (2010) examined the cognitive levels of all the questions and activities in the lecture and evaluation sections of the middle school mathematics textbooks. They stated that the cognitive levels of the questions and activities in each section were low, and this level could not meet the cognitive level targeted in the curriculum.

Purpose and Importance of the Study

This study examines the cognitive demand levels of mathematical task types in the Grade 8 middle school mathematics textbooks according to 2005, 2009, 2013, and 2018 middle school mathematics curricula in Turkey in the algebra learning domain because although the standards and priorities of the countries in many areas change according to the rapid developments and needs of today, matters such as the purpose of the curriculum, how to teach in the classroom and what to teach the students, and so on, always maintain their priority and importance (Houang & Schmidt, 2008). Naturally, textbooks come to the fore as the potential implementation of curricula in the classroom (Reys et al., 2004; Valverde et al., 2002). Because textbooks are essential tools that connect the curriculum and the implementation of the curriculum (Richards, 2001; Tyson & Woodward, 1989), textbooks are expected to guide students' learning, provide opportunities, and make the aims and concepts of the curriculum more visible (Yerushalmy, 2014). Considering that curricula are a collection of academic tasks (Doyle, 1983) and provide students with the opportunity to deal with specific content and tasks (Houang & Schmidt, 2008) (mathematics), it is understood that textbooks also appear to have an essential function in terms of the tasks they contain (especially during curriculums that are updated in the process).

While textbook authors interpret the intended curriculum and affect what teachers can present and convey in their classrooms (Ball & Cohen, 1996), textbooks are one of the essential sources of inequality in the classroom (see Hadar & Ruby, 2019) because textbooks sometimes limit the extent to which the content and topics (especially mathematical tasks) will be considered and applied in the classroom (Polikoff, 2015). Therefore, the tasks in the

textbooks and determining the cognitive demand levels of these tasks come to the fore. Because considering that the mathematical tasks that students deal with reveal not only the basis of what they learn but also their ability to understand and use mathematics (Estrella et al., 2020), it is thought that the results of the current study may make an essential contribution to the relevant literature in this sense.

Within the scope of this study, it is essential to evaluate the cognitive demand levels of the mathematical tasks in Turkey's middle school mathematics curriculum and mathematics textbooks that have been updated four times since the 2000s. In this way, it will be possible to get an overview of these materials' mathematical tasks and cognitive demand levels. In this way, it is possible to compare the types of tasks (formulating, employing, and interpreting) and the cognitive demand levels of these tasks in international comparative exams such as TIMSS and PISA.

As mentioned earlier, considering the low scores that Turkish students get from high stake exams (see Mullis et al., 2020), it is essential to note that education policymakers, curriculum developers, and course providers should use such comparisons to increase student success. First, the current study will show whether the Turkish mathematics curriculum must be updated again. Second, the present study argues that it is important to determine whether the mathematics curriculum is updated correctly. Third, an efficient update in mathematics textbooks and teaching programs is likely related to having a balanced distribution of the cognitive demand status of mathematical tasks in mathematics textbooks. Thus, this study may serve as a role model for mathematics education researchers in countries worldwide to make such comparisons.

Since updates are regularly made in mathematics teaching programs to prevent low scores in international exams such as TIMSS and PISA (Mullis et al., 2020), it is important to comparatively investigate the level of the cognitive demand in questions in these exams with applications and tasks in textbooks. In this current study, the cognitive demand levels of the tasks in the domain of algebra learning in mathematics textbooks were examined by considering the nature of algebra, its place and importance in mathematics learning, different types of tasks, and the cognitive demand levels of these tasks. In this sense, it is thought that the current study can provide a different perspective to the related literature. These results will give a reasonable basis for other mathematics learning domains (for example, geometry and measurement). In this context, the current study sought to answer the following question:

What are the trends of the cognitive demand levels of the mathematical tasks in the algebra learning domain of the Grade 8 mathematics textbooks written according to the mathematics curriculum in Turkey (2005, 2009, 2013, and 2018)?

Method

Research Design

In this study, the qualitative research method of document analysis was used to investigate written materials containing information about the case(s) that are intended to be investigated (Yıldırım & Şimşek, 2008). In this regard, the cognitive demand levels of the mathematical tasks in the algebra learning domain in Turkish Grade 8 mathematics textbooks (2005, 2009, 2013, and 2018) and mathematics curricula were examined.

