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Bloom Anderson's Taxonomy-Based Cognitive Level Analysis of Grade 10 Interactive Mathematics Book Questions

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Abstract

This research examines the distribution of cognitive abilities within the interactive mathematics textbook designed for 10th-grade students. The study recognizes the significance of mathematics education in nurturing students' cognitive skills. However, it also acknowledges the presence of ineffective methods that impede students' grasp of concepts and their capacity to solve problems. Employing a qualitative research approach, the study identifies and resolves questions in the interactive mathematics book. It explains each cognitive skill used to solve these questions and categorizes these skills according to Bloom's taxonomy. The findings reveal an uneven allocation of cognitive skills in both chapters. Questions falling under the application category (C3) are predominant, while those demanding higher-order thinking, such as creation (C6), are limited in number. This lack of diversity and balance underscores the necessity for incorporating a broader array of questions spanning various cognitive levels. The interactive mathematics book for 10th-grade students enhances comprehension and reinforces core principles. Nevertheless, it necessitates refinement in cognitive skill distribution, especially by including more questions that require advanced thinking. Rectifying this disparity would empower the book to foster students' critical thinking and problem-solving skills.

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1 Introduction

Mathematics lessons must be provided to students since elementary school to equip them with logical (Yuberti et al., 2022), critical (Sormin et al., 2022), systematic (Natanael & Kusumaningsih, 2021), analytical (Cholily, 2023), creative, and collaborative thinking skills (Asmiatun et al., 2021). There are still many ineffective practices in mathematics learning (Setio & Baiduri, 2023), resulting in students' poor understanding of the subject and difficulties in solving mathematical problems (Karim & Zoker, 2023).

Hidayat & Noer (2021) Educators should design learning activities to enhance students' critical thinking abilities. Field observations show that students still encounter difficulties and make errors in solving mathematical problems (Jamin & Sudiman, 2022; Susanto et al., 2022; Tapiah, 2022). Therefore, teachers must improve the quality of instruction (Abus & Usmiyatun, 2023).

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Instructional materials can be used to enhance the quality of education (Kusumaningsih et al., 2023; Sastromiharjo, 2011). Instructional materials are necessary as a guide for activities in the learning process and serve as the substance of the components taught to students (Choirudin et al., 2021; Noviani & Priyanti, 2022). Government Regulation Number 32 of 2013 on National Education Standards, Article 1, Paragraph 23 states that textbooks are the primary learning source to achieve essential content competencies. The Intan Pariwara interactive mathematics book for Grade 10 high school students can be used to support classroom learning. However, the cognitive level of the book's questions is unknown (Cholily, 2011; Marzuki et al., 2021). Hence, a study is needed to examine the distribution of mental levels in the daily assessments contained in the book using Bloom's taxonomy (Arneson, 2018; Leblanc, 2018).

Bloom's taxonomy categorizes questions and assesses their suitability in measuring students' abilities (Fauzi et al., 2021; Safitri et al., 2023). In general, the taxonomy of learning objectives should refer to three domains inherent in learners: (1) the cognitive domain, which relates to learning objectives and is oriented towards thinking abilities (Kusumaningsih et al., 2024); (2) the affective domain (Fauza et al., 2023), which is related to feelings (Darmawati, 2022), emotions, values, and attitudes; and (3) the psychomotor domain, which is oriented towards motor skills or the use of skeletal muscles (Kartini et al., 2022). Bloom's taxonomy comprises six commonly used levels: remembering, understanding, applying, analyzing, evaluating, and creating (Khalishah & Iklilah, 2021; Nurkanti et al., 2023).

Firstly, remembering refers to recalling relevant information from long-term memory (Eisenman, 2021; Laila et al., 2023; Lubis & Widiawati, 2020). Second, understanding involves constructing meaning or understanding based on prior knowledge, connecting new information and existing knowledge, or integrating new knowledge into existing mental frameworks (Ramlan Effendi, 2017). Thirdly, applying refers to solving problems in new situations using acquired knowledge, facts, techniques, and rules differently (Setiawan, 2018). Fourthly, analyzing involves breaking down and connecting information to obtain coherent results when solving problems (Dewangga & Sunarti, 2022).

Fifthly, evaluating is a process of making decisions based on standard criteria. These two abilities are crucial in problem-solving to ensure accurate decisions (Jailani & Ismunandar, 2022; Pandia et al., 2022). Lastly, creating is a cognitive process that combines elements to form a coherent unity, directing students to produce a new product by organizing multiple elements into different forms or patterns from before (Busri et al., 2021; Maharani & Budiarti, 2022). These categories are hierarchically organized from the most basic to the highest level of competence (Inganah et al., 2023). The higher the level of competence or level, the greater and more complex the intensity of student learning experiences, instructional processes, and assessments (Wahyuningtyas et al., 2022).

