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Cognitive demands in Indonesian elementary school mathematics textbook: textbook research on geometrical tasks

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Abstract (12-point, bold)

Examples and exercises in mathematics textbooks have an important role in directing teaching and learning to achieve the objectives of the mathematics curriculum. This study examines mathematical tasks, i.e., examples and exercises, for grade 4 elementary school mathematics textbooks published by the Indonesian Government in 2018. We focus on geometry tasks and categorize them based on the dimensions of cognitive processes and knowledge of the revised Bloom's taxonomy. Textbook research is used to achieve the objectives of this study. The validity of the data was carried out by employing peer debriefing. The findings of this study indicate that only about 30% of the number of geometry tasks in this mathematics textbook require high-level mathematical thinking skills. This study also shows that procedural knowledge is more dominant and becomes an orientation in presenting geometry tasks. This finding becomes less relevant to the orientation of researchers and policymakers who want the direction of mathematics education to be forming students as problem solvers.

Keywords: Bloom Taxonomy; Elementary School; Geometrical Task; Mathematics Textbook; Textbook Research

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Introduction

Mathematics textbooks are descriptions of teaching materials in mathematics subjects that students and teachers use as a guide in carrying out the mathematics learning process, arranged systematically, and selected based on the objectives and achievements of learning mathematics (Muslich, 2010; Ramadhani, 2020). Mathematics textbooks must also be compiled and adapted to the applicable curriculum (Fan, 2013) and have great potential in determining the teaching and learning process in the classroom (Aldahmash et al., 2016; Fan et al., 2013; Wijaya et al., 2015).

Once the role of textbooks is so important, it is natural that textbooks have experienced increased attention in mathematics education research in the past two decades (Fan, 2013; Trouche & Fan, 2018). More than that, textbooks are important to explore, in addition to finding the best formula for how the learning objectives or curriculum are achieved, but also used to streamline the role of the textbooks themselves because most teachers still rely on mathematics textbooks to carry out mathematics learning in the classroom either in planning, process, and evaluation (Kilpatrick et al., 2001; Purnomo et al., 2016; Sugiatno & Husna, 2020).

One of the important parts of mathematics textbooks and the focus of attention in conducting textbook research is examples and exercises (Bingolbali, 2020; Gracin, 2018; Purnomo et al., 2019). These sections are usually but are not limited to, used to practice skills, increase engagement, and as evaluation tools.

In solving problems in mathematics textbooks, of course, there are cognitive demands. One of the references often used as the basis for preparing questions is Bloom's taxonomy (Johar et al., 2017; Kul et al., 2018). This taxonomy is divided into two dimensions: the dimensions of cognitive processes and the dimensions of knowledge. Dimensions of cognitive processes are activities carried out such as remembering (C1), understanding (C2), applying (C3), analyzing (C4), assessing (C5), and creating (C6) to achieve goals. Second, the dimension of knowledge is the type of knowledge that is learned, such as knowledge of facts, concepts, principles, procedures, and metacognition (Anderson & Krathwohl, 2001). We focus on these two frameworks to identify textbooks and focus on one of the materials, namely Geometry tasks in grade 4 elementary school.

Some empirical evidence shows that geometry is one of the topics in mathematics that is challenging (Annizar et al., 2020; Pramudiani et al., 2017) and rarely becomes the focus of research (Chang & Silalahi, 2017), especially in textbook research (Purnomo et al., 2019). In contrast, geometry is one of the basic competencies in the curriculum for every basic education level. Therefore, this study aims to analyze the 4th-grade elementary school mathematics textbooks on geometry based on cognitive processes and knowledge in examples and exercises.

Methods

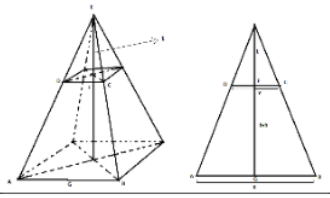
This research is a qualitative type of research that uses content analysis techniques. Leedy and Ormrod (2015) state that content analysis is a systematic and in-depth examination of the content of a particular material to identify patterns, themes, and biases. Because the focus is on textbooks, we are more comfortable using the term textbook research for this study (Fan, 2013; Fan et al., 2013; Purnomo et al., 2019; Rahmawati et al., 2020). The analysis chosen is to analyze one textbook with one specific topic, namely plane geometry. The object of the textbook that is analyzed is a mathematical task that includes worked examples and exercises.