Data Collection Tools

The current study's findings relate only to the Grade 8 PISA and TIMSS exams in Turkey (taken by Grade 8 and Grade 9 students). Respective mathematics textbooks (only the implementation parts of the concept) of a large-scale study including the analysis of 16 grades 6-8 mathematics textbooks prepared according to the Middle School Mathematics Curriculum

updated by the Ministry of National Education in 2005, 2009, 2013, and 2018 are investigated. The criterion sampling method was used to select all textbooks that met a predetermined set of criteria in the research process (see Creswell, 2012). These criteria included: (i) the MEB (Ministry of National Education) must have approved the examined textbook, and it must be used in Turkey, and (ii) the textbook should be written according to at least one of the four mathematics curriculums. The textbooks examined in the study are presented in Table 1.

Table 1.

Mathematics Textbooks and Codes Examined Within the Scope of the Research

Mathematics Textbook Grade Level	Based Curriculum			
	2005	2009	2013	2018
	Publication Year and Code of the Textbook			
Grade 8	2008 (26117)	2012 (28206)	2014 (29496)	2019-1 2019-2

*The codes of the books examined in the study in the MEB-TTKB library are given in parentheses.

Data Analysis and Process

The data were analyzed with the content analysis method. Content analysis is one of the analysis methods used to obtain results from the qualitative data examined in the research. In content analysis, the aim is to reach concepts and relationships that can explain the collected data (Yıldırım & Şimşek, 2008). In this context, in this study, the analysis process of the Grade 8 mathematics textbooks (for the algebra learning domain) consisted of three stages (see Figure 1). Brief information about these stages is below:

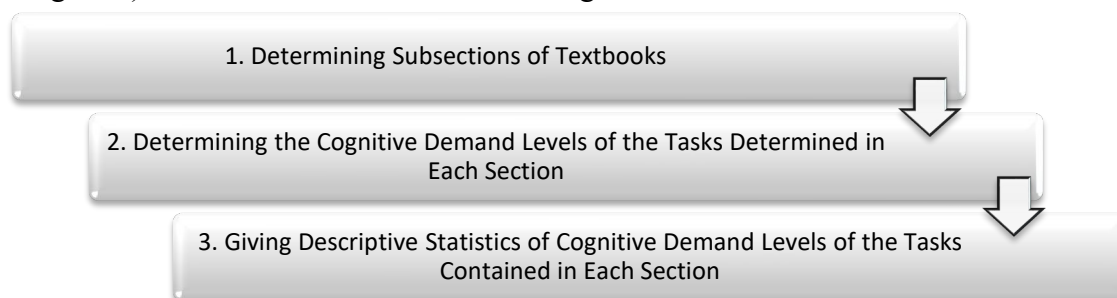


Figure 1. Stages of the analysis process

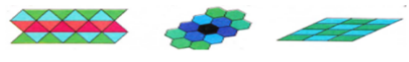
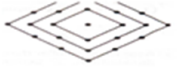
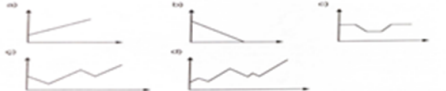
Determining subsections of textbooks. Determining the subsections of the textbooks, which is the first stage of the analysis process, included dividing the textbooks into analysis units. Textbooks were divided into two main sections: the presentation and implementation of the concept. The presentation of the concept detailed descriptions of the relevant topics, mathematical tasks (question, problem, activity), solved examples, and similar questions necessary for the subject narration were included. In implementing the concept, questions, unsolved examples, etc., were used to reinforce the learning of the subject described in the presentation of the concept. The implementation contained similar or different questions to measure the learning of the concept being taught.

In the current study, only the implementation of the concept was analyzed, as it is more comprehensive, and the tasks involved different levels of cognitive demand. From another perspective, the questions that students engaged in one-on-one immediately after the lecture on a topic were included. In addition, the questions that students were expected to solve after presenting more than one topic were included. The cognitive levels of mathematical tasks in textbooks were examined to answer the question. The implementation of the concept was

examined under three sub-titles (attainments questions, chapter questions, and end-unit questions) according to the locations of the questions in the book. Attention questions covered unsolved questions given after narrating a topic (e.g., patterns, exponential numbers). Chapter questions covered unsolved questions about related topics given after presenting more than one topic (e.g., patterns, equations, exponential numbers). Finally, end-unit questions covered unresolved questions about related topics after narrating too many topics in the unit. Some sample questions and descriptions regarding implementing the concept and its sub-titles are summarized in Table 2.

Table 2.