Putra (2021) analyzed the competency test questions on functions in a mathematics textbook for Grade 10 high school students based on Bloom's taxonomy. The results showed that the distribution of cognitive levels in the competency test questions for the function topic in the Mathematics Textbook Curriculum 2013 Revised 2017 was still imbalanced in terms of difficulty (da Silva Santiago et al., 2023). Marta, B, & Agustinsa (2021), In analyzing the cognitive levels of statistics questions for Grade 8 students based on the revised Bloom's taxonomy, the distribution of mental levels in the statistics exercise questions was not varied or proportional. Khairani, Susanta, & Yensy B (2021) Analyzed the cognitive level of enrichment module questions on the topics of linear equations and systems of linear equations with two variables for Grade 8 students based on the revised Bloom's taxonomy (Darmayanti, 2023) and the results showed that the questions in both topics still lacked variation. Based on the above elaboration (S. N. Hasanah et al., 2021; Rofiah et al., 2023), the research objective is to analyze the distribution of cognitive levels in the interactive mathematics book for Grade 10.

2 Theoretical Review

The cognitive styles of learners (In'am, 2009; Sakti & Yulianeta, 2018), whether field-independent or field-dependent, can significantly influence how they approach mathematical problems and communicate their solutions (Qomariyah et al., 2024). Research conducted by (Malaya et al., 2021) indicates that students with a field-independent cognitive style tend to excel in written mathematical communication (Budiarti & Darmayanti, 2020). They can illustrate problems through visuals and articulate mathematical concepts accurately (Asgafi et al., 2023), although improvements might still be necessary. Conversely, students with a field-dependent cognitive style also exhibit commendable mathematical communication skills but may struggle with depicting problems visually and expressing ideas with complete clarity (Ho & Kozhevnikov, 2023).

Nurmalia, Yuhana, and Fatah (2019) Researched vocational students' mathematical communication abilities. The study revealed that field-independent students demonstrated superior mathematical communication skills to their field-dependent counterparts (Cholily et al., 2021; Sugianto et al., 2023). Field-independent students exhibited analytical skills and the ability to work autonomously, while field-dependent students often worked independently but required assistance (Budiarti et al., 2022; Vargheese et al., 2022; Vecchione et al., 2023). Prawita, Amrullah, Salsabila, and Hayati (2022) expanded the perspective by exploring how individuals with the same cognitive style could communicate diverse mathematical ideas. The research found that (Sari et al., 2023; Wati et al., 2023), despite sharing a cognitive style, students with a field-independent cognitive style showcased more vital written mathematical communication skills than those with a field-dependent cognitive style. A study by (Azizah and Himmah, 2022) delved into a direct comparison between field-independent and field-dependent cognitive styles regarding written mathematical communication skills. The research highlighted that field-independent students had a marked advantage (Wicaksono et al., 2021), displaying a deeper understanding of, expression for, and evaluation of their mathematical ideas compared to their field-dependent peers (Bausir et al., 2023; N. Hasanah et al., 2023).

3 Method

The research methodology employed in this study is qualitative research. Qualitative research is a study that examines the quality of relationships, activities, situations, or various materials, emphasizing a holistic description by providing detailed explanations of ongoing activities or situations rather than comparing the effects of specific treatments (Fadli, 2021). Figure 1 illustrates the sequential phases of the research procedure to be conducted.

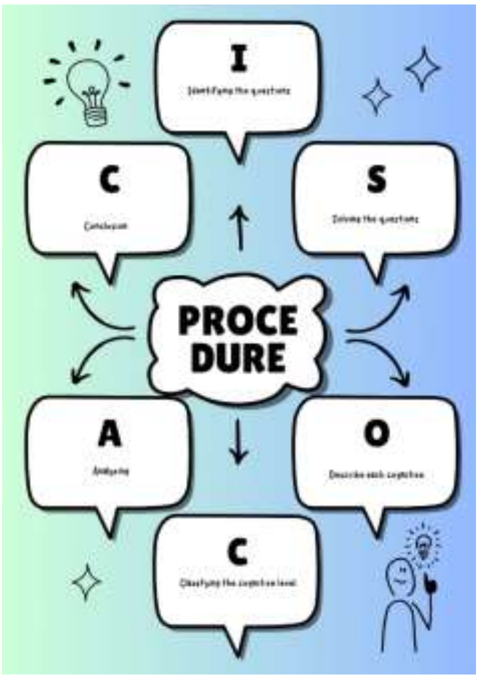


Figure 1. ISO-CAC Procedure

Figure 1 depicts the sequential process of the ISO-CAC procedure to be conducted (Yolcu, 2019; Yuwono et al., 2021):

1. Identifying the questions in the Interactive Mathematics Book for Grade 10 High School, First Semester.
2. Solving the questions in the Interactive Mathematics Book for Grade 10 High School, First Semester.
3. Describe each cognitive ability used in solving the questions.
4. Classifying the cognitive levels for each identified cognitive ability based on Bloom's taxonomy.
5. Analyzing the cognitive levels of the questions
6. Conclusion.

