Macrothink Institute™

International Journal of Social Science Research
ISSN 2327-5510
2024, Vol. 12, No. 1

Analysis of Cognitive Domain on Exercises in Numbers and Operations for Year 3 Mathematics Books

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Received: October 2, 2023 Accepted: December 20, 2023 Published: January 5, 2024

doi:10.5296/ijssr.v12i1.21592 URL: https://doi.org/10.5296/ijssr.v12i1.21592

Abstract

Pupils' low achievement in Numbers and Operations topics in Trends in International Mathematics and Science Study (TIMSS) 2019 has been a concern for the development of mathematics education in Malaysia. Therefore, the quality of mathematics textbooks and activity books, especially in the cognitive domain of exercises, is essential to ensure effective learning of mathematics contents. Thus, content analysis was performed to identify the cognitive domain of exercises in Numbers and Operations topics in the Year 3 mathematics textbook and activity book based on the TIMSS 2023 Mathematics Framework. In this study, the exercises in Numbers and Operations were categorised based on types of exercises and cognitive domain aspects. Results showed that most of the exercises of both the mathematics textbook and activity book topics are in the domain of knowing. The findings suggest that the percentage of exercises in applying and reasoning should be increased and aligned to the suggested percentage by the TIMSS 2023 Mathematics Framework. This situation should be aware by curriculum developers to enhance mathematics learning resources for Malaysian pupils towards the international level.

Keywords: Numbers and Operations topics, mathematics books, cognitive domain, exercise, TIMSS 2023 Mathematics Framework

1. Introduction

1.1 Background of the Study

Proficiency in Numbers and Operations topics has been a concern recently, especially for pupils in Malaysia. Results of TIMSS 2019 demonstrated that the average score of Malaysian Year 4 pupils for the Numbers and Operations topics was lower than the average score (461) and decreased by 14 points from 472 in 2015 to 458 in 2019 (Ministry of Education Malaysia, 2020). This result seems to reflect that most of the pupils cannot apply the knowledge learned to solve higher-order thinking skills (HOTS) questions due to their weakness in mastering the topics (Rajah & Setambah, 2022).

In the Malaysia education system, the significant resources for learning Mathematics in primary school are textbooks and activity books despite Malay-medium National Schools (*Sekolah Kebangsaan*, SK) or Chinese National-type Schools (*Sekolah Jenis Kebangsaan (Cina)*, SJK(C)). A textbook is the primary reference encompassing aspects of learning as specified in the mathematics curriculum. At the same time, the activity book is the primary tool for pupils to develop every content knowledge learned in the textbook (Ismail & Rosli, 2022). Hence, both are crucial in connecting the desired and implemented curricula (Reyhani & Izadi, 2018). Pupils learn mathematics skills through explanations, examples and exercises in the mathematics book. They use mathematics books to gain knowledge and gradually improve their understanding and proficiency in mathematical concepts more easily (Alabdulaziz & Higgins, 2021). This indicates the importance of quality exercises in mathematics books for pupils to learn and review lessons.

To ensure that the quality of exercises in the mathematics books from a cognitive aspect follows the international standards, three cognitive domains in the TIMSS 2023 Mathematics Framework have been referred to: knowing, applying and reasoning (Mullis et al., 2021). These three cognitive domains are essential for pupils in learning mathematics to perform relevant procedures, solve problems with existing knowledge, think logically and provide reasonable justifications for proposed assertions. Therefore, exercises encompassing all cognitive domain aspects should assist pupils in improving their level of mathematical achievement through proficiency in thinking and mathematical skills.

In summary, the achievements of TIMSS Malaysia in these few years have allowed educators to develop mathematics education in Malaysia. Although new mathematics books have been used after the revision of the standard curriculum for primary schools commonly known in the Malay language as *Kurikulum Standard Sekolah Rendah* (KSSR) in 2017 (Tay & Rosli, 2022), it is vital to explore whether the quality of mathematics books especially on the cognitive level are competent over time as they are the primary source for pupils to learn mathematics. Thus, this study aimed to identify the cognitive domain of exercises in Numbers and Operations topics in the revised (2017) KSSR Year 3 mathematics textbook and activity book for SJKC based on the TIMSS 2023 Mathematics Framework.