Description of the Implementation of the Concept Sections of the Textbooks

Section	Sub-section	Description	Sample
Attainments Questions		Tasks that lead students to interpret and use expressions and information about mathematical concepts about a topic given in the lecture section.	<u>Implementation...</u> 1. Write the properties of the polygons that make up the following patterns.  2. Determine the relationships in the patterns created with similar or equal polygons below. Draw 5 more shapes that continue the pattern.  3. Continuing the following patterns, decipher the relationship between the pattern model and the number of equal frames. 
			1. Express verbally the rule of the pattern given on the below. Find the number of points in the tenth step of the pattern.  2. The advertising revenue of a professional basketball player is 10 times the salary he receives from playing basketball. If the advertising revenue is 100,000 TL, how much is his salary? 3. Solve the following equations using the appropriate models. a) $x+5=9$ b) $a-3=2$ c) $2a+1=7$ ç) $3m-4=8$ d) $5k=10$ 4. Write the bases and Powers of the following exponential number. a) 8^3 b) 3^{10} c) 20^{10} d) 1999^{2000}
Chapter Questions		The lecture sections included tasks for students to interpret, use, and solve mathematical concepts, expressions, and information on multiple subjects.	<u>Unit Evaluation</u> 1. Write the simplest equivalent value of the following algebraic expressions. a) $2+3(x-4)+8x$ b) $a(2a+3)-2(2a^2+3)$ 2. $\frac{10}{3} \times \left(3 - \frac{6}{5}\right)$ which of the following is the result of the operation? A) 3 B) 4 C) 5 D) 6 3. Check out the graphs below. Determine which graph or graphs show a linear relationship.  4. 18^3 find the result of this expression using a calculator.
			Tasks measure whether the mathematical concepts in the whole unit are understood and whose solutions are left to the students to interpret and use expressions and information about mathematical concepts.

Determining cognitive demand levels of determined mathematical tasks. The cognitive demand levels of the tasks in applying the concept parts of the textbooks were analyzed using the cognitive demand levels framework created by Stein and Smith (1998) and later updated by Stein et al. (2000). The algebraic tasks determined in the context of this framework were divided into codes as memorization (Low-M), procedures without connections (Low-P), procedures with connections (High-P), and doing mathematics (High-M) according to cognitive demand levels. In this context, the cognitive demand levels, the codes of these levels, and some examples from the textbooks are presented in Table 3.

Table 3.
Analysis Framework of Cognitive Demand Levels

	<i>Low-Level Demand Code</i>	<i>Sample of Algebraic Tasks</i>	<i>Description</i>
Memorization Level (Low- M),	<u>1.1. Recalling previously learned information, rules, formulas, or definitions</u> <u>1.2. Not using a method or operation because it does not require a process or operation to be applied during the resolution phase</u> <u>1.3. Repetition of previously learned information, rules, formulas, or definitions. It is clear what is wanted to be done and what will be created with the knowledge that needs to be remembered and repeated, and there is no uncertainty here</u> <u>1.4. no situation requires connecting with the underlying meanings of information, rules, formulas, or definitions that must be remembered and repeated.</u>	Which of the following is the constant term of $2a^2 + 3ab^2$? A) 0 B) 2 C) 3 D) 5	Constant term information is remembered. It does not require a method to be applied in the solution phase.
Procedure Without Connections Level (Low-P),	<u>2.1. Containing algorithmic operations. There is an operation that must be applied in the solution process. Specifying the use of the operation, understanding from previous teaching and practice, or the task's location.</u> <u>2.2. Limited cognitive thinking is required to complete the task.</u> <u>2.3. There is a little uncertainty about what is wanted to be done or how to do it.</u> <u>2.4. Focusing on finding the correct answer by applying definitions and operations rather than improving mathematical understanding and thinking.</u>	$\frac{73^2 - 27^2}{25^2 - 21^2}$ What is the result of the operation? A) 75 B) 50 C) 40 D) 25	There is an operation that must be applied in the solution process. It contains minor uncertainties about what is wanted or how to do it.
	<i>High-Level Demand Code</i>		
Procedures With Connections Level (High- P),	<u>3.1. Allowing a deep understanding of mathematical concepts and ideas</u> <u>3.2. Suggesting hidden or explicit ways to follow general operations that make connections with conceptual ideas</u> <u>3.3. Using multiple representations (diagram, graphic, manipulative, symbols, algebraic, etc.) and establishing connections between these different representations</u> <u>3.4. Directing cognitive effort to identify conceptual ideas and underlying causes</u>	Write the appropriate inequality for the expression "The number of people getting into an elevator should be no more than 5".	It envisages using multiple representations (diagram, graphic, manipulative, symbols, algebraic, etc.) and establishing relationships between these different representations. Requires cognitive effort...
Doing Mathematics Level (High- M)	<u>4.1. Complex situations that cannot be solved by algorithms, without clear guidelines, and their consideration</u> <u>4.2. Understanding the nature of mathematical concepts, processes, or relationships</u> <u>4.3. Including self-management and self-regulation</u> <u>4.4. Accessing valid and relevant knowledge and using it throughout tasks (research project)</u> <u>4.5. Analyzing tasks, examining limitations (deficiencies) in a given task to include possible solutions and strategies</u> <u>4.6. Requires extra cognitive effort</u> <u>4.7. Causing mental confusion and anxiety in students because the structure of the solution process includes unpredictable methods and ways.</u>	Let usexamine the terms of the number pattern given as "1, 4, 9, 16..." and find the rule of the pattern.	It includes understanding mathematical concepts and the nature of processes or relationships. It requires more cognitive effort than necessary. Here, beyond discovering the relationship between the terms in the pattern, the mathematical expression of this situation and finding the general rule is a high-level process.

