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Opportunity-to-learn context-based tasks provided by mathematics textbooks

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Abstract Based on the findings of an error analysis revealing that Indonesian ninth- and tenth-graders had difficulties in solving context-based tasks, we investigated the opportunity-to-learn offered by Indonesian textbooks for solving context-based mathematics tasks and the relation of this opportunity-to-learn to students' difficulties in solving these tasks. An analysis framework was developed to investigate the characteristics of tasks in textbooks from four perspectives: the type of context used in tasks, the purpose of context-based tasks, the type of information provided in tasks, and the type of cognitive demands of tasks. With this framework, three Indonesian mathematics textbooks were analyzed. Our analysis showed that only about 10 % of the tasks in the textbooks are context-based tasks. Moreover, at least 85 % of these tasks provide exactly the information needed to solve them and do not leave room for students to select relevant information by themselves. Furthermore, of the context-based tasks, 45 % are reproduction tasks requiring performing routine mathematical procedures, 53 % are connection tasks requiring linking different mathematical curriculum strands, and only 2 % are reflection tasks, which are considered as tasks with the highest level of cognitive demand. A linkage between the findings of the error analysis and the textbook analysis suggests that the lacking opportunity-to-learn in Indonesian mathematics textbooks may cause Indonesian students' difficulties in solving context-based tasks. Based on the results of this study, recommendations are given for improving the opportunities-to-learn to solve context-based tasks as well as for doing further research on this topic.

Keywords Opportunity-to-learn · Textbook analysis · Indonesian mathematics textbooks · Context-based tasks · Students' difficulties in solving tasks

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1 Introduction

Students' ability to apply mathematics in various contexts in daily life is seen as a core goal of mathematics education (e.g., Boaler, 1993; De Lange, 2003; Graumann, 2011; Muller & Burkhardt, 2007; Niss, Blum, & Galbraith, 2007). This core goal of mathematics education is also reflected in the Programme for International Student Assessment (PISA) (OECD, 2003b) in which the assessment of students' mathematics achievement focuses on students' ability to solve mathematics problems situated in real-world contexts. According to the PISA framework (OECD, 2003b), such ability should be an educational core goal because today and in the future, every country needs mathematically literate citizens to deal with complex everyday surroundings and rapidly changing professional environments.

Contexts from daily life can also be used as a didactical tool to support the learning of mathematics. Students' experiences with these contexts give a meaningful basis to the mathematical concepts they have to learn (Cooper & Harries, 2002; Van den Heuvel-Panhuizen, 1996). Furthermore, contexts can provide context-connected solution strategies (Van den Heuvel-Panhuizen, 1996, 2005). However, this does not mean that context-based tasks are always easy to solve for students. Several studies revealed that many students have low performance on such tasks (e.g., Clements, 1980; Cummins, Kintsch, Reusser, & Weimer, 1988; Schwarzkopf, 2007; Verschaffel, Greer, & De Corte, 2000). When solving context-based tasks, students have difficulties in (1) understanding what a problem is about (Bernardo, 1999; Cummins et al., 1988), (2) distinguishing between relevant and irrelevant information (Cummins et al., 1988; Verschaffel et al., 2000), and (3) identifying the mathematical procedures required to solve a problem (Clements, 1980; Verschaffel et al., 2000).

As shown by the PISA surveys (OECD, 2003a, 2004, 2007, 2010), one country in which students have low performance on context-based mathematics tasks is Indonesia. For example, in PISA 2009 (OECD, 2010), only one third of Indonesian students could answer mathematics tasks embedded in familiar contexts and fewer than 1 % of the students could work with context-based tasks in complex situations which require well-developed thinking and reasoning skills. Furthermore, in a recent study (Wijaya, Van den Heuvel-Panhuizen, Doorman, & Robitzsch, 2014)—which was the first study of the Context-based Mathematics Tasks Indonesia (CoMTI) project—we found that the errors of Indonesian students when solving context-based tasks were mostly related to comprehending the tasks, particularly to selecting relevant information. Many mistakes were also made in choosing the correct mathematical operation or concept when transforming a context-based task into a mathematical problem.

The present study was set up to find an explanation for the difficulties Indonesian students experience when solving context-based tasks. The approach taken in the study was investigating what opportunity-to-learn Indonesian mathematics textbooks offer Indonesian students to develop the ability to solve context-based tasks. Although the study was situated in Indonesia, we think that it is relevant for an international audience because it contributes to existing knowledge about the relation between textbooks' content and what students learn. Moreover, this study brings in a new aspect of this relation by focusing on the difficulties students experience when solving context-based tasks.

2 Theoretical background and research questions

2.1 The concept of opportunity-to-learn

A plausible question when particular educational goals are not achieved by students is whether they have received the education enabling them to reach the competences expressed in these goals. Therefore, it is no wonder that the concept of opportunity-to-learn (OTL) came into being. Fifty years ago, this concept was coined by Carroll (1963) when referring to sufficient time for students to learn (Liu, 2009). OTL was also introduced to ensure the validity of international comparative studies of students' achievement. Researchers became aware that when comparing the achievement of students from different countries, curricular differences across national systems had to be taken into account (Liu, 2009; McDonnell, 1995). In the report of the First International Mathematics Studies (Husén, 1967), OTL was defined as "whether or not […] students have had the opportunity to study a particular topic or learn how to solve a particular type of problem." (pp. 162–163).

2.2 Assessing opportunity-to-learn

To examine OTL, several approaches are possible for which various aspects of OTL can be assessed. Liu (2009) considered four OTL variables: (a) content coverage, that is, the match between the curriculum taught and the content tested, (b) content exposure, that is, the time spent on the content tested, (c) content emphasis, that is, the emphasis the teachers have placed on the content tested, and (d) quality of instructional delivery, that is, the adequacy of teaching the content. Another approach was offered by Brewer and Stasz (1996) who distinguished three categories of concern when assessing OTL. The first category is the curriculum content, implying the assessment of whether the students have been taught the subjects and topics that are essential to attain the standards. The second category includes the instructional strategies, assessing whether students have experience with particular kinds of tasks and solution processes. The third category refers to the instructional resources. Here are assessed, for example, issues of teacher preparation and quality of instructional materials.

Besides different aspects of OTL that can be assessed, different methods can also reveal the OTL students receive. These methods vary from teacher and student surveys from questionnaires, to carrying out classroom observations, and to analyzing instructional materials. For example, the first measurements of OTL are based on questionnaires in which teachers have to indicate whether particular mathematical topics or kinds of problems have been taught to students. Such questionnaires were used in the international comparative studies FIMS, SIMS, and TIMSS (Floden, 2002). Furthermore, the TIMSS video studies are an example of revealing the OTL based on classroom observations (Hiebert et al., 2003). Another approach applied in TIMSS was to look at what content curricula offer. Schmidt, McKnight, Valverde, Houang, & Wiley (1997) see the curriculum—and in connection with this—textbook series as "a kind of underlying 'skeleton' that gives characteristic shape and direction to mathematics instruction in educational systems around the world" and that provides "a basic outline of planned and sequenced educational opportunities" (p. 4).

