AXIOM : Jurnal Pendidikan dan Matematika
(2024) Volume 13, No. 2, Page 244-253
https://doi.org/10.30821/axiom.v13i2.22124

Evaluating the influencing factors high order thinking skills of outstanding student by analytic hierarchy process (AHP) method

Dame Ifa Sihombing*, Tutiarny Naibaho, Adi Suarman Situmorang
Universitas HKBP Nommensen, North Sumatra, Indonesia.
*Correspondence: damesihombing@uhn.ac.id

Received: 19 October 2024 / Accepted: 27 December 2024 / Published Online: 31 December 2024

Abstract
This study aims to identify various factors that influence the development of higher-order thinking skills (HOTS) in the Master's program of the Mathematics Education Department at Universitas HKBP Nommensen. The systematic Analytical Hierarchy Process (AHP) method allows for accurate weighting and prioritization of these factors. The results provide a robust foundation for policy recommendations and educational practices aimed at enhancing higher-order thinking skills among outstanding students. The factors influencing HOTS among 100 outstanding students in the Master's program in Mathematics Education were ranked using a hierarchical analysis of one factor over another. By examining three criteria and ten sub-criteria, it was concluded that Criterion 2, or students, is the most influential factor in determining students' HOTS, with a weight of 0.53. The second most influential factor is Criterion 1, or lecturers, with a weight of 0.13. The least influential factor is the learning environment, with a weight of 0.07. Matrix interpretation reveals that the Lecturer factor (K1) is considered more important than the Student factor (K2) and the Learning Environment factor (K3) in influencing the HOTS of high-achieving students. This underscores the significant role of lecturers in fostering the development of higher-order thinking skills.

Keywords: Analytic hierarchy process, Higher order thinking skills, Institution related factors, Lecturer related factors, Student related factors

How to Cite: Sihombing, D.I., Naibaho, T., & Situmorang, A.S. (2024). Evaluating the influencing factors high order thinking skills of outstanding student by analytic hierarchy process (AHP) method. *AXIOM : Jurnal Pendidikan dan Matematika, 13*(2), 244-253. https://doi.org/10.30821/axiom.v13i2.22124

Introduction

The world of education has increasingly recognized the importance of Higher-Order Thinking Skills (HOTS) as emphasized by policymakers, educators, researchers, and the general public (Abosalem, 2016; Elfeky, 2018; Garcia, 2015). HOTS is a crucial element in the teaching and learning process, as thinking skills are a fundamental aspect of education. An individual's mindset can significantly influence their learning ability, speed, and effectiveness. Therefore, thinking skills are inherently linked to the learning process. Students trained to think critically and reflectively tend to exhibit positive progress in their educational development (Benidiktus, 2016). Analysis of previous research (Hwang et al., 2017) identified three main components of HOTS: problem-solving, critical thinking, and creativity. The ability to find, analyze, and apply appropriate solutions is essential for problem-solving

(Gong et al., 2020). Critical thinking involves objective analysis, rational thinking, and sound assessment of available information. Meanwhile, creativity encompasses the ability to generate new ideas, creative objects, and innovations through deep reflection, analysis, and evaluation of existing concepts. Higher-order thinking skills enable individuals to understand complex concepts, going beyond mere recall to higher cognitive abilities. These skills help students prepare to face challenges, difficulties, questions, or confusion. Consequently, student success can often be predicted by their higher-order thinking skills (Benidiktus, 2016; Tanujaya et al., 2017). Experts argue that HOTS is an integral part of 21st-century skills, which are essential for the younger generation in preparing for the future (Ananiadou & Claro, 2009; Chalkiadaki, 2018; Hwang et al., 2017; Yang, 2018). It is therefore important for educators to identify and implement learning environments that foster the growth of students' HOTS (Collins, 2014; Husamah et al., 2018).