We analyzed one mathematics textbook for grade 4 elementary school with curriculum 2013 revision (latest curriculum). This textbook is an electronic school textbook published by the Government, namely the Book Center of the Ministry of Education and Culture of the Republic of Indonesia. Electronic school textbooks are one of the Indonesian Government's programs launched in 2008 to provide quality, inexpensive, affordable schoolbooks that meet national standards. All copyrights for electronic school textbooks are purchased by the Government and can be downloaded for free in Portable Document Format (PDF) on the https://bse.learning.kemdikbud.go.id/ site. The textbook was chosen because it has been provided by the Government as a guide in learning mathematics and has become the main reference in learning mathematics in schools in Indonesia.

Textbook analysis was carried out by referring to the framework of the revised edition of Bloom's taxonomy (Anderson & Krathwohl, 2001). In the Bloom's revised taxonomy, there are two dimensions of the framework, namely the dimensions of cognitive processes and knowledge. The classification and coding for each level in the two dimensions and the respective examples are displayed in Table 1 (Anderson & Krathwohl, 2001; Kul et al., 2018).

Table 1. Coding for frameworks in the revised Bloom's Taxonomy

Level	Description	Example	Code
Dimensions of Cognitive Process			
Level 1 (Remembering)	Retrieve relevant knowledge from memory (remembering, recognizing)	How many sides and angles does a pentagon have?	C1
Level 2 (Understanding)	Building meaning from the learning process, including oral, written, drawing communication (interpreting, exemplifying, summarizing)	What are the characteristics of a square?	C2
Level 3 (Applying)	In the situation at hand, do or employ the procedure (using, carrying out, implementing).	What is the area of the square if the side length is 4 cm?	C3
Level 4 (Analyzing)	Break down a substance into its component elements and figure out how they connect	The price of a pencil package containing 12 pencils is IDR 20,000. Suppose John has IDR	C4

		to one another and to a larger structure or purpose (organizing, sorting, grouping, rearranging).	50,000 and wants to buy 24 pencils. How many packages should he buy?	
Level (Evaluating)	5	Make judgments/assessments based on criteria and standards (checking, judging, critiquing)	What are the possible ways to multiply two integers to get 60?	C5
Level (Creating)	6	Combine parts to make a logical or functioning whole: element reorganization into a new pattern or structure (hypothesizing, designing, producing).	How to find the volume of the following pyramid frustum? 	C6
Knowledge Dimension				
Factual Knowledge		The knowledge contains the basic elements that students must master if they are to be introduced to a discipline or solve any problem.	Please fill in the blanks below. • A quadrilateral has … interior angles. • A triangle has three … and ….	K1
Conceptual Knowledge		The knowledge that is able to make connections between basic elements that form a broader structure and perform functions together.	In which of the following cases, a triangle cannot be drawn? A. $\|BC\| = 7$ cm, $m\angle B = 64^0$, $m\angle C = 78^0$ B. $\|DF\| = 7$ cm, $\|EF\| = 9$ cm, $m\angle F = 90^0$ C. $m\angle A = 56^0$, $m\angle B = 38^0$, $m\angle C = 86^0$ D. $\|LM\| = 14$ cm, $\|KL\| = 10$ cm, $\|KM\| = 9$ cm	K2
Procedural Knowledge		Knowledge of how to do things, methods of inquiry, and criteria for using skills, algorithms, techniques, and methods to solve new problems.	The table below indicates that the four companies sell the same types of products in varying amounts, and discounts are applied to these prices. Which product, according to the table, is the best to buy? Discuss your choice with your friends.	K3

Company	Quantity (kg)	Sales
A	5	7.000
B	8	11.000
C	12	14.000
D	15	24.000

Metacognitive Knowledge	Knowledge of cognition in general as well as awareness of their own cognition.	Based on the number pattern 7, 12, 17, 22, … a) Create a model of this pattern and discuss it. b) Use the pattern rule's "number of representatives" to express yourself. c) Determine the pattern's 48th step.	K4

Table 1 shows that there are six levels of cognitive dimensions as well as four dimensions of knowledge. Each category is given a code, namely C1, C2, C3, C4, C5, C6 for the cognitive dimension and K1, K2, K3, K4 for the knowledge dimension. Each mathematical task is categorized based on the appropriate coding in the two dimensions.

The validity of the data was carried out by employing peer debriefing, namely the third, fourth, and fifth authors analyzed each textbook object and coded them according to the agreed categories. The results of the coding are cross-checked with each other and discussed to equalize perceptions. The analysis was continued by conducting focus group discussions for all researchers. The stage began with the presentation of the results of the previous analysis. Then, other researchers checked randomly, especially on unique cases, and included those doubtful from the previous analysis. The agreement from the discussion results is used as the basis for research findings. The analysis results are presented in a pie chart and show the percentage for each category.

