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Analysis of Student Mathematics Learning Outcomes on the Concept and Equality of Two Matrices Based on Bloom's Taxonomy

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ABSTRACT

The achievement of students in various mathematical learning materials needs to be analyzed. One of the topics that can be analyzed for its achievement is the concept and equality of two matrices. Achievements in mathematical learning should emphasize deep understanding and critical thinking abilities rather than mere memorization. Therefore, cognitive achievements in mathematics learning must be analyzed using Bloom's Taxonomy of cognitive levels to obtain a more comprehensive analysis. This study aims to classify daily test questions on the concept and equality of two matrices and describe eleventh-grade students' mathematics learning outcomes at SMAN 5 Pekanbaru for the 2022/2023 academic year, based on Bloom's Taxonomy cognitive domains. The research method used is descriptive with a qualitative approach. The subjects of this study are the eleventh-grade students of the MIPA 7 class. Based on the research findings, the mathematics learning outcomes of the eleventh-grade MIPA 7 students have reached the cognitive level of knowledge (C1) with an average percentage of 95.62% in the very good category, the cognitive level of understanding (C2) with an average percentage of 83.89% in the good category, and the cognitive level of application (C3) with an average percentage of 70.23% in the good category.

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INTRODUCTION

In the realm of education, learning is of paramount importance. Learning is a process that ensures students can effectively and efficiently optimize their cognitive, emotional, and psychomotor potential to achieve the desired behavioral changes. [1]. Formal education in mathematics helps build a strong foundation of knowledge, problem-solving abilities, and analytical thinking that are useful in various professions and areas of life [2]. Through mathematics education, students can be directed to develop critical, systematic, logical, and creative thinking abilities [3].

Mathematical learning activities conducted in formal education aim to achieve learning objectives, often referred to as learning outcomes. Learning outcomes are indicators of the success of a learning process, thereby measuring whether students have received the material from the teacher [4]. The learning outcomes achieved by a student can serve as a benchmark for their ability, willingness, and mastery over the knowledge, skills, and attitudes in a subject that has been taught after a certain period of learning activities [5].

Students' mathematics learning outcomes can be analyzed from various perspectives, including assessment, conceptual understanding, practical application, and the development of thinking skills. The approaches used can vary in assessment, ranging from written exams and quizzes to test basic knowledge to more innovative assessment methods such as projects, portfolio-based assessments, or

peer-to-peer assessments. These approaches help assess students' ability to recall information and apply concepts in real situations.

Another important aspect is students' conceptual understanding of mathematical material. This involves how students can understand mathematics's basic principles and theories rather than just memorizing formulas. Practical application is also vital, where students are challenged to use their mathematical knowledge in real-life contexts or practical problems, developing effective problem-solving skills.

Furthermore, developing critical and analytical thinking skills through mathematics education is crucial. This includes analyzing problems, identifying patterns, formulating hypotheses, and drawing logical conclusions. Technology in mathematics education, such as digital aids, educational apps, and online learning platforms, also significantly enhances students' understanding and provides a more interactive and engaging learning experience. Through a holistic approach to teaching and evaluating mathematics, educators can develop students' deep understanding of the subject and help them develop the skills necessary to succeed in the classroom and their daily lives.

Conceptual understanding, practical application, and the development of thinking skills can be achieved through mathematics education, one example being the study of matrix equality. Conceptual understanding can be seen from how students deeply understand a matrix and the principles determining the equality between two matrices. This is about memorizing definitions and understanding how matrices are organized and operated. Students can recognize patterns, relationships, and structures in matrices with a solid understanding.

Practical application can be seen in how mathematical concepts like matrix equality are brought into the real world. Matrix equality plays an important role in fields such as physics, engineering, and computer science. Through projects, experiments, and solving real-world problems, students can see how matrices address real-life issues, from image processing to solving linear equations in engineering and science. This strengthens their theoretical understanding and demonstrates the relevance of mathematics in daily life and its application across various disciplines.