1.2 Literature Review

1.2.1 Cognitive Learning Theory

According to Piaget's cognitive learning theory, there are four developmental stages in children's intelligence, namely the sensory-motor stage (from birth to 2 years), the pre-operational stage (2 to 7 years), the concrete operational stage (7 to 11 years) and formal operational stage (12 years and above) (Babakr et al., 2019). The cognitive development of primary school pupils is at the stage of concrete operations, where they gradually begin to learn mathematical concepts in a concrete form and move to an abstract form. At the concrete operational stage, the pupils experience the mathematics learning process, which begins with remembering and understanding before applying and reasoning mathematical knowledge to solve problems (Halpenny & Pettersen, 2013; Perrucci, 2017). Therefore, pupils still need fundamental knowledge and skills to shape the mathematical reasoning process regarding concrete situations or contexts (Tan & Rosli, 2021).

The cognitive domain refers to the intelligence dimension involving thought processes (Rashid et al., 2017). It is crucial in developing the pupils' cognitive level to be proficient in mathematics. A person's intelligence level depends on the extent to which they can use the knowledge and skills they have mastered. The cognitive domain focuses on developing an individual's knowledge, understanding and intellect (Mutalib et al., 2021; Nawot & Rosli, 2022). Six cognitive levels are presented in Bloom's Revised Taxonomy: remembering, understanding, analysing, applying, evaluating and creating (Krathwohl, 2002).

According to Krathwohl and Anderson (2001), the level of remembering means the ability to recall and recognise facts, processes, concepts and metacognitive knowledge. The level of understanding refers to the ability to describe, give meaning to, and explain concepts and knowledge learned. The level of analysis refers to the ability to identify elements such as inequality and so on. The applying level is the ability to use the knowledge learned in a given context. The assessment level emphasises the ability to convey ideas and provide justification based on theory and concept. The creative level is the highest cognitive level, where it requires individual competence in combining all elements to produce new things.

The six cognitive levels in Bloom's Revised Taxonomy are also applied in the Mathematics Curriculum and Assessment Standard Document (CASD) as the basis for the primary school mathematics curriculum (Ministry of Education, 2017). Among them, the cognitive level of remembering and understanding belongs to low order thinking skills (LOTS). In contrast, the other four cognitive levels, analysing, applying, evaluating and creating, are high order thinking skills (HOTS) (Azis & Rosli, 2021). The elements in LOTS and HOTS are gradually included in pupils' learning materials, such as mathematics textbooks and activity books. As a result, pupils can develop their understanding and thinking to be proficient in mathematical skills, especially in relating, comparing, justifying, and evaluating a context, issue, or mathematical problem.

Based on the TIMSS 2023 Mathematics Framework, the cognitive domain, as mentioned, is closely related to the cognitive level of Bloom's Revised Taxonomy. The knowing domain is

closely related to the level of remembering and understanding. In contrast, the applying domain is associated with the level of applying, and the reasoning domain is closely linked to the level of evaluating (Azis & Rosli, 2021). The knowing domain is crucial in learning mathematics in primary school as it includes pupils' proficiency in basic mathematical knowledge, skills, and concepts. High proficiency in the remembering domain will facilitate the development of mathematical knowledge involving a more complex cognitive level for solving mathematical problems. On the other hand, pupils will encounter difficulties and problems in learning mathematics with impromptu competence and thinking (Cheng & Rosli, 2020; Mamat & Wahab, 2022).

1.2.2 Analysis of Cognitive Domain in Mathematics Books

Mathematics textbooks are the primary materials often used by teachers in the planning and implementation of teaching and facilitation in Malaysia or other countries (Adu et al., 2020). In mathematics books, the exercises involve two types of thinking levels: low and high (Idris, 2005). Typically, low-level exercises strengthen and solidify specific mathematical knowledge pupils learn with memorising skills. In contrast, high-level exercises employ HOTS to improve pupils' understanding of the topic by applying the skills learned in solving non-routine problems (Gracin, 2018). Thus, a quality mathematics book must be equipped with exercises that contain various cognitive levels.

Tay and Rosli (2022) assessed the quality of mathematics textbooks. They reported that most of the exercises in the revised (2017) KSSR Year 5 mathematics textbook for SK and SJKC only emphasise the knowing domain. A study by Cheng and Rosli (2020) on the revised (2017) KSSR Year 6 mathematics textbook for SK and SJKC also indicated a lack of exercises, explanations, and assessments for the reasoning domain. For the old and new KSSR curriculum of Year 4 mathematics textbooks, Kai et al. (2018) revealed that most of the exercises in both mathematics textbooks are subject to the knowing domain. However, exercises related to the applying and reasoning domains have increased in mathematics textbooks for the new version. These findings have proved that most exercises in Year 4 to Year 6 mathematics textbooks still emphasise the knowing domain. The results of previous local studies also align with what Gracin (2018) reported. Gracin's study revealed that most activities in mathematics textbooks in Croatia involve mathematical calculations with low-order thinking skills only and a lack of exercises on explanations and justifications.