Results and Discussion

Textbook Overview

The mathematics textbook that we studied consists of 216 pages and includes 6 (six) chapters, namely fractions, HCF (Highest Common Factor) & LCM (Least Common Multiple), approximations, plane figures, statistics, and angle measurement. Thus, there is one chapter that includes geometry, namely shapes which are in chapter 4. Chapter 4 is divided into 4 (four) subchapters, namely polygons, the perimeter of shapes, the area of shapes, and relationships between lines. The sub-materials are allocated as many as 54 pages (25%).

In the shapes chapter, there are 144 mathematical tasks (30.25%) of the total number in the textbook, which is 476 items. The items referred to here are worked examples and exercises. Many items are counted down to each sub item, for example, number 1 has sub a, b, and c, then three tasks will be counted (1a, 1b, 1c). However, the researchers also consider whether each of the sub-items influences each other, so it is counted as one item. From many mathematical tasks and the allocation of pages for the topic of geometry in this book, it shows that there is an emphasis that geometry material is quite essential material in the fourth-grade Elementary School Mathematics subject.

Cognitive Demands on Geometrical Tasks

In this section, the researchers present the results of the analysis of a combination of examples and exercises contained in the textbook. The task analysis results based on the cognitive process dimensions of Bloom's taxonomy in 4th-grade mathematics textbooks are presented in Figure 1.

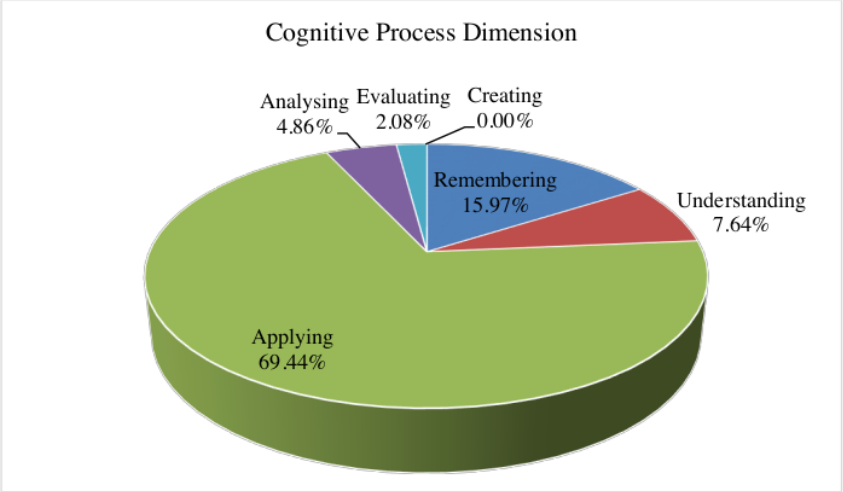


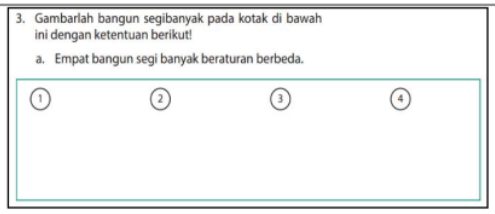
Figure 1. Task categories based on the Cognitive Process Dimension

Based on Figure 1, the most significant percentage of cognitive demands in the textbook is level applying, which is getting a portion of 69.44%. This percentage of more than 50% indicates that the distribution for variations in cognitive processes on geometrical tasks is still not varied, in which the task categories classified as C4, C5, and C6 only received a portion of 4.86%, 2.08%, and 0%, respectively. In other words, the demands of cognitive processes in this textbook, especially for the geometry task, are more oriented to lower-order thinking skills. Except for level 6, the following are sample tasks for each of the cognitive processing dimensions identified in the mathematics textbook.

Table 2. Sample tasks in each cognitive process dimension

Categories	**Sample task in the mathematics textbook**
Remembering	2. Berilah nama pada jenis garis berikut! a. D C b. X Y c. V W (p.147) *Translate:* *Name the following line types!*

Understanding


3. Gambarlah bangun segibanyak pada kotak di bawah ini dengan ketentuan berikut!
a. Empat bangun segi banyak beraturan berbeda.
① ② ③ ④

(p.111)

Translate:
3. Draw a polygon in the box below with the following conditions!
a. Four different regular polygons

Applying

7. Sebuah persegi panjang mempunyai panjang 15 cm dan lebar 10 cm. Hitunglah keliling dan luas persegi panjang!

(p.155)

Translate:
A rectangle has a length of 15 cm and a width of 10 cm. Find the perimeter and area of the rectangle!

