The International Journal of Learning Spaces Studies (IJLSS)

*Homepage: https://journals.artahub.com/*

ORIGINAL RESEARCH ARTICLE

# Content Analysis of Textbook Calculus 2 (Mathematics and Physics): Evaluation by Bloom's Cognitive Taxonomy

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## ARTICLE INFO

***Article History:***
Received: 2024-08-01
Revised: 2024-09-04
Accepted: 2024-11-15
Published Online: 2025-03-01

***Keywords:***
*Bloom's cognitive taxonomy, Calculus 2, Content analysis.*

*Number of Reference:* 22
*Number of Figures:* 0
*Number of Tables:5*

***DOI:*** *10.22034/lss.2025.498202.1031*



## ABSTRACT

One of pedagogical models that helps structure learning objectives at different levels of complexity is Bloom's taxonomy. Therefore, reviewing books based on this taxonomy can help develop students' cognitive skills. In the present study, the questions of the book "Calculus 2" were analyzed based on Bloom's cognitive taxonomy. This research is descriptive-analytical that its primary goal is to gain a deeper understanding of the subject under investigation by identifying patterns, relationships, and differences within the data. Unit of analysis this research is activities, class works and exercises. The questions discussed in this research include: To what extent has attention been paid to the different levels of Bloom's cognitive taxonomy in the formulation of questions in each chapter of the book "Calculus 2"? & Which level of Bloom's cognitive taxonomy accounts for the highest percentage of this book's questions? & Which level of Bloom's cognitive taxonomy accounts for the lowest percentage of questions in this book? The results of the research indicate that the highest percentage of the book's questions are related to the "Application" level, that is, the third level of Bloom's cognitive taxonomy that indicates students' ability to apply mathematical concepts and techniques. Among of the 275 analyzed questions, only 15 questions (5.45%) are related to the "Evaluation" level that indicates a lack of opportunities for critical thinking and judgment about information. Consequently, a mathematics textbook that primarily focuses on the application level and offers limited opportunities for assessment may hinder the comprehensive development of students' cognitive skills. 

►**Citation:** Ezatti, M. & Faraji, H. (2025). Content Analysis of Textbook Calculus 2 (Mathematics and Physics): Evaluation by Bloom's Cognitive Taxonomy. *The International Journal of Learning Space Studies (IJLSS), 2(4):72-79. 10.22034/lss.2025.498202.1031*

## 1. Introduction

Bloom’s Taxonomy is arguably one of the most recognized educational references published in the twentieth century. With teaching mathematics using revised Bloom’s taxonomy by teachers, students’ mindset of activities can be adjusted based on their condition in a classroom.

The original taxonomy dates back to the 1950s when a committee of educators convened to develop language and models that could help educators design and improve curricula and assessment tasks (Alayont, Karaali & Pehlivan, 2022). This taxonomy is often used as an aid when create test questions and assignments (Shorser, 2019).

Bloom's taxonomy is a hierarchical model that categorizes learning objectives at different levels of complexity, from basic knowledge and understanding to advanced evaluation and creation (Mcleod, 2023). These goals serve as the foundation for the structure and nature of educational activities. In centralized educational systems, textbooks are central to all school-based educational endeavors; thus, it is imperative that textbooks encompass all educational objectives. It can be argued that without the application of necessary operational and educational precision in goal formulation, educational needs may remain unaddressed (Maleki, 2010). Given that content is an important educational element that gives meaning and significance to the goal; a lack of effectiveness in the content to meet educational goals can hinder the teaching-learning process. The following are some of the reasons why textbook content is important:

- Providing learning opportunities in order to realize the general and specific goals of education.
- Center for Curriculum Planning and Textbook Development creates and disseminates a textbook for each subject across all educational levels nationwide.
- Educators structure and deliver their instructional activities in accordance with the content of the textbooks, adhering to a predetermined schedule.
- The majority of assessments conducted during the academic year are derived from the materials and content presented in the textbooks.
- Following their initial compilation, textbooks undergo a revision process informed by evaluations, limited pilot implementations, and feedback from educators and subject matter experts to ensure their readiness for final deployment (Mojahed & Sadeghi, 2013).

The new perspective on mathematics education emphasizes that the passive transmission of mathematical concepts and skills by teachers does not lead to meaningful learning for learners and will never foster the growth and dynamism of their mathematical thinking. It is the learners who, through their active participation in the field of mathematics education and learning based on their prior knowledge and experiences, make mathematics an understandable and enjoyable subject. The production, stabilization, and enhancement of mathematical thinking for learners occurs when, under the guidance of the teacher, they actively participate in constructing concepts, new mathematical skills, and achieving them (Alam Al-Hodaei, 2009).