The development of pupils ' knowledge and mathematical skills will be impeded if they are only exposed to knowing-level exercises (Lim & Rosli, 2021). Therefore, the quality of exercises in mathematics books from a cognitive aspect should be examined over time by increasing the HOTS elements in exercises and activities to benefit pupils in learning mathematics.

2. Method

The design of this study was case study where qualitative data were gathered. The content analysis method was used to identify the cognitive domain of the exercises in Numbers and Operations topics in the revised (2017) KSSR Year 3 mathematics textbook volume 1 and

activity book for SJKC based on the TIMSS 2023 Mathematics Framework. Year 3 mathematics books were examined because pupils' preparation for basic mathematics skills is essential before moving on to Year 4, which is also the focus of the TIMSS assessment. Subsequently, the revised mathematics books for KSSR were selected for this study as they are the latest version for pupils in SJKC after the reform curriculum in 2011 (Lim & Rosli, 2021). Besides, these two mathematics books are the leading official teaching and learning material for mathematics for Year 3 pupils of SJKC in Malaysia.

2.1 Analytical Criteria

All the exercises in the Numbers and Operation topics within the two mathematics books were analysed and coded into two analytical criteria: the type of exercise and cognitive domain. The mathematics textbook contains explanatory exercises (coded as E.E.) and assessment exercises (coded as A.E.). E.E. refers to the questions following some examples of mathematical questions learned, such as guidance exercises to clarify pupils' understanding of the mathematical concepts learned. On the other hand, A.E. refers to a set of questions given after the mathematical content has been presented as a reinforcement exercise to test the pupils' understanding of the concepts learned in the sub-topic. However, all the exercises in the mathematics activity book were classified as A.E. as they reinforced the mathematical concepts, skills, and knowledge learned.

Furthermore, each question in these mathematics books was classified and coded according to the cognitive domains proposed in the TIMSS 2023 Mathematics Framework, namely the domain of knowing (code A), the domain of applying (code B) and the domain of reasoning (code C) (Mullis et al., 2021). In the domain of knowing, four aspects were coded, which are recalling (code A1), identifying (code A2), organising (code A3) and calculating (code A4). As for the applying domain, three aspects were considered, namely formulating (code B1), implementing (code B2) and representing (code B3). The reasoning domain also contained four aspects, namely analysing (code C1), integrating (code C2), generalising (code C3) and justifying (code C4). Tables 1, 2 and 3 describe each cognitive domain aspect.

Table 1. Aspects of knowing domain

Aspects	Knowing Domain (Code A)
Recalling (A1)	• Able to recall definitions, terms, number properties, measurement units, geometric features and notation.
Identifying (A2)	• Able to identify Mathematical numbers, expressions, quantities, shapes and entities. • Able to read information from graphs, tables, text or other sources.
Organising (A3)	• Able to organise and classify numbers, expressions, quantities and shapes based on general characteristics.
Calculating (A4)	• Able to calculate arithmetic operations involving numbers, fractions, decimals and integers using algorithmic procedures. • Able to perform algebraic manipulations directly.

Table 2. Aspects of applying domain

Aspects	Applying Domain (Code B)
Formulating (B1)	• Able to determine appropriate and effective operations, strategies and tools to solve problems.
Implementing (B2)	• Able to perform appropriate strategies and operations to produce problem solutions.
Representing (B3)	• Able to represent data in tables or graphs; create equations, inequalities,geometric figures or diagrams that describe problem situations; and generate an equivalent representation of a mathematical entity or relationship.

Table 3. Aspects of the Reasoning Domain

Aspects	Reasoning Domain (Code C)
Analysing (C1)	• Able to describe and use relationships between numbers, expressions, quantities and shapes.
Integrating (C2)	• Able to connect different elements of knowledge, related representations, and steps.
Generalising (C3)	• Be able to make statements representing a mathematical relationship in general and relevant terms.
Justifying (C4)	• Able to provide mathematical arguments to support a strategy or solution

2.2 Analysis Method

In this study, exercises in Numbers and Operations in the Year 3 mathematics textbook and activity book were selected and categorised based on the frequency of questions, type of exercise, and cognitive domain aspects. A checklist form was employed as a research instrument in determining and classifying the exercises in Numbers and Operations topics based on the type of exercises and aspects of the cognitive domain. Tables 4 and 5 show examples of analysis conducted on exercises in the Year 3 mathematics textbook and activity book.