Subsequently, students develop critical thinking skills such as logic, analysis, and reasoning by exploring matrix similarity concepts. By exploring various ways to prove or refute the similarity of two matrices, they learn how to hypothesize, test their ideas, and construct logical and evidence-based arguments. These skills are crucial for mathematics and problem-solving in a broader academic and professional context.

Thus, the study of the similarity of two matrices imparts mathematical knowledge to students and develops their critical thinking abilities and the capacity to apply these concepts in various practical situations, preparing them for future challenges in advanced education and their professional careers.

The progress or achievements of students need to be understood by teachers to determine if corrective action is necessary [6]. An assessment is necessary to observe these achievements after studying matrix similarity. Assessment or evaluation to understand students' learning progress and outcomes is conducted at the end of the learning process. Evaluation is collecting, analyzing, and interpreting information to determine the extent to which students achieve learning objectives [7]. The teacher is primarily responsible for students' learning outcomes in the classroom. To determine these outcomes, teachers often use summative evaluations. Summative evaluation is an assessment activity that results in a score or grade used to understand student performance, conducted at the end of a topic, mid-semester, end of semester, or during grade promotion [8]. Daily tests and mid-semester

exams are examples of summative tests.

According to [9], teachers are expected to analyze student learning outcomes to identify weaknesses, difficulties, and progress made by students after the learning process. If teachers continuously analyze student learning outcomes, they can identify weaknesses and difficulties in learning, allowing them to make improvements to maximize the cognitive domain.

One taxonomy that can be used to analyze the cognitive domain of students is Bloom's taxonomy. Bloom's cognitive domain taxonomy is a fundamental framework for classifying educational goals, helpful in assisting teachers in organizing and structuring learning [10]. This cognitive domain consists of six levels, namely [11]:

1. Remember (C1) measures the ability of students to recognize or recall information/knowledge related to concepts, facts, terms, definitions, and formulas. For example, by memorizing a formula, we can understand how to use it.
2. Understanding (C2) requires recalling and comprehending the concepts taught in written, visual, or oral forms. Students must demonstrate an understanding of simple relationships between facts or concepts.
3. Apply (C3) demands students to act and appropriately apply the concepts and facts acquired in a given situation.
4. Analyze (C4) involves students analyzing and interrelating information/knowledge to gain a comprehensive understanding.
5. Evaluation (C5) involves judging a situation, value, or idea. Evaluation in this cognitive aspect involves "good/bad" questions based on postulates, principles, and knowledge.
6. Create (C6) requires the ability to reorganize elements of a problem and create something new and original.

In mathematics education, analyzing student learning outcomes in matrix concepts and equality based on Bloom's Taxonomy is essential to pedagogical and curricular development. Developed by Bloom and his colleagues, Bloom's Taxonomy is a framework for categorizing the cognitive levels of learning, ranging from knowledge and understanding to analysis, synthesis, and evaluation. The application of Bloom's Taxonomy in the analysis of learning outcomes provides deep insights into how students understand matrix concepts and apply, analyze, and evaluate this knowledge in different contexts.

The remembering and understanding levels in Bloom's Taxonomy provide a foundation for how students can recall facts and explain the basic concepts of matrix equality. This is an important initial step but insufficient for complete mastery of mathematics. Therefore, the advanced levels of Bloom's Taxonomy, such as application, analysis, and evaluation, are crucial. At the application level, students apply their knowledge of matrices to solve practical or theoretical problems. This tests their ability to use concepts in new and often more complex situations. Analysis involves breaking down concepts into smaller parts and understanding how these parts relate to each other in the context of matrices. This skill is vital in identifying patterns and relationships, integral to mathematical thinking. On the other hand, evaluation requires students to judge the value or effectiveness of various methods or solutions in the context of matrix equality. This hones their critical thinking skills, enabling them to assess the strengths and weaknesses of different mathematical approaches.