2.3 Opportunity-to-learn and the role of textbooks

Compared to the influence of curricula, textbooks play an even more direct role in what is addressed in instruction. Teachers' decisions about the selection of content and teaching strategies are often directly set by the textbooks teachers use (Freeman & Porter, 1989; Reys, Reys, & Chavez, 2004). Therefore, textbooks are considered to determine largely the degree of students' OTL (Schmidt et al., 1997; Tornroos, 2005). This means that if textbooks differ, students will get a different OTL (Haggarty & Pepin, 2002). As a result, different student outcomes will appear, which is confirmed by several studies that found a strong relation between the textbook used and the mathematics performance of the students (see, e.g., Tornroos, 2005; Xin, 2007).

Recognition of the role of textbooks with respect to students' chances to be taught particular mathematical topics and skills has recently led to a large amount of studies examining OTL offered in textbooks. For example, textbook analysis was applied to the distributive property (Ding & Li, 2010), the equal sign (Li, Ding, Capraro, & Capraro, 2008; McNeil et al., 2006), fractions (Charalambous, Delaney, Hsu, & Mesa, 2010), subtraction up to 100 (Van Zanten & Van den Heuvel-Panhuizen, 2014), non-routine problem solving (Kolovou, Van den Heuvel-Panhuizen, & Bakker, 2009; Xin, 2007), and mathematical modeling (Gatabi, Stacey, & Gooya , 2012).

2.4 Textbook analysis to identify the opportunity-to-learn

To disclose what content is intended to be taught to students, textbooks can be analyzed in several ways. In TIMSS, textbook analysis initially focused on investigating the content profiles of textbooks (Schmidt et al., 1997). Later, they were examined based on five measures (Valverde, Bianchi, Wolfe, Schmid, & Houang, 2002). The first measure is the classroom activities proposed by the textbook. The second measure corresponds to the amount of content covered in textbooks and the mode of presentation, whether abstract or concrete. The third measure deals with the sequencing of content. The fourth measure focuses on physical characteristics of textbooks, for example, the size of the book and the number of pages. The fifth measure characterizes the complexity of the demands for student performance.

Another approach to textbook analysis was proposed by Pepin and Haggarty (2001). They distinguished four areas on which a textbook analysis can focus, namely (a) the mathematics topics presented in textbooks and the beliefs about the nature of mathematics that underlie the textbooks' content, (b) the methods suggested in textbooks to help students understand the textbooks' content, (c) the sociological contexts of textbooks which examines whether textbooks are adaptive to students with different performance levels, and (d) the cultural traditions in textbooks, focusing on how textbooks reflect the cultural traditions and values.

Charalambous et al. (2010) classified the approaches to textbook analysis in three categories, namely horizontal, vertical, and contextual. The horizontal analysis examines the general characteristics of textbooks, such as physical characteristics and the organization of the textbooks' content. This analysis gives a first impression of the OTL because it can provide information about the quantity of exposure of textbooks' content. However, information about the quality and the didactical aspects of the textbooks' content is not revealed by a horizontal analysis. Therefore, a vertical analysis is needed to address how textbooks present and treat the content. Such an analysis offers an in-depth understanding of the mathematical content. The third category, the contextual analysis, focuses on how textbooks are used in instructional activities. Therefore, Charalambous et al. (2010) argued that, in fact, only the first two categories are appropriate to analyze the characteristics of textbooks.

2.5 Opportunity-to-learn required for solving context-based tasks

The primary requirement for students' learning to solve context-based tasks is that students should be offered experiences to deal with essential characteristics of context-based tasks and should be given the necessary practice in handling these characteristics.

2.5.1 Nature of the context

A critical characteristic of context-based tasks is the nature of the context. Concerning mathematical problems, there are several views on what a context means (De Lange, 1995; OECD, 2003b; Van den Heuvel-Panhuizen, 2005). In the present study, the focus is on real-world contexts, which in PISA are called “extra-mathematical contexts” (OECD, 2003b). In PISA, context-based tasks are defined as problems presented within a “situation” which can refer to a real world or fantasy setting, can be imagined by students, and can include personal, occupational, scientific, and public information. This interpretation of a context matches what De Lange (1995) called a “relevant and essential context”, which he contrasted with a “camouflage context.” Tasks with the latter context are merely dressed-up bare problems, which do not require modeling because the mathematical operations needed to solve the task are obvious.

2.5.2 Mathematization and modeling process

To solve tasks that include relevant and essential contexts, students need to transform the context situation into a mathematical form through the process of mathematization (OECD, 2003b). Therefore, it is important that context-based tasks use settings or situations that give access to and support the process of mathematization. In other words, it is crucial that the tasks provide information that can be organized mathematically and offer opportunities for students to use their knowledge and experiences (Van den Heuvel-Panhuizen, 2005).

The process of solving context-based tasks requires interplay between the real world and mathematics (Schwarzkopf, 2007) and is often described as a modeling process (Blum & Leiss, 2007), which in general contains the following steps: (1) understanding the problem situated in reality, (2) transforming the real-world problem into a mathematical problem, (3) solving the mathematical problem, and (4) interpreting the mathematical solution in terms of the real situation.

2.5.3 Adequate mathematical procedures

A further characteristic of a context-based task is that the task cannot be solved by simply translating it into a mathematical procedure (Verschaffel, Van Dooren, Greer, & Mukhopadhyay., 2010). This means that standard problems that have a straightforward relation between the problem context and the necessary mathematics do not help students build up experience to transform a real-world problem into a mathematical problem. Therefore, students should be set tasks in which the necessary mathematical procedures are more implicit.

2.5.4 Different information types

Solving a context-based task is not just combining all the information given in the task (Verschaffel et al., 2010). A context-based task may contain more information than needed for solving the problem or may even lack necessary information. Providing more or less information than needed for solving a context-based task is a way to encourage students to consider the context used in the task and not just take the numbers out of the context and process them mathematically in an automatic way (Maass, 2007). Therefore, students should be offered opportunities to deal with different types of information such as matching, missing, and superfluous information (Maass, 2010). In this way, they can learn to select relevant information and to add and ignore information.

2.5.5 Cognitive demands

A final requirement to support students’ learning to solve context-based tasks is that students can build experience with tasks covering the full range of levels of cognitive demands, including reproduction, connection, and reflection tasks (OECD, 2009). Reproduction tasks require the recall of mathematical properties and the application of routine procedures or standard algorithms. Such tasks do not require mathematical modeling. Connection tasks require integrating and linking different mathematical curriculum strands or different representations of a problem. These tasks also require interpreting a problem situation and engaging students in simple mathematical reasoning. Reflection tasks include complex problem situations in which it is not obvious in advance what mathematical procedures have to be carried out. In fact, this latter category of tasks is the closest to our definition of context-based tasks. What competences students will eventually master depends on the cognitive demands of mathematics tasks they have been engaged in (Stein & Smith, 1998); therefore, these reflection tasks should not be lacking in instruction.

2.5.6 Crucial aspects of opportunity-to-learn context-based tasks

In sum, three aspects of OTL are crucial to develop the competence of solving context-based tasks. The first aspect is giving students experience to work on tasks with real-world contexts and implicit mathematical procedures. The second aspect is giving students tasks with missing or superfluous information. The last aspect is offering students experience to work on tasks with high cognitive demands.