Giving descriptive statistics of cognitive demand levels of task types contained in each section. In the last stage of the analysis process, after determining the cognitive demand level at which the tasks in each chapter can come out, first, the ratios of cognitive demand levels of the tasks of the implementation of the concept (attainments, chapter, and end-unit questions) of the grade 8 mathematics textbooks written according to each curriculum were calculated. (e.g., the ratio of tasks at the memorization level in the attainments questions section of the grade 8 mathematics textbook written according to the 2005 curriculum was 7%). Afterward, the tendency of the cognitive demand levels of the tasks included in applying the concept subsections of the mathematics textbooks written according to the curriculum is presented (see Table 4). Finally, the tasks in the 8th-grade levels were examined separately in graphics for the subsections of applying the concept in the textbooks.

Sample Coding

In this section, an example of the coding process for a task in the Algebra Learning Domain of the Grade 8 textbooks taught by the MEB in 2008 is given below:

Write the algebraic expressions modeled below and their multipliers.

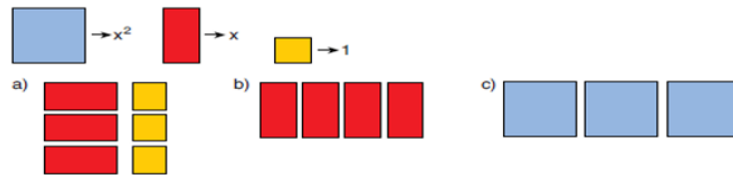


Figure 2. An example of the coding process

When the task is examined, it is understood that it is a sub-task containing more than one task as a, b, c. This mathematical task is a task in textbooks to measure whether students know the relationship between the subject of algebra and the subject of factorization. The task requires expressing algebraically the models given in each option and finding their multipliers. The task is coded as three separate tasks, requiring an answer for each option. Here, while determining the cognitive demand level of this mathematical task, the analysis framework given in Table 3 was used. For example, during the analysis, it was not considered a Memorization Level (Low-M) and Procedure Without Connections Level (Low-P) since it does not require remembering information in the question or applying a known algorithm directly. On the other hand, the task was coded as the level of operations based on connections (H-P) because it “requires algebraic restatement of models, the use of multiple representations (diagram, graphic, manipulative, symbols, algebraic, etc.) and the establishment of relations between these different representations.” As a result, the task was evaluated as containing three tasks at the level of operations based on connections (H-P).

Trustworthiness of the Study

To increase the trustworthiness of this study, thick descriptions, various data sources, and peer evaluations were used. Within the scope of thick description (see Creswell, 2012), the examples of tasks in the textbooks are given directly in the study. In the study, the coding process of the cognitive demand levels of the task types in the algebra learning domain of the textbooks was carried out in two stages. In the first stage, researchers independently coded the tasks while determining the task types according to the task analysis framework they created during the process. Next, the researchers reviewed their independent coding together and sought a consensus among them in different coding situations. In addition, 15% of the tasks

(see Macnealy, 1999) were sent to 3 researchers with doctorate degrees in mathematics education, and they were asked to code them by stating the types of tasks with their descriptions. In the second stage, the researchers determined the cognitive demand levels of the tasks in the Grade 8 mathematics textbooks (according to the framework in Table 3). Then, determining the types mentioned above mathematical tasks was followed here. At the end of this coding process, it was determined that it was done reliably (agreement-correlation coefficients, 82%, 88%, and 81%, respectively) (see Miles & Huberman, 2015).