The creating level in Bloom's Taxonomy represents the pinnacle of the cognitive learning process and is highly relevant in mathematics education. At this level, students understand, apply, analyze, and evaluate mathematical concepts and develop the ability to create, that is, to integrate the

knowledge and skills they have learned to produce something new and original. In contexts such as matrix equality, this level of creation can have significant implications for how students approach and understand mathematics.

At the creating level, students are expected to combine various elements of mathematics they have learned to generate innovative approaches, theories, or solutions. This may involve designing new methods for solving matrix problems, developing more efficient algorithms or models, or even creating practical applications of matrix concepts in everyday life or other disciplines.

The ability to create in mathematics reflects a deep understanding of existing concepts, creativity, critical thinking, and the ability to look beyond existing methods and solutions. It encourages students to be not just consumers of knowledge but also creators of knowledge. They learn to ask new questions, seek answers that don't yet exist, and challenge established understandings.

In teaching mathematics, the creating level can be encouraged through various activities, such as projects that encourage innovation, tasks that ask students to apply mathematical concepts in ways they have never done, or class discussions that encourage exploring new ideas. Overall, the creating level in Bloom's Taxonomy enriches the experience of learning mathematics by adding a dimension of creativity and innovation. It prepares students not only to master mathematical content but also to apply their knowledge in new and meaningful ways, which is important in a constantly changing world that requires innovative thinking.

Through the analysis of learning outcomes based on Bloom's Taxonomy, educators can identify strengths and areas for improvement in students' mathematical understanding and adjust teaching methods to encourage the development of higher-level cognitive skills. This also enables the development of a more balanced curriculum, which emphasizes memorization and basic understanding and application, analysis, and critical thinking skills, which are essential for student success in an increasingly complex and technology-driven world.

Based on this understanding, the researcher is interested in analyzing students' mathematics learning outcomes on the concepts and equality of two matrices based on Bloom's Taxonomy. This research aims to analyze and describe students' mathematics learning outcomes based on the cognitive domain of Bloom's Taxonomy in the concepts and equality of two matrices.

METHODS

The type of research employed in this study is descriptive research with a qualitative approach. This research was conducted at SMAN 5 Pekanbaru. The subjects of this study were students of class XI MIPA 7 at SMAN 5 Pekanbaru, totaling 37 individuals. The test data on student learning outcomes were analyzed using a percentage analysis of score attainment [12].

$$\text{Score Attainment} = \frac{\textit{Total Score Achieved}}{\textit{Maximum Possible Score}} \times 100\%$$

The categories of student learning outcomes success are presented in Table 1 [12].

Table 1. Categories of Student Learning Outcomes Success

Category Range (%)	Letter Grade	Criteria
85-100	A	Excellent
70-84	B	Good
60-69	C	Fair
0-59	D	Poor

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RESULTS AND DISCUSSION

In the context of the daily test on concepts and equality of two matrices for Class XI MIPA 7 in the academic year 2022/2023, the test comprises 5 essay questions, each with 5 sub-questions. The cognitive levels of these daily test questions for matrices for Class XI MIPA 7 at SMAN 5 Pekanbaru in the academic year 2022/2023 are described as follows:

1. At the cognitive level of remember (C1), there is one question consisting of 5 sub-questions, namely numbers 1a, 1b, 1c, 1d, and 1e. These questions are categorized at the cognitive level of remember (C1) as they require students to recall the concept of matrices (converting data from a table into matrix form).
2. There are two questions at the cognitive level of understanding (C2): numbers 3 and 4. These questions are categorized at the cognitive level of understanding (C2) because they require students to comprehend concepts such as matrix addition, matrix subtraction, and scalar multiplication of matrices.
3. At the cognitive level of apply (C3), there are two questions: numbers 2 and 5. These questions are categorized at the cognitive level C3 because they demand students to select specific concepts for calculation and to combine two or more pieces of information related to the transposition of matrices and the equality of two matrices.