2.6 Difficulties of Indonesian students in solving context-based tasks

The aforementioned aspects of OTL also emerged as relevant in the first study of the CoMTI project (Wijaya et al., 2014) in which we investigated Indonesian students' difficulties when solving context-based tasks. In the study, which involved a total of 362 Indonesian students (233 ninth graders and 129 tenth graders), four types of students' errors were identified: comprehension, transformation, mathematical processing, and encoding errors. Comprehension errors correspond to students' inability to understand a context-based task, including the inability to select relevant information. Transformation errors are related to students' inability to identify the correct mathematical procedure to solve a problem. The mathematical processing errors refer to mistakes in carrying out mathematical procedures. Encoding errors refer to answers that are unrealistic and do not fit the real-world situation described in the task.

Table 1 shows that comprehension and transformation errors were the most dominant errors made by the Indonesian ninth- and tenth-graders when solving context-based mathematics tasks. Within the former category, most errors were made in selecting the relevant information, whereas in the latter category, the students mostly used wrong procedures.

In addition, in agreement with the results of the PISA study 2003 (OECD, 2009), we found in our study that the reproduction tasks were the easiest for the students (67 % of the responses to these tasks gained full credit), whereas the tasks with higher cognitive demand, the connection and the reflection tasks, had lower percentages of correct answers (in both types of tasks 39 % of the responses gained full credit).

2.7 Research questions

The purpose of the present study was to disclose what OTL Indonesian mathematics textbooks offer to Indonesian students for developing the ability to solve context-based tasks. Based on the literature review, the focus was on four aspects of OTL: the exposure to context-based tasks, the purpose of the context-based tasks, the type of information provided in tasks, and the

Table 1 Frequency of students' errors when solving context-based mathematics tasks (Wijaya et al. 2014)

Type of error	Frequency (total errors=1718)	Sub-type of error	Frequency
Comprehension	38 %	- Misunderstanding the instruction	35 %
		- Misunderstanding a keyword	15 %
		- Error in selecting relevant information	50 %
		Total comprehension error=653	100 %
Transformation	42 %	- Using a common mathematical procedure that does not apply to the problem situation	12 %
		- Taking too much account of the context	8 %
		- Treating a graph as a picture	12 %
		- Otherwise using wrong mathematical procedure	68 %
		Total transformation error=723	100 %
Mathematical processing	17 %	–[a]	
		Total mathematical processing error=291	
Encoding	3 %	–[b]	
		Total encoding error=51	

[a] The sub-categories of mathematical processing error are task-specific

[b] There is no sub-type for the encoding error

type of cognitive demand required by tasks. Therefore, the following research questions were addressed:

1. *What are the amount of exposure and the purpose of context-based tasks in Indonesian mathematics textbooks?*
2. *To what extent are different types of information provided in tasks in Indonesian mathematics textbooks?*
3. *What are the cognitive demands of tasks in Indonesian mathematics textbooks?*

   The reason for this study was to find an explanation for the difficulties Indonesian students experience when solving context-based tasks. Therefore, we also investigated the connection between students' difficulties when solving context-based tasks with the OTL in Indonesian mathematics textbooks. This resulted in the next research question:
4. *What is the connection between students' errors when solving context-based tasks and the characteristics of tasks in Indonesian mathematics textbooks?*

3 Method

3.1 Mathematics textbooks analyzed

To answer the research questions, we carried out a textbook analysis in which we focused on grade 8. Although, according to the National Curriculum (Pusat Kurikulum, 2003a, b), the topics dealt with in the PISA tasks included in the CoMTI test are taught from grades 7 to 10, the main emphasis on these topics lies in grade 8. Of the topics, almost half are taught in grade 8 and the remaining part is distributed over the three other grades. Moreover, grade 8 can be considered as a relevant grade year to prepare students for being able to solve context-based tasks as assessed in the PISA studies.

The mathematics textbooks chosen for this analysis are shown in Table 2. These are the textbook series that were used in the schools involved in the first study of the CoMTI project (Wijaya et al., 2014). All the schools either used a combination of two of these textbook series or used all three. Of the textbook series MJHS, which is bilingual, we only analyzed the Indonesian pages.

The three textbooks have a similar main structure. All have nine chapters, each dealing with one mathematics topic. These chapters contain several sub-chapters discussing specific aspects of the mathematics topic covered in the chapter. For example, the chapter on "Equations of straight lines" contains the sub-chapters: (a) the general form of equations of straight lines, (b) the gradient, (c) the relation between a gradient and the equation of a straight line, and (d) the application of equations of straight lines.

Each sub-chapter consists of an explanation section, followed by one or more worked example sections and a task section with regular tasks that the students have to solve themselves. The explanation section discusses a particular mathematics concept, for example, how a rule or formula is obtained (see Fig. 1). The worked example section contains one or more tasks for which an answer is given (see Fig. 2). This section serves as a bridge between the explanation section and the task section (Fig. 3).

Although the three textbooks have the same number of chapters, they have different numbers of sub-chapters because they discuss the mathematics topics in different levels of detail. For example, MJHS discusses the topic of Equations of straight lines in three sub-chapters, whereas the other textbooks spend four sub-chapters on this topic.

3.2 Procedure of textbook analysis

Following Charalambous et al. (2010), we analyzed the textbooks from two perspectives, namely their physical characteristics and instructional components (horizontal analysis) and the characteristics of the tasks (vertical analysis). The physical characteristics and instructional components of the textbooks were investigated to provide information about the quantity of exposure to textbook content. We collected data about the page size, the number of pages, and the page surface area. Furthermore, we counted the number of explanation sections, the worked example sections, the task sections with regular tasks, the tasks in worked example sections, and the regular tasks in task sections. In this analysis, we considered as a task every question or problem with the answer provided (tasks in the worked example sections) or for which the students have to give an answer (regular tasks in the task sections). For

Table 2 Analyzed textbooks and material

Textbook series	Abbreviation	Material involved in analysis	Publisher
Matematika: Konsep dan Aplikasinya	MKA	"For Junior High School grade VIII"	Indonesian Ministry of National Education
Matematika	MS	"For Junior High School grade VIII: 2A and 2B"	Private publisher
Mathematics for Junior High School	MJHS	"Part 2"	Private publisher

b. The equation of line $y = mx + c$

Equation	Gradient	Point on Y axis
$y = \frac{3}{4}x$	$\frac{3}{4}$	(0, 0)
$y = \frac{3}{4}x + 2$	$\frac{3}{4}$	(0, 2)
$y = \frac{3}{4}x + 5$	$\frac{3}{4}$	(0, 5)
$y = \frac{3}{4}x - 3$	$\frac{3}{4}$	(0, −3)

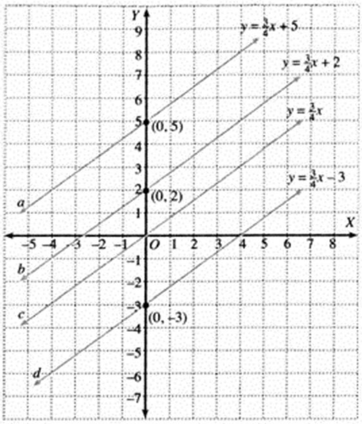


Figure 3.9

From the table above we have the following relations:

Line $y = \frac{3}{4}x + 2$ has a gradient of $\frac{3}{4}$ and passes (0, 2)

Line $y = \frac{3}{4}x - 3$ has a gradient of $\frac{3}{4}$ and passes (0, −3)

Line $y = \frac{3}{4}x + 5$ has a gradient of $\frac{3}{4}$ and passes (0, 5)

Based on the aforementioned explanation, the conclusion is:

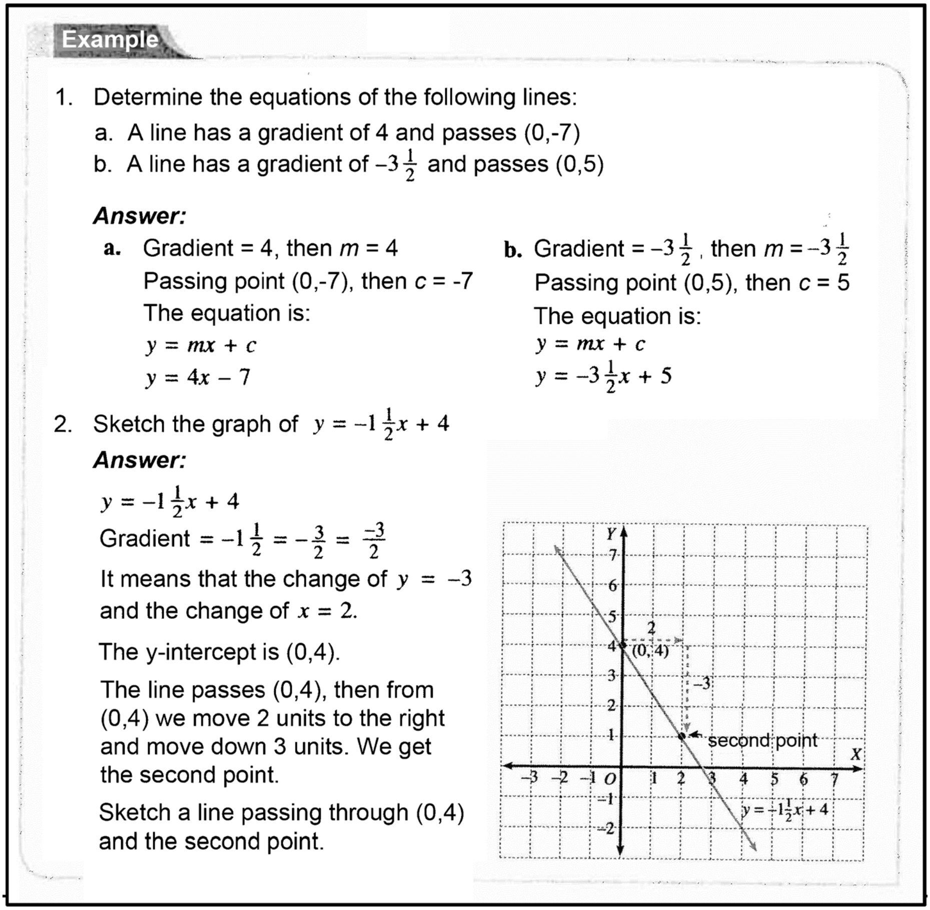
Line $y = mx + c$ has a **gradient of** m and **passes** $(0, c)$.
Point $(0, c)$ is the **intersection** of line $y = mx + c$ and the **Y axis**.

Fig. 1 Explanation section (MS 2A, p. 86)

example, although the task section in Fig. 3 contains two task numbers (7 and 8), in our approach, this section has five tasks (7a, 7b, 8a, 8b, and 8c). The tasks in the worked example sections were counted in a similar way; therefore, Fig. 2 contains three tasks (1a, 1b, and 2). The tasks in the worked example sections and in the task sections could be in a bare format (with only symbols) or context-based format.

3.2.1 Framework for textbook analysis focusing on OTL context-based tasks

The vertical analysis was meant to investigate the OTL to solve context-based tasks. For this purpose, an analysis framework (see Table 3) was developed addressing the task characteristics: type of context, type of information, and type of cognitive demand. To investigate the amount of exposure to context-based tasks, first, we identified the type of context used in the tasks in Indonesian mathematics textbooks. We used the categories distinguished by De Lange (1995) including “no context,” “camouflage context,” and “relevant and essential context.” As an extension to the type of context, we also included the “purpose of context-based task.” The reason for including this characteristic was to distinguish whether a context-based task is used for applying mathematics or for mathematical modeling (Muller & Burkhardt, 2007; Niss et al., 2007). In the former, the solvers know the mathematics they should apply because the task is given after an explanation section. In the latter, the solvers start with a real-world problem and have to identify what mathematics is suitable to solve the problem.



Example

1. Determine the equations of the following lines:
   a. A line has a gradient of 4 and passes (0,-7)
   b. A line has a gradient of $-3\frac{1}{2}$ and passes (0,5)

Answer:

a. Gradient = 4, then $m = 4$
Passing point (0,-7), then $c = -7$
The equation is:
$y = mx + c$
$y = 4x - 7$

b. Gradient = $-3\frac{1}{2}$, then $m = -3\frac{1}{2}$
Passing point (0,5), then $c = 5$
The equation is:
$y = mx + c$
$y = -3\frac{1}{2}x + 5$

2. Sketch the graph of $y = -1\frac{1}{2}x + 4$

Answer:

$y = -1\frac{1}{2}x + 4$
Gradient $= -1\frac{1}{2} = -\frac{3}{2} = \frac{-3}{2}$
It means that the change of $y = -3$ and the change of $x = 2$.
The y-intercept is (0,4).
The line passes (0,4), then from (0,4) we move 2 units to the right and move down 3 units. We get the second point.
Sketch a line passing through (0,4) and the second point.

Fig. 2 Worked example section (MS 2A, p. 87)

For types of information, we used three types described by Maass (2010): "matching information," "missing information," and "superfluous information." The categories for the cognitive demands of the tasks were established based on PISA's competence clusters (OECD, 2003b), which included reproduction, connection, and reflection tasks. These categories were used to identify the characteristics of the tasks in both the worked example sections and the task sections.

3.2.2 Coding procedure

All tasks in the three textbooks were coded by the first author using the analysis framework as shown in Table 3. Afterwards, the reliability of the coding was checked through an additional coding by an external coder who coded a random selection of about 15 % of the tasks. This extra coding resulted in a Cohen's kappa of .75 for the type of context, 1.00 for the purpose of the context-based task, .74 for the type of information, and .84 for the type of cognitive demands. These results indicate that the coding was reliable (Landis & Koch, 1977).

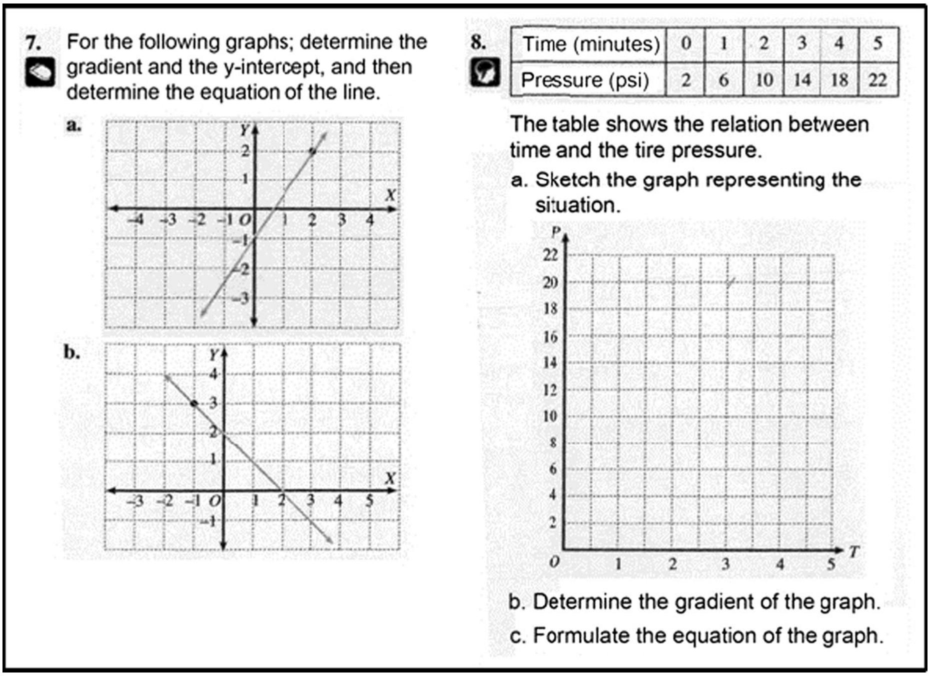


Fig. 3 Task section (MS 2B, p. 88)