Several previous studies have investigated the correlation between learning environment preferences, learning motivation, learning strategies, and learning interactions in various educational contexts. Classroom preferences may impact students' learning motivation in a technologically supported classroom environment (Gong et al., 2020; MacLeod et al., 2018; Zaharin et al., 2018). Meanwhile, Li et al. (2019) found that students' preferences for Internet-based, constructivist learning environments were related to their learning strategies and achievements. Higher-order thinking skills (HOTS) are influenced by various factors. Saptono et al. (2020) found that variables such as students' self-concept, family environment, and learning environment positively impacted their higher-order thinking skills. Heong et al. (2016) and Ichsan et al. (2019) found that curriculum, teaching methods, and learning requirements are crucial in improving students' thinking skilll. Yusoff and Seman (2018) stated that educators' knowledge of higher-order thinking skills is an important component in enhancing students' HOTS at the elementary level. Jerome et al. (2017) similarly stated that subjects, activities, and learning approaches are essential components in improving students' HOTS at the elementary level. Yusoff & Seman (2018) further indicated that teachers often lack knowledge of higher-order thinking skills, and their evaluation processes are ineffective in teaching these skills.

Currently, research involving students' perspectives on the correlation between important factors in student learning and higher-order thinking skills (HOTS) in the context of high-achieving students is still very limited. The only recent study conducted by (Lu et al., 2020) explored the influence of students' learning motivation, learning styles, and attitudes toward the internet on their HOTS abilities in the classroom. This study analyzed data from 758 students and found that learning styles and attitudes toward the internet have a direct influence on students' HOTS abilities, whereas learning motivation did not show a significant impact. However, the influence of other key learning factors on HOTS in high-achieving students remains unclear. Furthermore, there are still few studies investigating the relationship between key factors influencing student learning and their HOTS abilities in a high-achieving classroom environment (Zohar & Agmon, 2018).

This indicates that the environment of high-achieving students can stimulate their learning motivation, encourage active learning, and improve academic performance. However, the impact of the environment on students' higher-order thinking skills (HOTS) is still uncertain.

From several existing studies, it was found that learning styles and attitudes towards the internet have a direct influence on students' HOTS abilities, while learning motivation does not show a significant impact. Therefore, this study aims to examine the factors that influence the HOTS of high-achieving students in order to help educators and curriculum designers develop better learning opportunities and more effective assessment tools. Understanding the components that influence HOTS can aid teachers and curriculum designers in creating better learning environments and assessment tools.

To compile the factors that influence higher-order thinking skills (HOTS), an appropriate method is required. One of the methods that can be utilized is the Analytical Hierarchy Process (AHP). This method, developed by mathematician Thomas L. Saaty, assists in solving complex problems by organizing a hierarchy of criteria, stakeholders, and outcomes, and by considering various factors to determine weights or priorities. This method is relevant and includes the calculation of consistency values in determining the priority levels of criteria choices (Garside & Kristiandy, 2014; Munthafa & Mubarok, 2017). Therefore, in this study, the Analytical Hierarchy Process (AHP) method will be used to analyze the components that influence the HOTS of high-achieving students (Hozairi et al., 2022).

Method

This study employs a quantitative descriptive method with the aim of developing an optimal structural model that elucidates the interconnected factors influencing higher-order thinking skills (HOTS) among outstanding students. Data collection was conducted through a questionnaire distributed via Google Forms to 50 postgraduate students in the Mathematics Education Master's program. The questionnaire captured the preferences of outstanding students in learning related to lecturers, students, and the learning environment. This research was conducted during the first semester of the 2024/2025 academic year, from September to October 2024. The analysis and interpretation of this research began with identifying the problem, determining the research objectives, reviewing the literature, compiling a hierarchy of research objectives (criteria, sub-criteria, and alternatives), analyzing the questionnaire results, and processing the data using the Analytical Hierarchy Process (AHP) method to identify the most influential factors. The three main criteria used in this study are Lecturers (K1), Students (K2), and Learning Environment (K3), as detailed in Table 1.