Therefore, it is essential for the textbook's content to be structured in a manner that promotes critical thinking and allows students to draw upon their existing knowledge, thereby stimulating the learning process. The presentation of the material should be deliberate and targeted, aiming to engage learners with the text and motivate them to participate actively and energetically in thoughtful and inquiry-based activities and to avoid neglect so that the necessary conditions are favorable for their intellectual education and cognitive development (Soleymanpour, 2004). The integration of cognitive processes into educational practices, while simultaneously addressing factors such as student motivation, self-organization, self-efficacy, and self-actualization, has emerged as an important focus for the educational community worldwide (Ghasemi & Belyad, 2022).

Mathematics educators and specialists possess the capability to discern the deficiencies present in textbooks through the application of content analysis, subsequently implementing measures to rectify these shortcomings. The significance of content analysis is particularly pronounced in nations with centralized educational frameworks, as opposed to those with decentralized systems. Recognizing the critical role of mathematics in education, various educational systems endeavor to integrate mathematics into their curricula, thereby fostering the cognitive development of students and enhancing their reasoning skills. This preparation is essential for equipping students to navigate the ongoing scientific and technological advancements they will encounter in their future endeavors (Ashayeri, Omidian & Haji Yakhchali, 2022).

Krippendorff & Weber (Ma'rufi & Youssefzadeh, 2010) state: "Content analysis is a systematic technique for transforming textual expressions into specific categories, based on explicit coding rules, in order to determine the emphases of individuals, groups, and messages contained in the text."

Yar Mohammadian (quoting Ranjbari, Ranjbar & Dehghani, 2021) has defined content analysis of textbooks as a systematic research method for objectively and quantitatively describing the content of books and curriculum texts or comparing messages and content structure with curriculum goal.

The taxonomy of educational objectives was first introduced in 1945. Education specialists have provided various taxonomy for educational objectives; Benjamin Bloom addressed the taxonomy of educational goals in the cognitive domain in 1956. In Bloom's taxonomy, educational objectives are divided into three categories: cognitive, affective, and psychomotor. In mathematics lessons, cognitive objectives are primarily considered. Cognitive objectives relate to processes that involve students' mental and intellectual activities.

In this regard, the cognitive domain is considered the most important area of learning. This is because most academic activities in schools and the majority of subjects and educational goals pertain to this area. Learning objectives in the cognitive domain, according to Bloom's taxonomy, include six levels, as follows (Pour Bagheri & Durnema, 2018):

1. **Knowledge**: Includes recalling specific and general facts, recalling methods and processes, and recalling patterns and previously learned material.
2. **Comprehension**: Comprehension occurs when a student can establish a connection between prior knowledge and new information. If a student can utilize various representations of a concept (including: visual, written, verbal, etc.) and has the ability to interpret each representation and convert it into another representation, they have deeply understood the concept. It is worth mentioning that the comprehension level includes interpreting, providing examples, classifying, comparing, summarizing, inferring, and explaining.
3. **Application**: Applying is essentially the actualization of learned concepts and includes the use of methods and processes to perform exercises or solve problems, consisting of two components: executing and doing.
4. **Analysis:** The ability to break down a concept into its constituent elements. At this stage, the student can test their knowledge and examine the concept from various perspectives. Analysis includes distinguishing, organizing, and attributing.
5. **Synthesis**: This includes questions which ask the student to develop their own classification system.
6. **Evaluation:** Judgment about the value of Contents and subjects for specific purposes (Seif, 2006 quoting Ranjbari, Ranjbar & Dehghani, 2021). In this category, the learner develops the ability to critique and evaluate concepts, which includes two parts: examining and critiquing.

Considering the importance of content analysis of the textbook, this research aims to evaluate the content of the 12th grade calculus textbook in the field of mathematics and physics is from the perspective of Bloom's cognitive taxonomy. Undoubtedly, the results of this research can be beneficial for educational planners and textbook authors, helping to address the deficiencies and weaknesses of the Calculus 2 textbook and contribute to the qualitative improvement and effectiveness of this resource in student learning.

## 2. Literature Review

In recent years, numerous studies have been conducted regarding content analysis in the context of Bloom's cognitive taxonomy.