The data source used in this research is the Interactive Mathematics Book for Grade 10 High School, First Semester, published by Intan Pariwara and compiled (Blooma, 2013; Wasiłowska, 2022). Figure 2 below provides the structure of Bloom-Anderson's taxonomy and the verbs used.

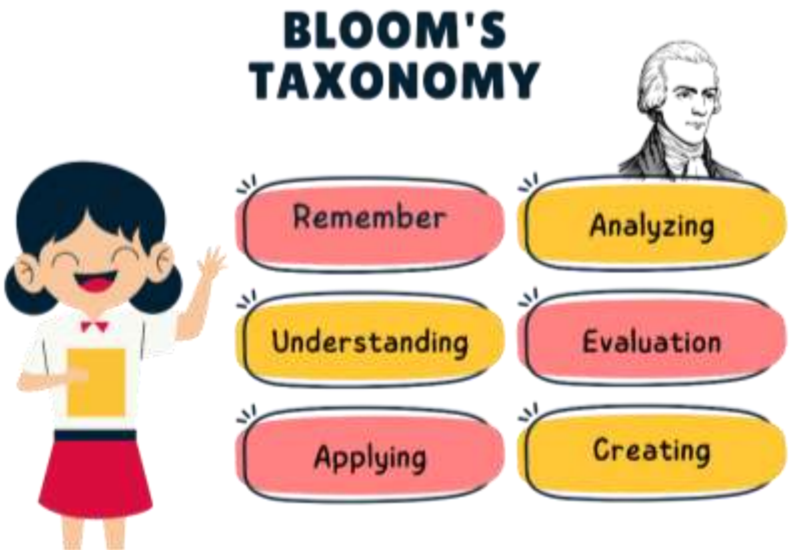


Figure 2. Bloom's Taxonomy Level

4 Results and Discussion

Based on the analysis, there are two chapters in the book, namely the chapter on exponential and logarithmic functions. The chapter on exponential functions contains three competency tests (Crowe, 2008; Rad-Menéndez, 2018), daily assessments, and mid-semester assessments consisting of 70 multiple-choice questions (Adams, 2015; Thompson, 2015), 41 short-answer questions (Azuma, 2004), and 20 essay questions (Pikhart, 2019). The distribution of cognitive levels is as follows:

Table `1. Analysis of cognitive levels in the chapter on exponential functions

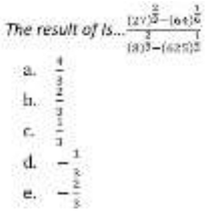
N	Cognitive Level	Percentage
1	Remembering	0%
2	Understanding	0%
3	Applying	74.8%
4	Analyzing	16.21%
5	Evaluating	5.41%
6	Creating	3.59%

The logarithmic functions chapter contains three competency tests, daily assessments, and end-of-semester assessments consisting of 80 multiple-choice questions (Nkhoma, 2017), 41 short-answer questions (Amer, 2006), and 18 essay questions (Ramirez, 2017). The distribution of cognitive levels is as follows:

Table `2. Analysis of mental levels in the logarithmic functions chapter

N	Cognitive Level	Percentage
1	Remembering	0%
2	Understanding	0%
3	Applying	58.22%
4	Analyzing	30.3%%
5	Evaluating	8.93%
6	Creating	2.56%

Based on the results, the questions in the exponential functions chapter still lack variation and proportionality. This can be seen from the high percentage of questions classified as C3 (Applying) at 74.8%. In comparison, only 3.59% of questions fall into the C6 (Creating) category, and there are no questions classified as C1 (Remembering) and C2 (Understanding). The same pattern applies to the logarithmic functions chapter, where the questions lack variation and proportionality. Again, a high percentage of questions are classified as C3 (Applying) at 74.8%, while only 3.59% of questions belong to C6 (Creating), and no questions are classified as C1 and C2.



An example of a question falling below the C3 (Applying) level can be found in the mid-semester assessment, multiple-choice question 2, as follows:

The graph is obtained by shifting the function's graph from one unit to the right and two units downward. The equation of the function is...$g(x) f(x) = 2^x g(x)$?