Table 4. Example of analysis of exercises in Year 3 mathematics textbook

Textbook/Activity Book of Year 3 Mathematics (Topics: Numbers/**Operations**) Domains of **Knowing (code A)** / Applying (code B) / Reasoning (code C)				
Mathematics Exercise Question	Frequency of Question	Type of Exercise	Aspect	Description
Practice it. 1 3 164 + 15 2 724 + 648 3 4 582 + 3 150 4 6 276 + 2 889 *Textbook page 34	4	A.E.	A4	They are coded as a **calculating** aspect as pupils need to solve the questions related to addition operation.

Table 5. Example of analysis of exercises in Year 3 mathematics activity book

Textbook/**Activity Book** of Year 3 Mathematics (Topics: **Numbers**/Operations) Domains of Knowing (code A) / Applying (code B) / **Reasoning (code C)**				
Mathematics Exercise Question	Frequency of Question	Type of Exercise	Aspect	Description
 Translation: I want to send 6800 brush pen sticks. Calculate whether the number of brush pens is sufficient. Explain your answer. *Activity book page 14	1	A.E.	C4	They are coded as an aspect of **justifying**; pupils need to justify to support the answer to the given question.

2.3 Reliability and Validity of Study

Expert review was conducted to increase the validity of the checklist form used during coding. According to Bıkmaz and Mızıkacı (2022), the expert review method is one of the suggested strategies to strengthen the credibility of the research instrument. To ensure data reliability, this study employed the inter-rater agreement method. An external evaluator was briefed, and the coding was conducted using the same research instrument. Then, the result was compared to seek any significant differences in the coding process. Based on Bıkmaz and Mızıkacı (2022), consistency and differences in opinion between experts are determined, and agreement is achieved through Miles and Huberman's (1994) reliability formula, which is reliability = agreement/agreement + difference, where if the value exceeds 70%, then the data are reliable. From the outcome of the reliability test done, the percentage of inter-rater

agreement is more than 90%, indicating high reliability among researchers and external evaluators.

3. Results

3.1 Analysis of Cognitive Domain of the Exercises in Numbers and Operations Topics for Revised (2017) KSSR Year 3 Mathematics Textbook for SJKC

All the exercises in the Numbers and Operations topics in the revised (2017) KSSR Year 3 Mathematics textbook for SJKC were analysed based on the TIMSS 2023 Mathematics Framework. Table 6 shows the analysis results of the types of exercises and cognitive domains for the exercises in both topics in the textbook.

Table 6. Analysis results of exercises in Numbers and Operations topics in the Year 3 mathematics textbook

Cognitive Domain	Numbers Topic		Total	Operations Topic		Total	Overall Total
	E.E	A.E.		E.E.	A.E.		
Knowing	15	13	28	10	46	56	84
Applying	1	0	1	12	1	13	14
Reasoning	4	0	4	7	1	8	12
Total	20	13	33	22	55	77	110

From Table 6, a total of 110 questions were identified from the exercises in Numbers and Operations topics. All of them were classified according to the type of exercise. Based on the analysis result, it was found that there was more assessment exercise (A.E.) than explanatory exercises (E.E.), with a total number of 88 questions and 42 questions, respectively.

Furthermore, analysis of the cognitive domain of the exercises in Numbers and Operations topics showed that most exercises were categorised under the knowing domain with 84 questions altogether. In comparison, the most minor exercises were categorised under the reasoning domain with 12 questions only. This simple comparison showed that exercises in Numbers and Operations topics in the Year 3 mathematics textbook were mainly categorised under the knowing domain.

Figure 1 depicts the cognitive domain percentage of exercises in the Numbers and Operations topics in the revised (2017) KSSR Year 3 mathematics textbook for SJKC. From the figure, the percentage of questions under the knowing domain was the highest (76%). The percentages of questions in the applying and reasoning domains were 13% and 11%, respectively. This indicated that the domain of knowing was the predominant cognitive domain for the exercise questions in the Year 3 mathematics textbook.