Table 1. Hierarchical Analysis of Factors Influencing HOTS of High-Achieving Students

Code	Factors Influencing University Students' HOTS	Sub-Criteria Code	
K1	Lecturers	SK11	Lecturer's understanding of HOTS
		SK12	Professionalism
		SK13	Learning strategies
		SK14	Evaluation Process
K2	University Students	SK21	Attitude towards learning
		SK22	Motivation to learn
		SK23	Students' Internal Locus of Control
K3	Learning Environment	SK31	Campus Facilities and Amenities
		SK32	Administration
		SK33	Curriculum

Source: (Bhattacharya & Mohalik, 2021)

The principles of the Analytical Hierarchy Process (AHP) used in problem-solving include decomposition, comparative judgment, synthesis of priorities, and logical consistency. After defining the problem, it is decomposed into components that form a hierarchy of criteria and sub-criteria. Each criterion and sub-criterion is then assessed and compared according to its level of importance using a comparison scale developed by (Saaty, 2008). To ensure consistency in the assessment of criteria, the AHP method incorporates a Consistency Index (CI) value, calculated based on the consistency ratio of the AHP method, as shown in Table 2.

Table 2. Random Index (RI)

Number of Criteria (n)	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
RI_n	0	0,58	0,90	1,12	1,24	1,32	1,41	1,45	1,49

The maximum eigenvalue (λ_max) serves as the basis for measuring the consistency of a matrix. The closer the λ_max value is to the number of elements (n), the more consistent the results. The Consistency Index (CI) measures deviation and is calculated using Formula (1)

$$CI = (\lambda maks - n) / (n - 1) \quad (1)$$

Notes:
CI : Consistency Index
λmaks : Maximum eigenvalue
n : Number of elements

The maximum eigenvalue of a matrix will never be smaller than n, so the CI will never be negative. The Consistency Ratio (CR) is the ratio between the CI and the RI of a matrix, calculated using Formula (2).

$$CR = CI / RI \quad (2)$$

Notes:
CI : Consistency Index
CR : Consistency Ratio
RI : Random Index

If the Consistency Ratio meets the Random Index category, this guarantees the consistency of assessment in decision-making.

Results

The study results reveal a comprehensive hierarchical structure for analyzing factors that influence higher-order thinking skills (HOTS) in high-achieving students. This hierarchy consists of three main levels: (1) Objectives: The top level of the hierarchy sets the primary objective of the analysis, which is to identify the factors that most influence HOTS in high-achieving students. (2) Criteria: The second level comprises three main criteria: Lecturers

(K1), Students (K2), and Learning Environment (K3). Each criterion represents a key aspect of the learning ecosystem that has the potential to influence the development of HOTS. (3) Sub-criteria: The third level breaks down each main criterion into more specific sub-criteria, enabling a more detailed analysis of the factors contributing to HOTS, as detailed in Table 1.

After conducting an assessment based on the distributed questionnaire, Table 3 presents a comparison matrix of the importance levels of each element.

Table 3. Pairwise Comparison Matrix Between Criteria

	Criteria 1	Criteria 2	Criteria 3
Criteria 1	1	0,14	3
Criteria 2	7	1	5
Criteria 3	0,33	0,2	1

The same approach is applied to the assessment of sub-criteria 1, sub-criteria 2, and sub-criteria 3, resulting in a pairwise comparison matrix as shown in Table 3. The next step involves testing the consistency of the assessment by calculating the maximum lambda (λ_max) for each row to obtain a consistency ratio, as shown in Table 4.

Table 4. Results of Calculating the Maximum Lambda for Each Criterion

	Number of Rows	Priority
K1	0,44	0,13
K2	4,18	0,53
K3	0,22	0,07

The sub-criteria assessment using Formula (1) is conducted to obtain the maximum lambda value for each row of each sub-criteria, as shown in Table 5, Table 6, and Table 7.

Table 5. Results of Calculating the Maximum Lambda for Sub-criteria 1

	Number of Rows	Priority
SK11	0,89	0,20
SK12	2,45	0,54
SK13	0,77	0,19
SK14	0,28	0,06

Table 6. Results of Calculating the Maximum Lambda for Sub-criteria 2

	Number of Rows	Priority
SK21	0,65	0,21
SK22	2,25	0,68
SK23	0,30	0,10

Table 7. Results of Calculating the Maximum Lambda for Sub-criteria 3

	Number of Rows	Priority
SK31	0,77	0,23
SK32	0,42	0,13
SK33	2,23	0,62

Next, after obtaining the λ_{maks} value based on Formula (1) and (2), the Consistency Index (CI) and Consistency Ratio (CR) values are calculated to ensure the assessment's consistency, with the condition that the CR value <1 according to Table 2. Based on the results of the consistency ratio calculation, it can be concluded that the comparison of the

importance levels of each factor influencing the HOTS of outstanding students is consistent with the guidelines by (Saaty, 2008). The next step involves analyzing the obtained priorities.