- $g(x) = 2^{x+1} - 2$
- $g(x) = 2^{x+1} + 2$
- $g(x) = 2^{x-1} - 2$
- $g(x) = 2^{x+2} + 1$
- $g(x) = 2^{x+2} - 1$

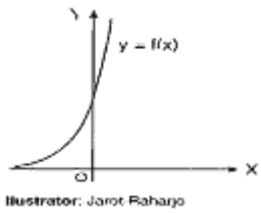
This question can be classified as C3 (Applying) because students must find the solution or solve exponential operations as stated in the question. To solve this question, students need to apply the basic concepts or principles they have learned previously, thus classifying it as an Applying-level question.

Given the statement, "The logarithmic function is defined for all real numbers, " Determine the statement's truth value.$f(x) = x^6 \log(x^2 - 2x + 4)$ x

This question can be classified as C4 (Analyzing) because students are asked to find a new function equation derived from another transformed function. To solve this question, students need to use the given initial equation and see the new equation with specific conditions, thus classifying it as an Analyzing-level question.

Another example of a question falling below the C5 (Evaluating) level is found in the end-of-semester assessment, essay question 1, as follows:

Consider the following graph.



The equation of the graph above is...

- $y = 3 \times 2^{x+2}$
- $y = 3 \times 2^{x+1}$
- $y = 3 \times 2^{x}$
- $y = 3 \times 2^{x-1}$
- $y = 3 \times 2^{x-2}$

This question can be classified as C6 (Creating) because students are asked to find the equation of the graph. However, the only information given is that the graph intersects the x-axis at the point (0.6) and is tangent to the x-axis. To solve this problem, students must plan a solution strategy to find the requested function equation, thus classifying it as a developing-level question.

Based on the results, it can be concluded that the interactive mathematics book for Grade 10 still lacks variation and proportionality in the cognitive levels of the questions. Most questions are classified as C3 (Applying) at 74.8% for exponential functions and 58.22% for logarithmic functions. C4 (Analyzing) questions account for 16.21% of exponential functions and 30.3% of logarithmic functions.

Questions organized as C5 (Evaluating) account for 5.41% of exponential functions and 8.93% of logarithmic functions. Finally, questions classified as C6 (Creating) account for 3.59% of exponential and 2.56% of logarithmic functions. It can be observed that questions are dominant at the Applying level, while questions at the Developing level have a tiny proportion. Therefore, it can be concluded that the book is suitable for practice to enhance understanding of concepts and reinforce material. Still, for higher-level questions, it may not be sufficient for training.

The analysis showed that the chapters of the book's exponential and logarithmic functions lacked variation and proportionality in the cognitive levels of the questions (Abduljabbar, 2015). Most questions were classified as C3 (Applying), indicating that students mainly applied their knowledge rather than engaging in higher-order thinking (Assaly, 2015). Questions at the C6 (Creating) level were significantly limited, indicating a lack of opportunities for students to generate new ideas or solutions.

Examples of questions from different cognitive levels were provided to illustrate the classification. It is clear that questions falling under the C3 (Applying) level dominated, while questions at the C6 (Creating) level were scarce. This imbalance suggests the need for more diverse and proportionate questions across the cognitive levels.

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The results of descriptive data analysis show that student learning outcomes before learning mathematics through the blended learning model with a STEM approach are in the deficient category with a percentage of 53%, where only five students achieved the minimum score criteria. Meanwhile, after being treated with a blended learning model with a STEM approach, 21 students out of a total of 26 students had reached the minimum assessment score criteria.

Positive student activity by applying blended learning with a STEM approach is 87%, and the percentage of harmful student activity is 13%. So, student activities that use blended learning with a STEM approach are practical because they meet the classical student activity criteria, namely,≥ 75% of students are actively involved in the learning process. The requirement that students respond positively to learning activities is that more than 75% respond positively to the number of aspects asked. A student's positive response to learning is said to be achieved if the criteria for a positive student response to learning activities are met. Based on student answers from the distributed questionnaire, data was obtained that 83% of students gave positive responses to several questions, meaning that the positive response criteria for learning activities were met. Based on the research results, students' learning outcomes, activities, and responses have met the requirements. This aligns with research by Syamsuriyawati and Setyawan (2019), which concluded that 33 students (91.67%) had achieved individual mastery, and classical mastery had been completed (Syamsuriyawati & Setyawan, 2019). Meanwhile, according to Nasution (2022), the average percentage of student activity frequency for each indicator reaches the effective criteria, namely 82.78%. The student response questionnaire showed that the student response to the probing prompting learning model was positive. Namely, 85% of the students' positive response to learning was achieved because the students' positive response criteria for learning activities were met with 86.07% (Nasution, 2022).

5 Conclusion

The interactive mathematics book for Grade 10 enhances students' understanding of concepts and reinforcing material. However, it requires further development to include a more balanced distribution of cognitive levels, particularly at higher levels of thinking. The book can better support students' critical thinking and problem-solving skills by addressing this imbalance.

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