Findings

This section examined the findings on the general trend of cognitive demand levels of mathematical tasks in the algebra learning domain in applying the concept sections of the Grade 8 mathematics textbooks (5 textbooks in total) written according to the mathematics curriculum.

Trends of Cognitive Demand Levels of Mathematical Tasks

Table 4 shows the trend of cognitive demand levels of mathematical tasks in applying the concept (attainments, chapter, and end-unit questions) in the Grade 8 mathematics textbooks according to 2005, 2009, 2013, and 2018 curricula.

Table 4.

Trends of cognitive demand levels of mathematical tasks in applying the concept section according to the curricula

Cognitive Demand Level	Applying the Concept											
	Attainment Questions				Chapter Questions				End of Unit Questions			
	2005	2009	2013	2018	2005	2009	2013	2018	2005	2009	2013	2018
L-M	7	7	3	6	4	4	0	0	2	2	0	5
L-P	62	62	65	61	60	60	0	0	60	60	55	68
H-P	24	24	27	31	32	32	0	0	25	25	45	25
H-M	7	7	5	2	4	4	0	0	13	13	0	2

Low-demand level tasks predominate in almost all parts of the application of the concept. It has been determined that in the Grade 8 textbooks written according to all curricula, the tasks at the Procedures without connections (Low-P) level are in the majority. Secondly, it has been determined that the tasks are intense at the level of Procedures with connections (High-P). Finally, in applying the concept section, it is noteworthy that the tasks at the cognitive demand level of doing mathematics are in third or last place. The tasks in each section of applying the concept in the textbooks below are examined through graphs regarding trends in cognitive demand situations.

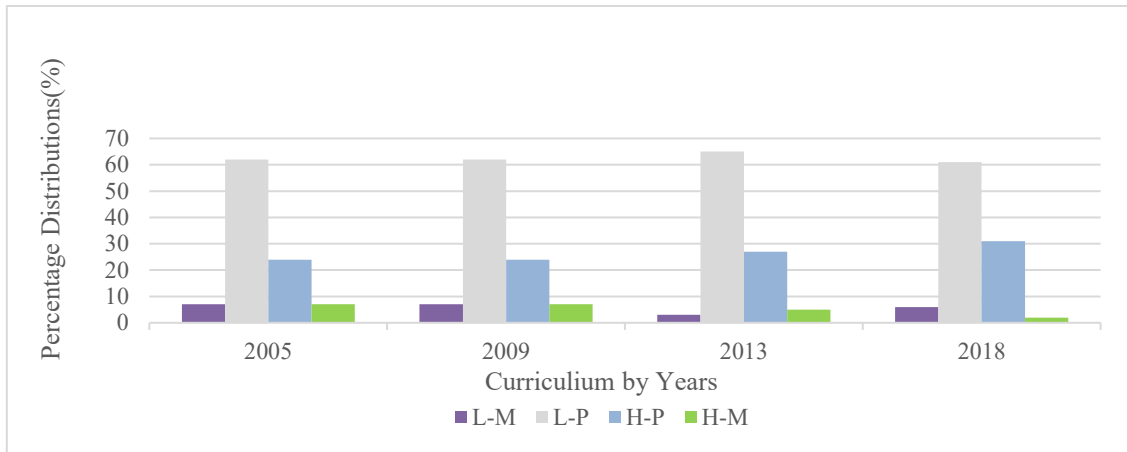


Figure 3. The percentages of the tasks in the attainments questions section of the Grade 8 textbooks in terms of cognitive demand levels in the curriculum.

In Figure 3, the percentage of the total tasks in the attainments questions section in mathematics textbooks is written according to the curriculum in terms of cognitive demand levels. Low-demand level tasks predominate in all curricula. It has been determined that the tasks at the procedures without connections (Low-P) level are intense in all curricula. Secondly, it has been determined that tasks are predominantly included in the level of procedures with connections (High-P). Parallel to this, it is seen that tasks at the level of procedures with connections (High-P) are included in the curriculum at increasing rates (24%, 24%, 27%, and 31%, respectively) after 2009. Remarkably, the rate of memorization level (Low-M) task type included in the achievement questions section of the textbooks in the 2005-2018 period was between 3% and 7%. Similarly, it was determined that the doing math (High-M) task type had a decrease in the rate of taking part in the 2005-2018 process (7%, 7%, 5%, and 2%, respectively) and the lowest rate (2%) was found in the 2018 curriculum.

The graphic below examines the tasks' status in the chapter questions section in the curriculum according to the cognitive demand levels.