4 Results

4.1 Physical characteristics and instructional components of the textbooks

As shown in Table 4, MS has the largest page number and page surface area; whereas MJHS has the lowest number for these physical characteristics. MKA takes a middle position and has a page number and page surface area close to the average of mathematics textbooks from other countries. As reported by Valverde et al. (2002), the international average number of pages for grade 8 mathematics textbooks is 225 pages and the international median of page surface area is 115,000 cm^2.

Regarding instructional components, MS has the largest number of explanation sections, which is more than double that in MJHS. The largest worked example sections are also in MS, but for this instructional component, the difference between the three textbooks is small. For the task sections, MJHS has slightly more than the two other textbooks. We found a large difference between the textbooks for the number of tasks. MS has a total of 1187 tasks, which is double the number in MKA and triple that in MJHS. A similar ratio was found for the regular tasks in the task sections, with respectively 318, 440, and 969 tasks for MJHS, MKA, and MS.

4.2 The amount of exposure and the purpose of context-based tasks

In relation to research question 1, it was found that only 8 to 16 % of the tasks in the three textbooks are context-based, with the highest proportion of these tasks in MS (see Table 5). In MS, the proportion of context-based tasks in the worked example sections and the task sections

Table 3 Analysis framework for textbook analysis

Task characteristic	Sub-category	Explanation
Type of context	No context	- Refers only to mathematical objects, symbols, or structures
	Camouflage context	- Experiences from everyday life or common sense reasoning are not needed - The mathematical operations needed to solve the problems are already obvious. - The solution can be found by combining all numbers given in the text.
	Relevant and essential context	- Common sense reasoning within the context is needed to understand and solve the problem. - The mathematical operation is not explicitly given. - Mathematical modeling is needed.
Purpose of context-based task	Application	- The task is given after the explanation section.
	Modelling	- The task is given before the explanation section.
Type of information	Matching	- The tasks contain exactly the information needed to find the solution.
	Missing	- The tasks contain less information than needed, so students need to derive additional data.
	Superfluous	- The tasks contain more information than needed so students need to select information.
Type of cognitive demand	Reproduction	- Reproducing representations, definitions or facts - Interpreting simple and familiar representations - Memorization or performing explicit routine computations/ procedures
	Connection	- Integrating and connecting across content, situations or representations - Non-routine problem solving - Interpretation of problem situations and mathematical statements - Engaging in simple mathematical reasoning
	Reflection	- Reflecting on and gaining insight into mathematics - Constructing original mathematical approaches - Communicating complex arguments and complex reasoning - Making generalizations

is about the same, whereas in MJHS and MKA, context-based tasks are used more often in the task sections. In all three textbooks, most of the contexts belong to the category of camouflage context. Regarding the purpose of the context-based tasks, we found that all these tasks were intended for application as indicated by their position after the explanation sections.

Examples of each type of context are given in Figs. 4, 5, and 6. Both tasks in Figs. 4 and 5 are related to the concept of gradient. The task in Fig. 4 only uses mathematical objects and symbols.

The task in Fig. 5 is set in the context of a ski slope, which is not a daily life situation for Indonesian students. This context is an example of a camouflage context, because it can be neglected in solving the problem. Although the task includes a real-world situation, the photograph of the ski slope is cut and arranged so that it exactly resembles a straight line and the arrows informing the vertical and horizontal differences also resemble a coordinate system. Furthermore, the words “slope” and “gradient” are mentioned explicitly, and the numbers in the picture are given in such a way that students can immediately interpret the problem as a mathematical problem and follow the common procedure for calculating the slope or gradient.

Table 4 Physical characteristics and instructional components of Indonesian mathematics textbooks

	Textbook		
	MJHS[a]	MKA	MS
Physical characteristic			
Page size (in mm)	205×277	176×250	176×250
Number of pages	146	252	336
Page surface area[b] (in cm^2)	82,906	110,880	147,840
Instructional components			
Number of explanation sections	25	42	56
Number of worked example sections	80	73	90
Number of task sections	79	63	68
Total number of tasks	437	531	1187
Number of tasks in worked example sections	119	91	218
Number of tasks in task sections	318	440	969

[a] Only the Indonesian pages of this textbook were analyzed

[b] Multiplication of the page number and the area of a page (Valverde et al. 2002)

A task with a relevant and essential context is shown in Fig. 6. This task asks to determine the price of four pairs of shoes and five pairs of sandals. To solve this task, students are expected to transform the “price problem” into linear equations with two variables. However, this mathematical procedure is not explicitly mentioned in the task, nor are the numbers presented so that a solution procedure is afforded. The variables for setting up the equations, that is, the number of pairs of shoes and the number of pairs of sandals, are not explicitly indicated in the task. Consequently, students need to identify the relevant information and a solution strategy for solving the task.

Table 5 Frequency of types of context

	Type of context	Textbook					
		MJHS		MKA		MS	
		n	%	*n*	%	*n*	%
Tasks in worked example sections	Relevant and essential context	1	1	2	2	10	5
	Camouflage context	4	3	1	1	28	13
	No context	114	96	88	97	180	83
	Total	119	100	91	100	218	101
Regular tasks in task sections	Relevant and essential context	7	2	17	4	29	3
	Camouflage context	24	8	26	6	127	13
	No context	287	90	397	90	813	84
	Total	318	100	440	100	813	100
All tasks	Relevant and essential context	8	2	19	4	39	3
	Camouflage context	28	6	27	5	155	13
	No context	401	92	485	91	993	84
	Total	437	100	531	100	1187	100

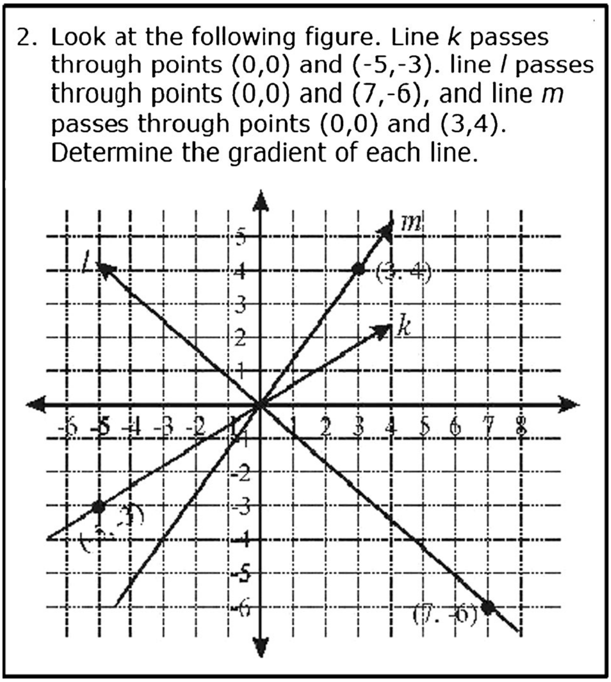


Fig. 4 Task with no context (MKA, p. 70)