Radmehr & Alam Al-Hodaei (2012) in a study titled “Revised Bloom's Taxonomy and its Application in Teaching-Learning Mathematics and Curriculum” introduced the revised Bloom's Taxonomy and its method of use, and also introduced the weak points of the original Bloom's Taxonomy. Then, they discussed the applications of Bloom's Taxonomy to improve teaching-learning and assessment methods, using four questions. In this study, the mathematical performance of students was examined according to this taxonomy. The results indicate that students' mathematical performance decreases from foundational knowledge to metacognitive knowledge, and they exhibit significant weaknesses in solving mathematical problems related to metacognitive knowledge.

Mousapour conducted a study in 2018 titled "Analysis of the Function Chapter of Mathematics and Statistics 2 for the 11th Grade Based on Three Different Models" and concluded that the application level accounted for the highest percentage of attention, while higher levels of Bloom's cognitive taxonomy were not addressed.

Karami et al. (2012) conducted a study titled "Content Analysis of the Mathematics Book for the 7th Grade Based on William Rumi's Technique and Bloom's Cognitive taxonomy ". The findings revealed that 81% of the exercises, activities, and problems in the book are at the comprehension level. This analysis showed that the number of exercises, activities, and problems at higher levels of the Bloom's cognitive taxonomy in the book is very limited.

Additionally, in a study conducted by Rabati & Kalaki (2020) titled "Content Analysis of the 9th Grade Mathematics Textbook Using the William Rumi Technique and Bloom's taxonomy" they concluded that this book is positioned at higher levels of Bloom's cognitive taxonomy in the sections of exercises and class activities.

## 3. Method

The methodology of this research is carefully structured to ensure a systematic and reliable approach to using Bloom's Taxonomy in the Book of mathematics and physics calculus 2 content analysis. The method of this research is descriptive, of the content analysis type, and applied; because the questions of the book have been examined without any modification, and descriptive statistics, namely frequency and percentage of data, have been used in data analysis. This research examines the content of the 12th grade calculus textbook in the field of mathematics and physics (published in 2018-2019) in terms of attention to the cognitive levels of Bloom's taxonomy.

For this purpose, all activities, class work, and exercises from the entire book have been examined, and the level of questions has been classified and in the following, it is determined in which field of Bloom's cognitive taxonomy each question is placed. The collected information has been described and analyzed using frequency tables and percentages; And finally, the coverage percentage of each level of Bloom's cognitive taxonomy is determined by the content of this book.

The questions discussed in this research include:

- To what extent has attention been paid to the different levels of Bloom's cognitive taxonomy in the formulation of questions (exercises, activities, and class work) in each chapter of the book "Calculus 2"?

- Which level of Bloom's cognitive taxonomy accounts for the highest percentage of questions in this book?
- Which level of Bloom's cognitive taxonomy accounts for the lowest percentage of questions in this book?

## 4. Findings

We will examine the results of the research by chapter; The frequency (It is displayed with F in the tables) and percentage (It is displayed with P in the tables) of each category of Bloom's cognitive taxonomy are noticeable in the table related to each chapter. Additionally, at the end of this section, the percentage of each level in the entire book is recorded.

### *4.1. Chapter 1*

According to Table 1, in the activities section of Chapter 1, the percentage of questions at the "Application" level is the highest, and the "Analysis" level is in second place with 25%. Among the class work questions, the highest percentage pertains to the "Application" level, and in the exercises section, most questions fall into the "Application" level. The data in the table indicates adherence to Bloom's cognitive taxonomy levels in the compilation of this chapter of the book.

***Table 1.*** *Analysis of the questions in Chapter 1 based on Bloom's cognitive taxonomy*

| | Knowledge | | Comprehension | | Application | | Analysis | | Synthesis | | Evaluation | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | F | P | F | P | F | P | F | P | F | P | F | P |
| **Activities** | 0 | 0 | 2 | 12.5 | 7 | 43.75 | 4 | 25 | 0 | 0 | 3 | 18.75 |
| **Class works** | 5 | 17.24 | 3 | 10.34 | 14 | 48.27 | 4 | 13.79 | 2 | 6.89 | 1 | 3.44 |
| **Practices** | 0 | 0 | 2 | 12.5 | 10 | 62.5 | 3 | 18.75 | 0 | 0 | 1 | 6.25 |

### *4.2.Chapter 2*

According to the table below, most questions in the activities section of Chapter 2 are at the "Understanding" and "Application" levels, and only 4 questions related to the "Analysis" level. In the class work section, questions are only at the "Understanding" and "Application" levels, with the "Application" section accounting for 60% of the questions. Additionally, in the exercises section of this chapter, the "Application" and "Analysis" levels have similar percentages. Overall the "Application" level has the highest percentage of questions in this chapter.