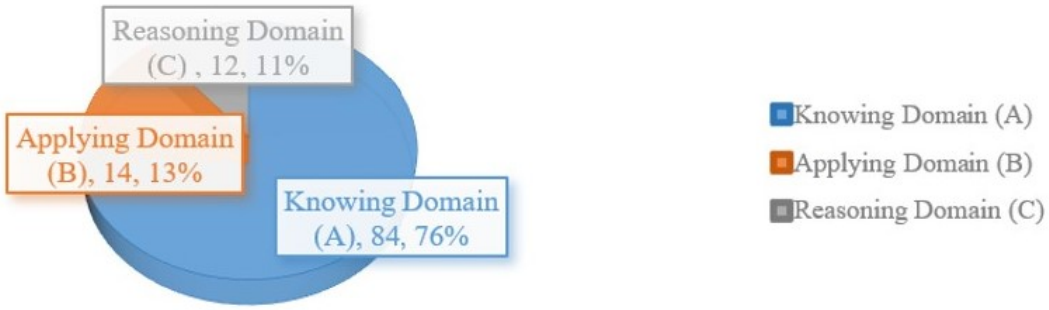

Figure 1. Cognitive Domain Percentage of Exercises in Number and Operations Topics in Year 3 Mathematics Textbook

3.2 Cognitive Domain Analysis of Exercises in Numbers and Operations Topics in KSSR Revised (2017) KSSR Year 3 Mathematics Activity Book for SJKC

Exercises in the Numbers and Operations topics in the revised (2017) KSSR Year 3 mathematics activity book for SJKC were analysed based on the TIMSS 2023 Mathematics Framework. Table 7 shows the analysis results of the exercises and cognitive domain types for the exercises in both topics in the activity book.

Table 7. Analysis results of exercises in Numbers and Operations topics in Year 3 mathematics activity book

Cognitive Domain	Numbers Topic		Total	Operations Topic		Total	Overall Total
	E.E.	A.E.		E.E.	A.E.		
Knowing	0	72	72	0	115	115	187
Applying	0	8	8	0	37	37	45
Reasoning	0	5	5	0	8	8	13
Total	0	85	85	0	159	159	244

Referring to Table 7, altogether 244 questions were identified through the exercises in Numbers and Operations topic in the activity book. Based on the analysis of the types of exercises, it was found that all the exercises in the activity book were classified as assessment exercises (A.E.) without explanatory exercises (E.E).

Moreover, analysis of cognitive domain of the exercises in Numbers and Operations topics showed that most of the exercises were categorized under knowing domain with a total of 187 questions while least exercises were categorized under reasoning domain with only 13 questions. This simple comparison showed that the condition of the cognitive domain of exercises in Numbers and Operations topics in the Year 3 mathematics activity book was the same as in the textbook, where exercises were mainly categorised under the knowing domain.

Figure 2 depicts the cognitive domain percentage of exercises in the Numbers and Operations topics in the revised (2017) KSSR Year 3 mathematics activity book for SJKC. From the figure, the percentage of questions in the knowing domain was the highest (76%). The percentages of questions in the applying and reasoning domains were 19% and 5%, respectively. This indicated that the domain of knowing was the predominant cognitive domain for the exercise questions in the Year 3 mathematics activity book.

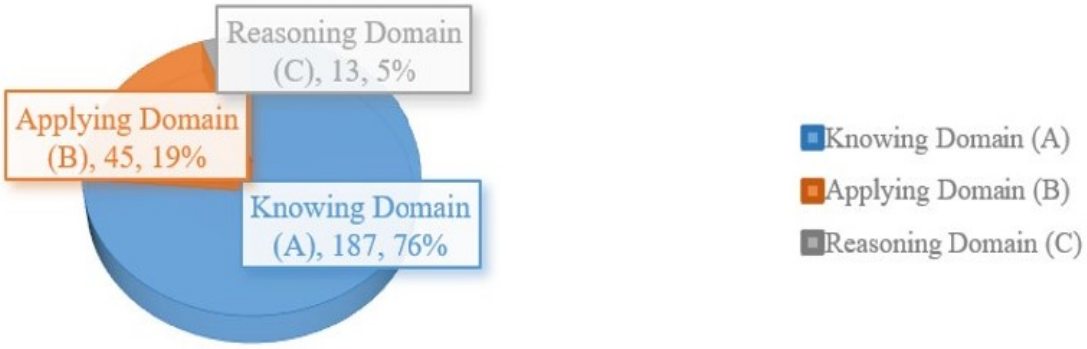

Figure 2. Cognitive Domain Percentage of Exercises in Number and Operations Topics in Year 3 Mathematics Activity Book

4. Discussion

The results of this study demonstrated that A.E. was greater than E.E., especially for the Operations topic. This is because pupils must perform considerable exercises to strengthen the skills they learned and to improve their understanding of mathematical concepts before mastering the four basic operations (Alabdulaziz & Higgins, 2021).