4.3 Types of information provided in tasks

As an answer to research question 2, we found that for the bare tasks, that is, tasks with no context, almost all (98, 99, and 99 % of the bare tasks in MJHS, MKA, and MS respectively) give students exactly the information needed to solve the problems. However, for the context-based tasks, the proportions of tasks with matching information are lower (i.e., 86, 85, and 89 % of the context-based tasks in respectively MJHS, MKA, and MS) (see Table 6). The remaining tasks have missing information (i.e., 14, 15, and 10 % of the context-based tasks in MJHS, MKA, and MS respectively), whereas, except for one task in MS, no tasks with superfluous information were found.

An example of a task with matching information is shown in Fig. 7. This task involves finding the width of a river. The width of the river is mathematically the leg of a right-angled

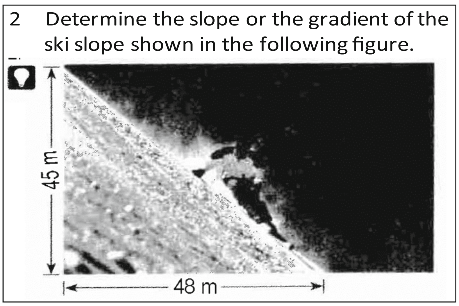


Fig. 5 Task with camouflage context (MS 2A, p. 79)

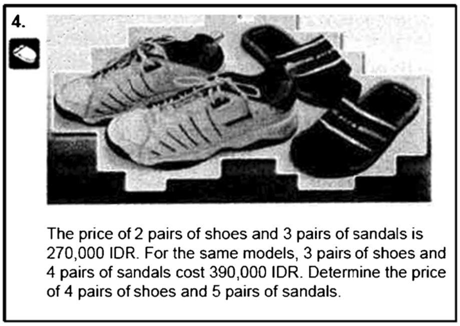


Fig. 6 Task situated in relevant and essential context (MS 2A, p. 132)

triangle that can be found by applying the Pythagorean theorem. All the information required to apply the Pythagorean theorem, that is, the lengths of the hypotenuse and another leg, was given.

In the task in Fig. 8, the students are asked to find the minimum length of rope needed to tie up the three pipes. This task is an example of a task with missing information, in the sense that not all data are directly given to carry out a mathematical procedure leading to the answer. In fact, for solving this task, students have to add the lengths of the three external tangents and the three arcs. However, these lengths are not given. Thus, the students must first generate these data by using further knowledge that can be derived from the contextual situation, such as the three arcs together constituting precisely a full circle and that one tangent equals two radii, that is, equals the diameter of a pipe.

The task in Fig. 9 is an example of a task with superfluous information. The task was about finding the height of a flashlight. The task provided the diameter of the top circle and the bottom circle of the flashlight and the shape and volume of the flashlight box. The shape of the flashlight box was cuboid; therefore, the diameter of the bottom of the flashlight was not

Table 6 Frequency of types of information in context-based tasks

	Type of information	Textbook					
		MJHS		MKA		MS	
		n	%	*n*	%	*n*	%
Context-based tasks in worked example sections	Matching	4	80	2	67	35	92
	Missing	1	20	1	33	2	5
	Superfluous	0	0	0	0	1	3
	Total	5	100	3	100	38	100
Context-based tasks in task sections	Matching	27	77	37	86	138	88
	Missing	4	23	6	14	18	12
	Superfluous	0	0	0	0	0	0
	Total	31	100	43	100	156	100
All context-based tasks	Matching	31	86	39	85	173	89
	Missing	5	14	7	15	20	10
	Superfluous	0	0	0	0	1	1
	Total	36	100	46	100	194	100

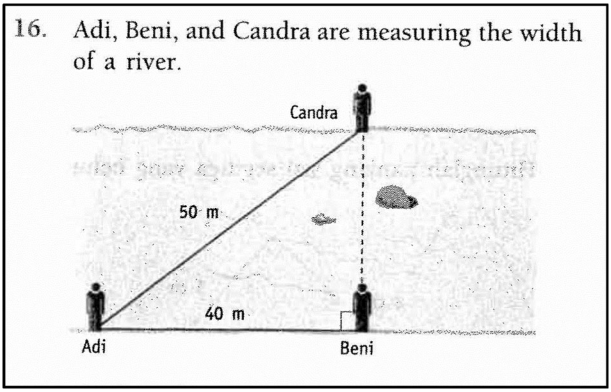


Fig. 7 Task with matching information (MJHS, p. 156)

needed to solve the task. Noteworthy is that we only found one task with superfluous information, which is in the worked example section.

4.4 Cognitive demands required for solving the tasks

Table 7 shows the answers to research question 3. In all three textbooks, almost all bare tasks were identified as reproduction tasks (95, 93, and 93 % of the bare tasks in MJHS, MKA, and MS respectively). The three textbooks have a small proportion of connection tasks, ranging from 5 to 7 %. Only MS includes reflection tasks, that is, 1 % of bare tasks.

Focusing only on the context-based tasks (see Table 8), including a relevant and essential context or a camouflage context, the proportions of task types according to their cognitive demand changed remarkably. The proportions of reproduction tasks in the context-based tasks (47, 33, and 56 % of the context-based tasks in MJHS, MKA, and MS respectively) are much lower than in the bare tasks. In the context-based tasks, substantial proportions of connection tasks were found (50, 67, and 42 % of the context-based tasks in MJHS, MKA, and MS respectively). However, reflection tasks are still either a minority or absent. Only one such task was found in MJHS and three in MS. Differences between the three textbooks were also found for the balance in the type of tasks. MKA contains more connection tasks than reproduction

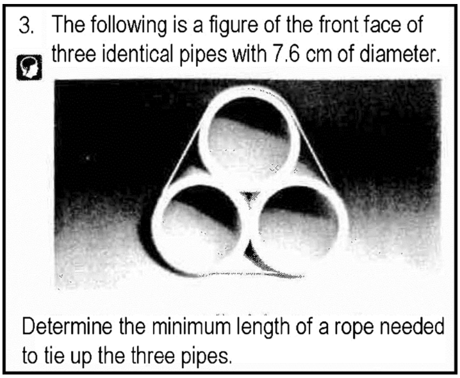


Fig. 8 Task with missing information (MS 2B, p. 143)

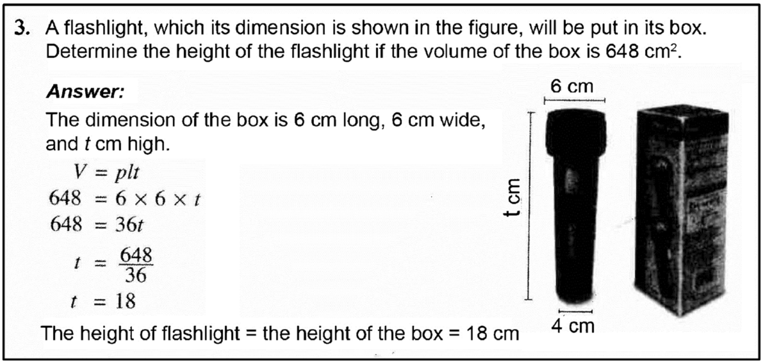


Fig. 9 Task with superfluous information (MS 2B, p. 106)

tasks, whereas MJHS and MS have about the same proportion of reproduction and connection tasks.