***Table 2.*** *Analysis of the questions in Chapter 2 based on Bloom's cognitive taxonomy*

| | Knowledge | | Comprehension | | Application | | Analysis | | Synthesis | | Evaluation | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | F | P | F | P | F | P | F | P | F | P | F | P |
| **Activities** | 1 | 4.76 | 7 | 33.33 | 7 | 33.33 | 2 | 9.52 | 0 | 0 | 4 | 19.04 |
| **Class works** | 1 | 20 | 0 | 0 | 3 | 60 | 1 | 20 | 0 | 0 | 0 | 0 |
| **Practices** | 0 | 0 | 0 | 0 | 4 | 50 | 4 | 50 | 0 | 0 | 0 | 0 |

### *4.3.Chapter 3*

Based on the information in Table 3, among the questions in the activities section of Chapter 3, the "Understanding" level has the highest percentage, while "Knowledge" and "Evaluation" have the lowest percentages. The difference between this chapter and Chapter 2 is in the percentage of questions at the "Synthesis " level in the class work section, which is considered a strength of this chapter compared to the second chapter.

Additionally, in the exercises section, the highest percentage pertains to the "Application" level of Bloom's cognitive taxonomy. Another strength of this chapter compared to the previous two is the presence of questions related to the "Synthesis" level among the questions in the exercises section.

***Table 3.*** *Analysis of the questions in Chapter 3 based on Bloom's cognitive taxonomy*

| | Knowledge | | Comprehension | | Application | | Analysis | | Synthesis | | Evaluation | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | F | P | F | P | F | P | F | P | F | P | F | P |
| **Activities** | 0 | 0 | 7 | 46.66 | 5 | 33.33 | 1 | 13.33 | 0 | 0 | 1 | 6.66 |
| **Class works** | 0 | 4.76 | 5 | 23.8 | 12 | 57.14 | 1 | 9.52 | 1 | 4.76 | 0 | 0 |
| **Practices** | 0 | 7.69 | 1 | 7.69 | 9 | 69.23 | 1 | 7.69 | 1 | 7.69 | 0 | 0 |

### *4.4.Chapter 4*

According to the data in the table, Chapter Four of the book is the only chapter that contains questions in the exercises section across all levels of Bloom's cognitive taxonomy. The highest percentage of questions in the exercises section is allocated to the "Application" level.

In the class work section, the "Application" level accounts for 56%, and in the activity section, the "Understanding" level accounts for 46.15% of the related questions, which are the highest percentages in both sections. The questions in this chapter, like those in previous chapters, have been formulated considering Bloom's cognitive taxonomy and aim to enhance the students' understanding of the subject and concept in question.

**Table 4.** Analysis of the questions in Chapter 4 based on Bloom's cognitive taxonomy

| | Knowledge | | Comprehension | | Application | | Analysis | | Synthesis | | Evaluation | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | F | P | F | P | F | P | F | P | F | P | F | P |
| **Activities** | 2 | 15.38 | 6 | 46.15 | 4 | 30.76 | 0 | 0 | 0 | 0 | 1 | 7.69 |
| **Class works** | 2 | 8 | 3 | 12 | 14 | 56 | 3 | 12 | 0 | 0 | 3 | 12 |
| **Practices** | 2 | 5.40 | 6 | 16.21 | 22 | 59.45 | 3 | 8.1 | 3 | 8.1 | 1 | 2.7 |

### *4.5. Chapter 5*

Recall that the data in Table 5, the highest percentage among the questions in the activity section is allocated to the "Understanding" level. Additionally, in the class work questions, the percentage for the "Understanding" level is the highest among all levels in this section.

In the exercises section, as in other chapters of the book, more than half of the questions pertain to the "Application" level. An important point in this chapter is the relatively good attention to the "Synthesis" level questions in the exercises, resulting in 31.57% of the questions in this section being allocated to the "Synthesis" level.