Analyzing

5. Beni ingin membuat taplak meja berbentuk persegi dari kain batik. Sisi pada taplak meja tersebut adalah 150 cm. Harga 1 m^2 kain batik Rp50.000,00. Berapakah luas kain batik yang dibutuhkan oleh Beni? Jika Beni membawa uang Rp150.000,00, berapakah uang kembalian Beni?

(p.132)

Translate:
Beni wants to make a square-shaped tablecloth from batik cloth. The side on the tablecloth is 150 cm. The price of 1 m2 of batik cloth is IDR 50,000.00. How much area of batik cloth does Beni need? If Beni brings IDR 150,000.00, how much money will Beni change?

Evaluating

2. Sebuah bangun datar mempunyai sifat-sifat sebagai berikut:
   1) Mempunyai empat sisi sama panjang
   2) Mempunyai empat sudut sama besar
   3) Kedua diagonalnya sama panjang dan saling berpotongan tegak lurus

   Bangun datar yang mempunyai sifat-sifat tersebut adalah ….
   A. Persegi C. belah ketupat
   B. Persegi panjang D. jajar genjang

(p.197)

Translate:
2. A shape has the following properties:
1) It has four equal sides
2) It has four equal angles
3) The two diagonals are the same length and intersect at right angles to each other

A shape that has these properties is….
A. Square C. Rhombus
B. Rectangle D. Parallelogram

Table 2 shows that there are only five dimensions of cognitive processes offered in mathematics textbooks: remembering, understanding, applying, analyzing, and evaluating, while for the create level, we did not find them in the geometrical task. We are interested in discussing the sample tasks for level evaluation, which are shown in Table 2. Students are required to analyze, choose, and make decisions that match the defined criteria in this task. Because students are asked to evaluate the situation at hand, we have classified it as a level 5 activity. The point we wish to make is that the demands of students' thinking levels are not determined by the level of difficulty of the questions. Therefore, it is important to provide more easy tasks but require higher-order thinking skills.

The Trend of Knowledge Offered in Geometrical Tasks

The analysis results on the dimensions of knowledge offered by the Grade 4 Elementary Mathematics Textbook are presented in Figure 2 below.

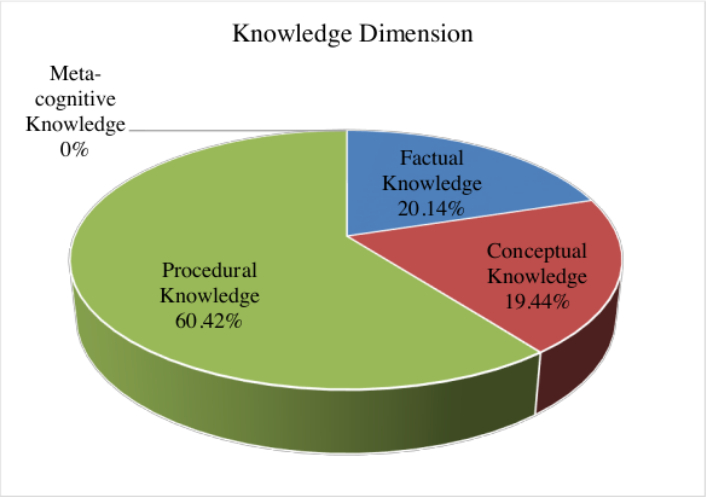
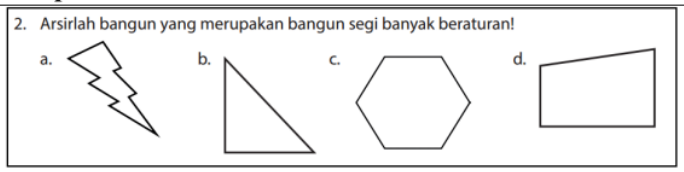


Figure 2. Task categories based on knowledge dimension

Figure 2 shows that procedural knowledge received the highest percentage, with 60.42 percent. In other words, this knowledge encompasses 87 of the 144 items. Then came factual knowledge, which accounted for 20.14 percent, and conceptual knowledge, which accounted for 19.44 percent. Table 3 shows each sample task from each knowledge category.

Table 3. Sample tasks in each knowledge dimension

Categories	Sample task in the mathematics textbook
Factual Knowledge	 (p.154)

Translate:
Shade the shapes, which are regular polygons!