Table 2. Percentage of Mathematics Learning Outcomes for Students of Class XI MIPA 7 Based on the Cognitive Domain of Bloom's Taxonomy

Student Name	Student Answer Percentage (%)					
	C1	C2	C3	C4	C5	C6
A1	100	100	100	-	-	-
A2	100	100	100	-	-	-
A3	100	100	87,5	-	-	-
A4	100	100	100	-	-	-
A5	100	75	50	-	-	-
A6	75	27	20,5	-	-	-
A7	100	100	70	-	-	-
A8	100	100	100	-	-	-
A9	100	70	27	-	-	-
A10	100	100	100	-	-	-
A11	100	65	20,5	-	-	-
A12	100	100	40	-	-	-
A13	88	100	100	-	-	-
A14	90	100	80	-	-	-
A15	100	100	97	-	-	-
A16	100	100	100	-	-	-
A17	100	32	18,5	-	-	-
A18	100	100	100	-	-	-
A19	100	40	34	-	-	-
A20	100	100	100	-	-	-
A21	50	35	22,5	-	-	-
A22	90	30	55	-	-	-
A23	100	100	87,5	-	-	-
A24	95	100	65	-	-	-
A25	100	100	87,5	-	-	-
A26	100	45	30,5	-	-	-
A27	100	60	35	-	-	-
A28	100	100	100	-	-	-
A29	100	100	100	-	-	-
A30	100	100	100	-	-	-
A31	100	100	100	-	-	-
A32	100	100	55	-	-	-
A33	100	100	52	-	-	-

A34	100	100	78,5	-	-	-
A35	100	100	100	-	-	-
A36	50	25	15	-	-	-
A37	100	100	70	-	-	-

Table 3. Percentage Results for Each Cognitive Domain

Cognitive Domain	Percentage (%)	Category
C1	95,62	Excellent
C2	83,89	Good
C3	70,23	Good

Based on the detailed analysis presented in Table 3, it is evident that the matrix material daily quiz questions covered the cognitive levels of remember (C1), understand (C2), and apply (C3). The average percentage of cognitive levels in class XI MIPA 7 are as follows: (a) remember level (C1) at 95.62%, categorized as excellent; (b) understand level (C2) at 83.89%, categorized as good; (c) apply level (C3) at 70.23% also categorized as good. Common errors made by students included mistakes in naming matrix elements and misconceptions in combining the concept of matrix equality with transposition, among others.

Previous research conducted by Amelia et al. (2016) indicated that student learning outcomes in mathematics were quite good in the daily quiz on the topic of sets, with cognitive level percentages as follows: (a) remember level (C1) at 92.5%, categorized as excellent; (b) understand level (C2) at 61.2%, categorized as sufficient; and (c) apply level (C3) at 71.2%, categorized as good. Furthermore, research by [13] on the daily quiz topics of triangles and quadrilaterals also showed satisfactory mathematical learning outcomes, as demonstrated by the cognitive level percentages: (a) remember level (C1) at 41.67%, categorized as poor; (b) understand level (C2) at 91.67%, categorized as excellent; (c) apply level (C3) at 66.67%, categorized as good; and analyze level (C4) at 91.67%, categorized as excellent.

In the study conducted with class XI MIPA 7 students at SMAN 5 Pekanbaru for the academic year 2022/2023 on the understanding of concepts and equality of two matrices, the results provide profound insights into the effectiveness of teaching methods and student understanding in the cognitive domain of mathematics. The daily quiz, designed to assess remember (C1), understand (C2), and apply (C3) levels, has yielded significant data.

The remember level (C1) achieved a high success percentage (95.62%), indicating that most students successfully recalled and identified basic matrix concepts. This skill includes transforming data from tables into matrix form. Such proficiency is a fundamental foundation in matrix mathematics understanding, and high scores at this level indicate the effectiveness of prior basic education and the teaching in class XI MIPA 7.

In the understanding domain (C2), students scored 83.89%, also falling into the good category. This indicates that most students could interpret basic concepts of matrix operations such as addition, subtraction, and scalar multiplication. They could differentiate between various operations and understand how each functions in the context of matrices. Although there were some errors in understanding, most students demonstrated solid conceptual comprehension.