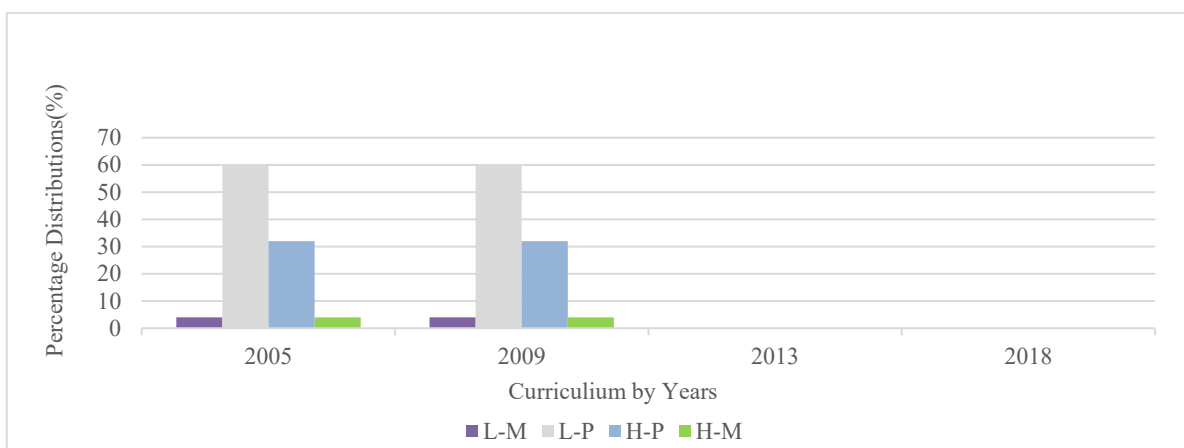


Figure 4. The percentages of the total tasks included in the attainments questions section of the Grade 8 textbooks regarding cognitive demand levels in the curriculum.

Figure 4 shows the percentage of the total tasks included in the chapter questions section of the Grade 8 mathematics textbooks regarding cognitive demand levels in the curriculum. In the 2005 and 2009 curricula, it was determined that the tasks at the low operational level were dense (60%). Still, a significant proportion of the high operational level tasks were also included (36%). It was determined that the tasks at the level of memorization (L-M) and the level of doing mathematics (H-M) were included in the curriculum at an equal and low rate (4%). Another remarkable finding is that the attainment questions sections are not included in the 2013 and 2018 curricula.

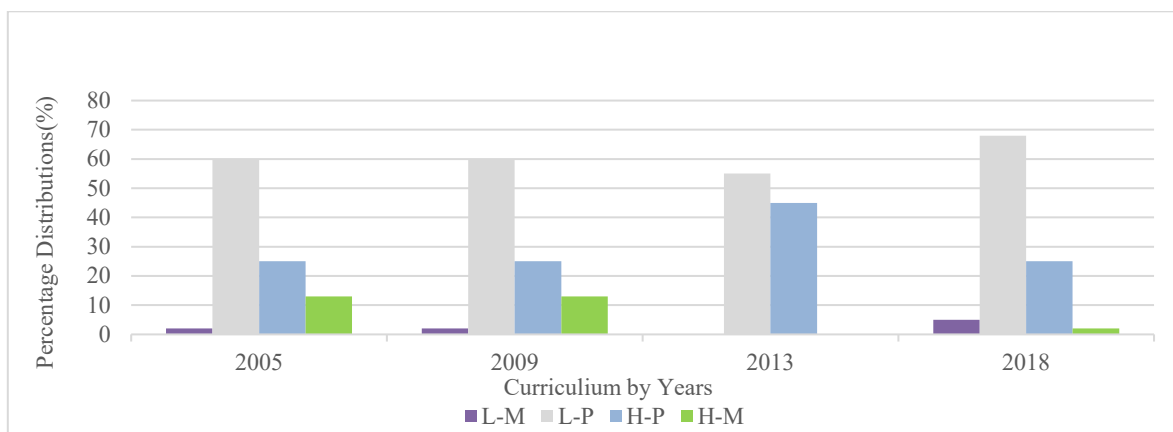


Figure 5. The percentages of the total tasks included in the end-unit questions section of the Grade 8 textbooks regarding cognitive demand levels in the curriculum.