Conceptual Knowledge

2. Sebuah bangun datar mempunyai sifat-sifat sebagai berikut:
   1) Mempunyai empat sisi sama panjang
   2) Mempunyai empat sudut sama besar
   3) Kedua diagonalnya sama panjang dan saling berpotongan tegak lurus

   Bangun datar yang mempunyai sifat-sifat tersebut adalah ….

   A. Persegi
   B. Persegi panjang
   C. belah ketupat
   D. jajar genjang

(p.197)

Translate:
2. A shape has the following properties:
1) It has four equal sides
2) It has four equal angles
3) The two diagonals are the same length and intersect at right angles to each other

A shape that has these properties is....
A. Square
B. Rectangle
C. Rhombus
D. Parallelogram

Procedural Knowledge

3. Ayah Meli akan membuat tangga dari bambu seperti pada gambar di bawah. Jika tiap ruas bambu panjangnya 30 cm, berapakah panjang bambu yang dibutuhkan ayah Meli untuk membuat tangga tersebut?

Gambar 4.16 Tangga Bambu

(p. 151)

Translate:
Meli's father will make a ladder out of bamboo, as in the picture below. If each segment of bamboo is 30 cm long, how much length of bamboo does Meli's father need to build the ladder?

Table 3 shows three dimensions of knowledge identified in our sample textbooks, while metacognitive knowledge was not identified in our analysis. The dominance of procedural knowledge is directly proportional to the dominance of cognitive processes for the level of application offered in this book. This finding is in line with the findings of Purnomo et al.

(2019) on mathematics textbooks in junior high schools dominated by non-contextual problems so that the orientation and emphasis on procedural knowledge; focus on results than process.

Although some problems have presented contextual tasks, the orientation is still on procedural knowledge and includes realistic rather than authentic contexts. The authentic context is closer to the reader in everyday life, while the realistic context is more to the author's imagination in providing examples of everyday life so that sometimes it does not happen (Gracin, 2018; Purnomo et al., 2019). Furthermore, Purnomo et al. (2019) state that authentic context-related tasks allow students to build a sense of the subject and real-life connections while engaging in mathematics examples and exercises fostering concept construction. This context can be exemplified in the sample task for procedural knowledge (see Table 2). The bamboo is composed of pieces of bamboo that are not found in real life, so it is purely the imagination of the author of the book. It is recommended that contextual features be offered proportionally, both in the dimensions of authentic, realistic, and intra-mathematical context (non-context).

The findings of this study also indicate that the mathematical tasks in the textbooks in this sample have not provided variations in cognitive demands, especially in the realm of higher-order thinking skills. The percentage of higher-order thinking skills indicates this, the ability to analyse, evaluate, and create, which is much lower than other lower levels of thinking. In line with these findings, conceptual and metacognitive knowledge also has not received a proportional portion. This is a critique of our learning orientation that requires students to think critically and face global changes and progress happening so fast. Children also need this ability in its application in everyday life and their work in the future, whether directly related to mathematics or not. The complexity of the relationship between the dimensions of cognitive processes and knowledge is also identified in this study.

The complexity in question is a relationship not necessarily directly proportional and random between the two dimensions. For example, we found that one task was in conceptual knowledge, but it was at the evaluating level on the cognitive process dimension. We also found several examples of tasks at the applying level, not only at the procedural knowledge but also at the conceptual level. This focus can also be found in relevant studies (Kar et al., 2018; Kul et al., 2018; Yang & Sianturi, 2017) but have not explored what, why, and how these two dimensions of cognition and knowledge related empirically. Therefore, it would be more meaningful if the next researchers could explore this more deeply by considering the diverse samples and the inquiry method.

Conclusion

A textbook is a teaching material used by teachers and students to guide teaching and learning in the classroom equipped with learning objectives so that the teaching and learning process can be carried out properly according to learning outcomes. Our study on mathematics textbooks focuses on topic shapes in grade 4 elementary school. The findings of this study indicate that most of the tasks provided by textbooks tend to lead to the orientation of low-

level thinking skills and procedural thinking. More than 50% of tasks demand the ability to apply and provide questions with procedural knowledge orientation. Therefore, textbooks should and will be more meaningful when the variation of cognition and knowledge is more varied and proportional. In addition to these main findings, we also identified a complex relationship between the dimensions of cognitive processes and knowledge. Therefore, future researchers can explore this relationship more deeply, both methodically and with sample diversity.

Conflicts of Interest

The authors declare no conflict of interest.

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PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7

PAGE 8

PAGE 9

PAGE 10

PAGE 11

PAGE 12