The apply level (C3) scored lower than C1 and C2, with a percentage of 70.23%. This indicates that although students understand the basic concepts and operations of matrices, they encounter more difficulties when required to apply these concepts in more complex situations, such as determining the equivalence of two matrices or combining information from the transpose of a

matrix. These difficulties may arise from the demands of applying knowledge in new or more complex contexts, necessitating further critical thinking and problem-solving abilities.

Common mistakes students make include errors in naming matrix elements and applying the concept of combining the equivalence of two matrices with their transpose. These errors could indicate deeper conceptual or applicative misunderstandings that need to be addressed by teachers through more innovative and interactive teaching approaches.

The results of this study have several important implications. First, the high scores at level C1 indicate that the teaching approach used successfully imparts basic matrix concepts. However, the decline in scores from C1 to C3 suggests that students experience more difficulty when introduced to tasks requiring deeper conceptual understanding and practical application.

Strong conceptual understanding (C2) is crucial as a bridge between remembering facts (C1) and applying them in real-life situations (C3). Therefore, teachers should focus on teaching that emphasizes memorization and a deep understanding of these concepts. Classroom discussions, demonstrations, and real-life case examples can enhance this understanding.

In the context of application (C3), students should be given more opportunities to apply their knowledge in various situations, including non-standard or critically challenging ones. Using case studies, group projects, and open-ended problems can stimulate analytical and creative thinking in students. Additionally, constructive feedback from teachers is vital in helping students understand and correct their mistakes.

Integrating technology into learning can also enhance the understanding and application of matrix concepts. Tools such as matrix processing software, educational apps, and interactive platforms can give students a more dynamic and engaging learning experience, allowing them to explore and practice concepts more interestingly.

Finally, this study underscores the importance of continually evaluating teaching methods and curricula. This helps identify areas where students may need additional support and provides valuable feedback for teachers in planning and adjusting their teaching strategies.

This study indicates that while the student subjects generally have a good understanding of basic matrix concepts, there is a need for teaching methods more focused on developing conceptual understanding and application skills. Innovative teaching approaches, the use of technology, and an emphasis on critical thinking are key to enhancing student competencies in mathematics, particularly in matrices. These conclusions are important for guiding future curriculum development and teaching methods.

CONCLUSIONS AND SUGGESTIONS

Based on the data analysis and discussion, it can be concluded that the percentage of each cognitive level in Bloom's Taxonomy for the mathematics learning outcomes of the 11th-grade MIPA 7 students at SMAN 5 Pekanbaru for the academic year 2022/2023 is quite satisfactory. This is evident from the mathematics learning outcomes of the students, which have reached the cognitive level of knowledge (C1) with an average percentage of 95.62%, categorized as excellent, the cognitive level of understanding (C2) with an average percentage of 83.89%, categorized as good, and the cognitive level of application (C3) with an average percentage of 70.23%, also categorized as good.

The recommendation that can be given based on the research findings is the need for more in-depth and practical teaching strategies in the context of C2 and C3, where basic concepts of matrices are integrated into real-life situations or more complex problems. Teachers must provide more

opportunities for applicative practice, assist students in connecting theory with practice, and enhance their problem-solving skills.

An instructional approach tailored to the topics and learning needs of the students, along with the need for continuous evaluation of teaching methods to ensure that all cognitive aspects of the students are facilitated, should also be considered. This means that research can be conducted not only on matrix material but also on other mathematical topics.

Furthermore, the difficulties experienced by students at the application level (C3), such as in identifying matrix elements and errors in the concept of combining the equality of two matrices with transposition, indicate that students need more practice and a deeper understanding of these aspects. Teachers might need to introduce more diverse examples, case studies, or simulations that allow students to apply concepts in various contexts.

The findings of this research can provide insights for curriculum developers and educational policymakers in evaluating and enhancing teaching materials and methods in mathematics. By understanding where students face difficulties and where they excel, teaching approaches can be adjusted to support more effective and comprehensive learning in mathematics and other subjects that require critical thinking and applicative skills.

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