Figures 4 and 5 show examples of reproduction tasks. The word gradient was explicitly mentioned in the tasks, so students could easily identify the required mathematics procedure and apply it by using all the information. Figure 8, the task about the three pipes, is an example of a connection task situated in a camouflage context. The main focus of this task was finding the minimum length of rope to tie up three pipes, which mathematically was related to the concept of common tangent of two circles. To find the minimum length of rope, students need to find not only the length of the three common tangents but also the length of the arcs. Here, a connection to the concept of an equilateral triangle is needed to find the measure of the central angle required to calculate the length of the arcs.

A connection task could also be assigned to a bare task, for example, the task in Fig. 10. This task was about determining the perimeter and the area of a non-regular shape. Connecting across representations, that is, circles with different sizes, was required to solve this task.

Table 7 Frequency of types of cognitive demands of bare tasks

	Type of cognitive demands	Textbook					
		MJHS		MKA		MS	
		n	%	*n*	%	*n*	%
Bare tasks in worked example sections	Reproduction	110	96	83	94	172	96
	Connection	4	4	5	6	8	4
	Reflection	0	0	0	0	0	0
	Total	114	100	88	100	180	100
Bare tasks in task sections	Reproduction	271	96	370	93	756	93
	Connection	16	4	27	7	48	6
	Reflection	0	0	0	0	9	1
	Total	287	100	397	100	813	100
All bare tasks	Reproduction	381	95	453	93	928	93
	Connection	20	5	32	7	56	6
	Reflection	0	0	0	0	9	1
	Total	401	100	485	100	993	100

Table 8 Frequency of types of cognitive demands of context-based tasks

	Type of cognitive demands	Textbook					
		MJHS		MKA		MS	
		n	%	*n*	%	*n*	%
Context-based tasks in worked example sections	Reproduction	2	40	1	33	22	58
	Connection	3	60	2	67	16	42
	Reflection	0	0	0	0	0	0
	Total	5	100	3	100	38	100
Context-based tasks in task sections	Reproduction	15	48	14	33	87	56
	Connection	15	48	29	67	66	42
	Reflection	1	3	0	0	3	2
	Total	31	99	43	100	156	100
All context-based tasks	Reproduction	17	47	15	33	109	56
	Connection	18	50	31	67	82	42
	Reflection	1	3	0	0	3	2
	Total	36	100	46	100	194	100

Figure 11 shows an example of a reflection task in a relevant and essential context. The task involved gaining insight into the mathematical meaning of "horizontal floor." Although the figures of triangles and their measures are provided, the mathematical concept related to horizontal floor was not explicitly given. Here, students needed to identify that the task was related to the Pythagorean theorem.

4.5 Opportunity-to-learn provided in textbooks and students' errors

To answer research question 4, we related the results from the textbook analysis to the errors students made when solving context-based tasks, as found in our first study in the CoMTI project (Wijaya et al., 2014). Because we only knew that the group of ninth-graders used the textbooks involved in our analysis, we decided to focus on the results from the ninth-graders and exclude the tenth-graders. Moreover, because the schools in our first study used different combinations of textbooks, we could not exactly classify students' errors according to the particular textbooks with which they were taught. Therefore, in Table 9, we included the total of errors over all schools and for each textbook the proportions of tasks that relate to these errors.

Combining the findings from the textbook analysis and the error analysis, a recognizable similarity between these two findings emerged. In 21 % of the total of 934 errors (made by 233 ninth-graders), students made comprehension errors by not selecting the relevant information

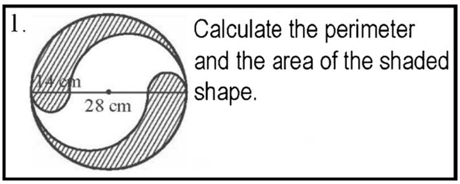


Fig. 10 Connection task situated in no context (MKA, p. 168)

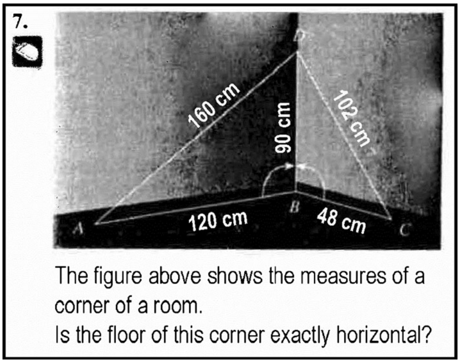


Fig. 11 Reflection task situated in a relevant and essential context (MS 2A, p. 151)

for solving the tasks. Correspondingly, the textbook analysis revealed that the textbooks mainly provide context-based tasks with matching information, and only 11 to 15 % of the context-based tasks had missing or superfluous information.

In relation to the high proportion of transformation errors, the textbook analysis disclosed that the proportions of context-based tasks in the three textbooks only range from 8 to 16 %. It was also found that only 2 to 4 % of these tasks use relevant and essential contexts. Furthermore, all context-based tasks are located after the explanation sections in which a particular mathematics topic is discussed. This means that these tasks are just meant to apply what has been demonstrated in the explanation section. Thus, from the textbooks' content, students can scarcely build up experience in constructing a mathematical model by mathematizing a real-world situation.

Lastly, regarding the percentage of wrong answers for the context-based tasks of the various types of cognitive demand, we also found a match with what is offered in the textbooks. The

Table 9 Relation between students' errors and task characteristics in textbooks

Ninth-graders' errors found in Wijaya et al. (2014) (934 errors)	Task characteristic		Textbook Proportion of tasks (%) MJHS	MKA	MS
Comprehension errors: Proportion of errors in selecting relevant information: 21 % of all errors	Type of information in context-based tasks	Matching	86	85	89
		Missing	14	15	10
		Superfluous	0	0	1
Transformation errors: Proportion of these errors: 45 % of all errors	Type of context in all tasks	No context	92	91	84
		Camouflage context	6	5	13
		Relevant and essential context	2	4	3
Percentage of wrong answers for each type of cognitive demand - Reproduction: 32 % - Connection: 61 % - Reflection: 61 %	Type of cognitive demand in context-based tasks	Reproduction	47	33	56
		Connection	50	67	42
		Reflection	3	0	2

lowest percentage of wrong answers was obtained for the reproduction tasks that cover 33 to 56 % of the context-based tasks in the three textbooks. For the connections tasks, which form 42 to 67 % of the context-based tasks, about half of the answers were wrong. The largest percentage of wrong answers belonged to the reflection tasks that include only 0 to 3 % of the context-based tasks in the textbooks.

5 Discussion

As the PISA studies (OECD, 2003a, 2004, 2007, 2010) have shown and our first CoMTI study (Wijaya et al., 2014) has confirmed, Indonesian students have difficulties in solving context-based tasks. The present study was meant to disclose a possible reason for these difficulties by conducting an analysis of three Indonesian mathematics textbooks. This analysis focused on the OTL to solve context-based tasks offered by the textbooks. For identifying the characteristics of the tasks in the textbooks, we developed an analysis framework including four perspectives: the types of contexts in tasks, the purpose of the context-based tasks, the information used in tasks, and the types of cognitive demands in tasks.