In Figure 5, the percentage of the total tasks included in the end-unit questions section in the curriculum in terms of cognitive demand levels is given. It can be said that low-level tasks predominate in all curriculums (62%, 62%, 55%, and 73%, respectively). Secondly, at the level of procedures with connections (High-P), it was determined that the tasks were intense (25%, 25%, 45%, and 25%, respectively). Notably, the ratio of task types decreased (60%, 60%, 55%, and 68%, respectively) at the level of procedures without connections (Low-P) during the 2009-2013 period, but it followed an increasing trend after 2013. In the 2018 curriculum, it is seen that the rate of tasks with low demand levels increased (73%), while tasks with high demand levels took place at low rates (27%). It was determined that the tasks at the memorization level (L-M) were not included in the 2013 curriculum, while they were included at low rates (2%, 2%, 5%, respectively) in other curriculums. On the other hand, at the level of procedures with connections (High- P), it is seen that tasks are stable in the 2005-2009 period, increasing in the 2009-2013 transition period and decreasing in the 2013-2020 interval. It has been determined that the ratio of doing mathematics (H-M) tasks is not included in the 2013 curriculums, the highest rate (13%) in the 2005 and 2009 curriculums, and the low rate (2%) in the 2018 curriculum.

Discussion

In this study, cognitive demand states of the tasks in the algebra sub-learning domain were examined by applying the concept sections of the Grade 8 mathematics textbooks written according to the updated mathematics curriculum in Turkey in 2005, 2009, 2013, and 2018.

When the total tasks in the attainment questions section of the Grade 8 mathematics textbooks written according to the curriculum were examined in terms of cognitive demand levels, it was determined that the tasks with low demand levels (69%, 69%, 68%, and 67%, respectively) predominated. Considering the low scores that Turkish students have taken in

international exams such as TIMSS and PISA (Mullis et al., 2020) and the prevention of falling behind the needs of the age (TTKB, 2004), it can be seen that it is not given importance to include questions about the level of these exams, which have questions at the high cognitive demand level, in the application parts of the textbooks. Notably, the tasks at the level of procedures without connections (Low-P) after 2005 are decreasing at the highest rates. Parallel to this, it is seen that tasks at the level of procedures with connections (High-P) are included in the curriculum at increasing rates. The rate of tasks at this cognitive demand level has been increasing since 2009, but this rate is far behind the rate of tasks at a low demand level. On the other hand, it was determined that doing mathematics (H-M) task type decreased in the rate of being included in the attainment questions section of the textbooks during the 2005-2018 period, it was not included in the 2005 curriculum, and it took place at the lowest rate (2%) in the 2018 curriculum.

When the total tasks in the section questions section of the Grade 8 mathematics textbooks written according to the curriculum were examined in terms of cognitive demand levels, it was found that the tasks at the low operational level in the 2005 and 2009 curriculums were dense (60%). This may indicate that similar tasks are included in the lecture parts. It was determined that the memorization level (L-M) and the level of doing mathematics (H-M) tasks were included in the textbooks written according to the curriculum at an equal and low rate (4%). Therefore, considering that there are tasks related to more than one subject in the lecture sections of the chapter questions, there are fewer tasks at the level of doing mathematics on different topics in the textbooks. On the other hand, it is remarkable that most of the Grade 8 textbooks do not include section questions. This is because the textbook authors have the question/sample task type left to the students to solve in the lecture parts. On the other hand, it may be due to the thought that the end-of-unit questions may be sufficient.

When the cognitive demand levels of the total tasks in the end-of-unit questions section of the Grade 8 textbooks written according to the curriculum are evaluated, it can be said that low demand level tasks predominate in all curriculums (62%, 62%, 55%, and 73%, respectively). Considering that international exams such as PISA focus not only on what students learn and remember but also on determining the level of using what they have learned in life, solving problems in new situations, estimating, and reasoning (MEB, 2010), it is considered that the textbooks should include questions with a high cognitive demand level to support student's success in these exams. On the other hand, it is surprising that the textbooks are created with a low demand level task weight, despite high demand level attainments being more involved. In the literature, a similar situation is similar to the fact that the cognitive demand levels of the tasks are reduced in the classroom environment and used in practice (Henningsen & Stein, 1997; Wilhelm, 2014). On the other hand, considering that the exercises have a critical role in mathematics education (Sullivan, Clarke, & Clarke, 2013), it is more important to examine the structure and cognitive demand of these exercises and to have rich content (Glasnovic Gracin, 2018).

The fact that the curriculum other than the 2018 curriculum consists of low-level tasks may be related to the high school entrance exam applied in these periods. When different national exam questions are considered from different perspectives in terms of their levels, it is seen that they mostly contain less high-level questions (Güler, Özdemir & Dikici, 2012; Yakacı, 2016). In the 2005-2013 period, the ratio of task types at the level of procedures without connections (Low-P) decreased slightly but followed a course within a certain range (60%, 60%, 55%, and 68%, respectively).