Subsequently, the results also indicated that the cognitive domain of most of the exercise questions in the Number and Operations topics in the revised KSSR Year 3 mathematics textbook and activity book for SJKC were similar and categorised in the domain of knowing. The cognitive domain for both mathematics books is aligned and uniform with the learning development of the Year 3 pupils towards their skills and knowledge in both topics. These findings are in agreement with those reported by Cheng and Rosli (2020), Kai et al. (2018) and Tay and Rosli (2022). Those studies found that most exercises in revised KSSR Year 4, 5 and 6 mathematics textbooks for SJKC and SK were under the knowing domain. Similarly, Gracin (2018) claimed that mathematics textbooks in Croatia provided low-level thinking skills exercises and a lack of explanatory and justification exercises for pupils. Thus, it was evident that the exercises in Malaysia's Year 3 mathematics textbook, particularly Number and Operations topics, are similar to those in mathematics textbooks in other countries.

Accordingly, the percentage of questions in Numbers and Operations topics categorised in applying and reasoning in both mathematics books was deficient. This could be because the pupils need to master basic mathematics concepts covering the knowledge domain in the

Numbers and Operations topics before learning other topics. This is in line with Piaget's cognitive theory, where children's learning process at the concrete operational level begins with remembering and understanding before they can form reasoning for problem-solving (Perrucci, 2017). Too many exercises in the domain of reasoning will reduce pupils' interest in learning Mathematics (Tor & Rosli, 2022).

This statement also aligns with the finding of Xi's (2022) survey that learning basic mathematical knowledge and skills is crucial for pupils to possess sufficient existing knowledge to form mathematical skills on other topics related to numbers, such as integers, fractions, and so on. Furthermore, Tan and Rosli (2021) also agreed that pupils need sufficient fundamental knowledge and skills to form mathematical reasoning processes regarding concrete situations or contexts. This could be why the exercises in the Numbers and Operations topics in the Year 3 textbook and activity book focus more on knowing than other domains.

From another point of view, it is likely to hinder the development of pupils' mathematical thinking if they are only exposed to exercises under the knowing domain. Therefore, the percentage of the exercise under the categories of applying and reasoning in both the Year 3 mathematics textbook and activity book should be increased and aligned with the suggested percentages from TIMSS 2023 Mathematics Framework, which are 40% for knowing domain, 40% for applying domain and lastly 20% from reasoning domain.

5. Conclusion

In conclusion, the results of this study demonstrated that the knowing domain is the most dominant cognitive domain of exercises in the Numbers and Operations topics for both the revised (2017) KSSR Year 3 mathematics textbook and activity book KSSR for SJKC. This finding aligns with the analysis results of Years 4, 5 and 6 mathematics textbooks conducted by several previous researchers, as aforementioned throughout this paper. The results of this study are vital and can be used as implications for mathematics teachers, curriculum developers, textbook authors and mathematics researchers. It is crucial for a mathematics teacher as a good curriculum designer to plan and implement effective and appropriate teaching based on the cognitive domain of exercises and pupils' achievement in guiding their learning towards the desired domain levels. Furthermore, mathematics curriculum developers can obtain helpful information in exploring new curricula, particularly in rectifying weaknesses and improving existing strengths. The results of this study can also be used as a reference for other mathematics textbook authors to determine the type and level of the cognitive domain for each mathematical exercise produced. In addition, researchers can also obtain guidance and references when conducting analyses of mathematics books. As a result, the quality of Malaysian mathematics books can be improved and on par with the international level.

For future research, it is suggested to employ a similar approach for other mathematical topics, such as fractions, money, time, space, etc. Future research can also make comparisons of mathematics books of different streams to be more comprehensive. Finally, it is also suggested that this research area should be expanded for more book analysis, especially on

mathematics books of Years 1, 2, and 3, as related studies are scarce in Malaysia.

Acknowledgement

The authors would like to express their profound appreciation to Universiti Kebangsaan Malaysia under GUP-2021-028 for supporting this study.

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