***Table 5.*** *Analysis of the questions in Chapter 5 based on Bloom's cognitive taxonomy*

| | Knowledge | | Comprehension | | Application | | Analysis | | Synthesis | | Evaluation | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | F | P | F | P | F | P | F | P | F | P | F | P |
| **activities** | 4 | 20 | 9 | 45 | 4 | 20 | 1 | 5 | 2 | 10 | 0 | 0 |
| **Class works** | 6 | 35.29 | 6 | 35.29 | 4 | 23.52 | 0 | 0 | 1 | 5.88 | 0 | 0 |
| **practices** | 0 | 0 | 1 | 5.26 | 12 | 63.15 | 0 | 0 | 6 | 31.57 | 0 | 0 |

Now, we will state the percentages of each level of Bloom's cognitive taxonomy for the entire book:

- The "Knowledge" with a frequency of 25, it has taken 9.09%.
- The "Understanding" with a frequency of 58, it has taken 21.09%.
- The "Application" with a frequency of 131, it has taken 47.63%.
- The "Analysis" with a frequency of 30, it has taken 10.90%.
- The " Synthesis" with a frequency of 16, it has taken 5.81%.
- And finally, the "Evaluation" with a frequency of for 15, it has taken 5.45%.

## 5. Discussion

Since textbooks hold a special place in the educational process, examining these books and analyzing their content to identify weaknesses and deficiencies, and consequently improve the quality of the books, is very important. Based on the results obtained in this research, it can

be said that in the compilation and authorship in book of mathematics and physics calculus 2, Bloom's cognitive taxonomy have been considered; however, the higher levels of Bloom's cognitive taxonomy have received lower percentages. On the other hand, there seems to be little consistency among the levels. In response to the second research question (which level of Bloom's cognitive taxonomy accounts for the highest percentage of questions in this book?), according to the final data (for the entire book), 47.63% of the questions in the book pertain to the "Application" level; therefore, the third level of Bloom's cognitive taxonomy has the most questions in this book. Additionally, 21.09% of the questions in the book are at the "Understanding" level of Bloom's cognitive taxonomy. The lowest percentage corresponds to the highest level of the cognitive domain, which is "Evaluation" and out of 275 questions, only 15 questions, equivalent to 5.45%, relate to the "Evaluation" level.

## 6. Conclusion

The following key points can be highlighted regarding the importance of the findings:

- Focus on the application of concepts:

Such a book primarily focuses on the application of mathematical concepts and techniques in real-life situations. This helps students learn practical skills in problem-solving and enhances their ability to use mathematical knowledge in everyday life.

- Limitations in Critical Thinking:

The lack of sufficient opportunities to evaluate and judge problems can hinder the development of students' critical and analytical thinking skills. Higher cognitive levels of Bloom's taxonomy, such as analysis and evaluation, require deeper judgment about information and outcomes. In the absence of such questions, students may only learn to solve low-level problems and may not be able to achieve a deeper analysis and understanding of the topics.

- Impact on the Learning Process:

If a textbook focuses solely on the application level, it can lead to superficial learning, without a deep understanding of fundamental concepts. Students may be able to solve problems, but without a complete understanding of the underlying principles and theories, they will not succeed in applying that knowledge in more complex contexts.

- Need for Balance in Question Levels:

To foster deeper insights and critical thinking, it is essential that textbooks include a variety of Bloom's cognitive levels. This means incorporating questions at different levels—from application to analysis and evaluation. This diversity allows students not only to learn concepts but also to critique and examine them.

- Educational Implications:

Teachers and curriculum planners must pay attention to the fact that relying on only one type of question cannot be sufficient for comprehensive learning. Therefore, there is a need to develop diverse and multidimensional educational content that encompasses all cognitive levels and helps empower students.

Ultimately, a combination of questions at different cognitive levels is essential for deeper learning and the development of real skills.

Therefore, based on the results obtained, the following suggestions are made to improve the book of mathematics and physics calculus 2:

- Textbook authors should utilize content analysis research for the revision and correction of textbooks to enhance the learning process and increase the scientific level and effectiveness of the books.
- It is suggested that teachers and researchers examine this book with other techniques, including Guilford's creativity technique and problem distribution based on context, to enhance the book's effectiveness and efficiency from all aspects.
- It is recommended that curriculum designers address higher levels of Bloom's cognitive taxonomy, such as Synthesis and evaluation, in more questions to elevate students'

academic level and their deep understanding of concepts and subjects, while maintaining a balance of levels.

- The design of questions and problems should be such that, in addition to prompting students to think and be creative, it also connects with their prior knowledge.

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