In the 2018 curriculum, it is seen that the rate of tasks with low demand levels increased (73%), while tasks with high demand levels took place at low rates (27%). Here, it cannot be said that this situation parallels the distribution of LGS (high-school entrance exam) questions

in force in 2018. Indeed, when LGS mathematics questions were examined in terms of mathematical competence, the questions were distributed between procedural fluency (10%), conceptual understanding (25%), strategic competence (30%), and logical thinking (35%) competence levels. Conceptual understanding and logical thinking from the mathematical competence components took place predominantly in the levels (Dönmez & Dede, 2020). Thus, mathematics textbooks written according to the 2018 curriculum were influenced by the previous exam, and the changes in the question formats in our national exams in recent years after the 2018 curriculum did not occur.

It was determined that tasks at the memorization level (L—M) were not included in the 2013 curriculum, while included in other curricula at low rates (2%-5%). Although there are no attainments at this cognitive demand level (Polat & Dede, 2022), it is an example of the textbook authors acting outside the structure of the acquisitions when they are included in the course books.

While tasks at the doing mathematics level (H-M) are not included in the 2013 curriculum, they are at the highest and equal rate (13%) in the 2005 and 2009 curricula and the low rate (2%) in the 2018 curriculum. Considering that 20% of the question items in the international TIMSS exam aim to measure reasoning skills (TIMSS, 2015), the fact that Grade 8 mathematics textbooks do not include tasks at the level of cognitive demand to do mathematics towards the present may indicate that there is a critical deficiency in terms of the preparation of our students for international exams.

Considering that the aim of the current study is not to determine which tasks are good or not, it may be useful to emphasize that the tasks that reveal or do not reveal mathematical thinking should be included in the textbooks in line with the attainments and include all cognitive demands, considering the cognitive differences. This becomes even more important when considering that the cognitive demand levels of different textbooks interpreting the same curriculum presents an additional potential source of inequality arising from the choice of the textbook (Hadar & Ruby, 2019).

Turkish students in the PISA exam ranked 45th among 64 countries with an average of 420 in 2015 and 42nd in 2018 with a score of 454, remaining below the international average in all these exams (Suna, Tanberkan, Taş, Eroğlu & Altun, 2018; Taş, Beekeeper, Ozarkan & Freedom, 2016). In this context, it may be beneficial to include tasks with different levels of cognitive demand (incredibly high cognitive demand) in mathematics teaching environments and processes and textbooks to increase the mathematics achievement of Turkish students in such comparative exams (see Vincent & Stacey, 2008).

Further Research and Limitations

With the awareness that textbooks reflect the curriculum, authors may be expected to know that textbooks should reflect the curriculum realistically in their internal structures, apart from their formal features, and write textbooks under these conditions. It may be thought that raising the awareness of textbook authors about the need to include tasks at different cognitive demand levels in the application parts of the books will make a critical contribution to creating textbooks that reflect student-centered curriculums.

This study is limited only to the algebra learning domain and the application of the concept. Therefore, further research on other learning domains or other parts of the books (introduction to the subject, presentation of the concept...) may help obtain more detailed data.

Textbook authors may be made aware that the acquisition of mathematical thinking and process skills depends on keeping students busy with different task types so that the task types at various levels should be balanced rather than one or two cognitive demand-level task types in the textbooks. Textbook authors should be informed about what kind of process they

should follow while creating the inner sections of the books, which sections (outcome questions, section questions...) should be included, the creation of textbooks with all internal sections, and the principle of equality in education.

Finally, writing the cognitive demand levels of the tasks in applying the concept sections of the mathematics textbooks by the task types in international exams such as PISA may be helpful. In this way, students can become familiar with high-level cognitive demand questions and deal with them, increasing their mathematics achievement.

Future research might reveal the current status of the cognitive demand levels of the tasks in learning algebra in Turkish primary and high school mathematics textbooks. In this way, it is possible to make a good comparison with the results of the present study, and the general trends of the cognitive demand levels of the tasks in the Turkish mathematics textbooks according to the education levels (primary-high school) may be revealed. This situation may offer mathematics curriculum preparers and textbook authors a good perspective.

Acknowledgment

This study was produced from the first author's doctoral thesis under the supervision of the second author.

Disclosure Statement

No potential conflict of interest was reported by the author(s).

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