5.1 Opportunity-to-learn and students' difficulties

Our analysis revealed that context-based tasks are seldom available in Indonesian mathematics textbooks. The textbooks mostly provide tasks without a context, which do not require mathematization or modeling activities from the students. Furthermore, the few context-based tasks in the textbooks mostly do not have a relevant and essential context. In addition, the context-based tasks in the Indonesian textbooks are all located after the explanation sections. This means that the mathematics procedure to be applied is more or less given and students do not have to identify an appropriate mathematics procedure to solve the tasks and consequently they are not getting enough experience to develop their ability to transform a context-based task into a mathematical problem. This lack of experience is a plausible explanation for the high number of transformation errors made by Indonesian students. The foregoing conclusion is in agreement with several studies that showed students' lack of experience in a particular type of task corresponds to their difficulties with the task. For example, Haines and Crouch (2007) mentioned that particular difficulties of students in mathematical modeling are due to unfamiliarity with tasks in which students have to identify what mathematics is appropriate to solve the problem. Similarly, Stein and Smith (1998) reported that students' lack of prior experience with open-ended tasks leads to difficulties when solving tasks in which the mathematical procedure is implicit. A lack of particular experience is also directly related to a missing OTL in textbooks as shown in the studies by Li et al. (2008) and McNeil et al. (2006), which revealed that students have difficulties in interpreting the equal sign as a relation because the textbooks they use rarely provide equal signs with operations on both sides.

A specific characteristic of context-based tasks that we found missing in the three Indonesian textbooks is the use of incomplete or irrelevant information, which, according to Forman and Steen (2001), and Greer, Verschaffel, and Mukhopadhyay (2007), is crucial for developing students' ability to apply mathematics in real-world problems. Of the 276 context-based tasks in the three textbooks, only 32 have missing information and just 1 task contains superfluous information. This means that Indonesian students who worked with these textbooks could not really build up experience in selecting relevant information or using knowledge of the context to add missing information. Moreover, taking the freedom to include one's own knowledge or to neglect given information is something with which the students should be familiar. Chapman (2006) emphasized that when students are encouraged to use their own real-world experiences and to relate school experiences to life outside school, they will consider contextual information in a task as important to comprehend and solve the task. The lack of tasks that give students such experiences could explain why the students made so many comprehension errors.

The substantial number of errors made by Indonesian students in tasks with high cognitive demands can also be traced back to the content of the Indonesian textbooks. Of the context-based tasks, fewer than 3 % were reflection tasks. However, the connection tasks were found in about half the context-based tasks. This proportion is similar to the proportion of connection tasks in the PISA study 2003 (OECD, 2009), which might give an impression that Indonesian students have OTL to solve these tasks. However, we should take into account that the context-based connection tasks in Indonesian textbooks are low in number. Over the three textbooks, only 131 context-based tasks (see Table 8; MJHS: 18; MKA: 31; MS: 82) out of all the 2155 tasks together (see Table 4; MJHS: 437; MKA: 531; MS: 1187) ask for integrating and connecting different mathematical curriculum strands or linking different representations of a problem.

In sum, the results from our analysis of three Indonesian textbooks provide evidence of a relation between the errors Indonesian students make when solving context-based tasks and the content offered by the textbooks they use. This conclusion adds to earlier studies that showed a positive relation between OTL provided in textbooks and student achievement: The students learn what is "taught" by the textbook. For example, Tornroos (2005) found a high correlation between student achievement in a test and the amount of textbook content related to the test items. Also, Xin (2007) revealed that the algorithmic strategy used by Chinese students to solve word problem tasks was the strategy suggested in their textbooks.

5.2 Educational implications

Based on our findings, we recommend including more context-based tasks in textbooks. Moreover, these tasks should not only be given after an explanation section, because then the mathematical procedure to be chosen is more or less fixed (see also De Lange, 2003). The quality of the context-based tasks should also be of concern. Textbooks should include context-based tasks that offer students opportunities for mathematization (Freudenthal, 1986; Van den Heuvel-Panhuizen, 2005). This means that instead of camouflage contexts, relevant and essential contexts should be used that demand mathematical organization or ask for mathematization. The context-based tasks to be included in textbooks should also have superfluous or missing information. Giving such tasks will provide students not only OTL to select relevant information (Maass, 2010) but also to identify appropriate mathematics procedures (Greer et al., 2007). Lastly, attention should also be paid to the cognitive demands of context-based tasks. The investigated textbooks contain too few reflection tasks to make it possible for students to develop their ability in complex reasoning. Including more reflection tasks is essential because they stimulate mathematical thinking and reasoning related to authentic settings (OECD, 2003b).

Although this study was situated in Indonesia, the results of the study may also be beneficial for other countries where students have a low performance in context-based tasks. For such countries, our study gives strong indications for examining the OTL to solve context-based tasks as offered in the textbooks in use in these countries.

5.3 Limitations of the study and directions for future research

To be able to provide strong indications for the relation of OTL as offered in textbooks and the achievements of students, it is necessary to know at least of every student which textbook was used to teach him or her. Only then it is possible to obtain a direct proof of this relation. However, in our study, we did not have a one-to-one link between students' errors and the textbook the students worked with because the schools involved in our study used a combination of textbooks. Not knowing which textbook(s) each student used can be seen as a limitation of our study; yet, we found that in the three textbooks, the number of context-based tasks offered and the nature of these tasks were quite similar. However, for getting more robust evidence for our findings, it would be necessary to conduct a further study in which it is known for all students with which textbook(s) they are taught. In addition, including more grades in a textbook analysis would provide a better overview of the OTL in textbooks and the relation with students' achievements. Moreover, for the purpose of generalizability, our study could be repeated in other countries where students have low performance on, for example, context-based tasks used in the PISA studies.

A final limitation of our study is that the relation between student difficulties and OTL was only investigated from the perspective of OTL in textbooks. Although textbooks might be used as the main teaching and learning resources in the classroom (see, e.g., Reys et al., 2004; Valverde et al., 2002), it is clear that teachers also have an important role. For example, Pepin and Haggarty (2001) found that teachers determine how textbooks are used in classrooms. Teachers determine the textbook sections used for students' exercises, when the textbooks should be used, and the ways students work with the textbooks. Regarding the use of context-based tasks for modeling, Ikeda (2007) emphasized the important role of teachers by arguing that the obstacle in teaching modeling is not only a lack of modeling tasks in textbooks but also teachers' perceptions of mathematics and understanding of modeling. As noted by Bishop (1988), teachers have a crucial role in integrating students' experiences and cultures in mathematics learning. Furthermore, following Lampert (1990) and Boaler (1993), if teachers assume that mathematics is a static body of knowledge and learning is the reproduction of facts, procedures, and truths, teachers will fail to engage students with context-based problems or problems with missing or superfluous information. Considering these facts, we believe that revealing possible reasons for students' difficulties in solving context-based tasks should also include investigations into teachers' teaching practice and teachers' beliefs and knowledge about context-based tasks. Consequently, the OTL offered by teachers will be the next focus of the CoMTI project. Another issue that also needs further attention is the influence of the classroom culture on the OTL offered to students (see Pepin & Haggarty, 2001).

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