The ranking of priority levels is derived from a survey of 50 outstanding postgraduate students at HKBP Nommensen University using a hierarchical approach based on their respective importance levels. Figure 1 illustrates a simulation of the AHP method.

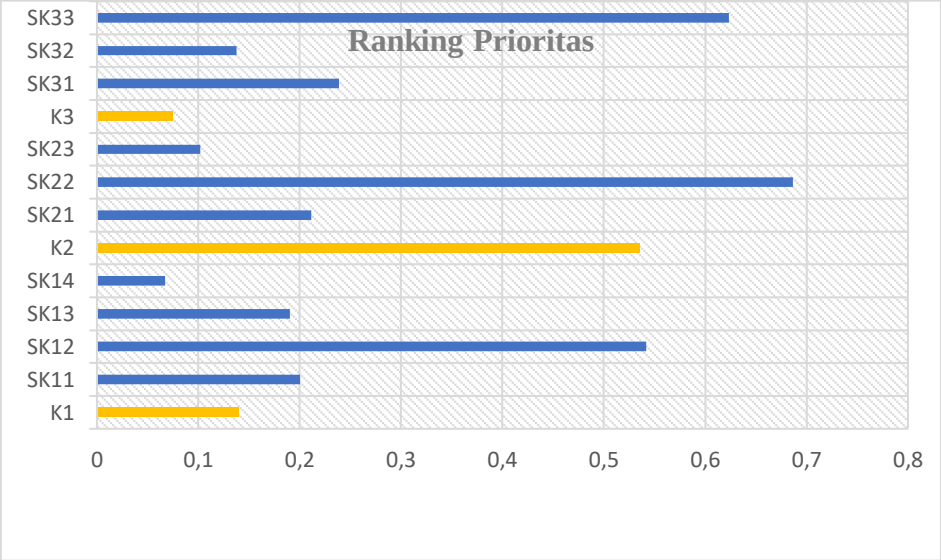

Figure 1. Results of the Ranking of Factors That Most Influence the HOTS of High-Achieving Students in the Postgraduate Program at HKBP Nommensen University

Interpretation of the matrix based on Figure 1 shows that the Lecturer factor (K1) is considered more important than Students (K2) and Learning Environment (K3) in influencing the HOTS of high-achieving students, with rankings of 0.53, 0.17, and 0.07, respectively. This underscores the crucial role of lecturers in facilitating the development of high-level thinking skills. Further analysis of this matrix, including the calculation of eigenvalues and eigenvectors, will provide more precise weightings for each criterion, enabling more accurate prioritization of factors that influence HOTS.

Additionally, this study explains that each criterion has sub-criteria that indicate their importance in decision-making. In Criterion 2, the first priority is student learning motivation. For Criterion 1, the top priority is the professionalism of lecturers in teaching related to HOTS. Criterion 3 ranks the college curriculum as the most important. The results reveal that for the most influential criterion, Students, the sub-criterion related to student learning motivation is paramount. For the Lecturer criterion, the sub-criterion related to the lecturer's professionalism holds the highest importance. Lastly, for the Learning Environment criterion, the sub-criterion related to the learning environment itself is most significant.

Discussion

The ability to employ various cognitive strategies for problem-solving and achieving goals is referred to as higher-order thinking skills (HOTS). To effectively make decisions, generate solutions, and address challenges, students must comprehend and practice these skills. Field evidence (Xia, 2017) indicates that the HOTS levels of students remain low

across all educational levels, necessitating efforts to enhance these skills for student development.

The development and implementation of diverse learning models, teaching methods, teaching materials, student worksheets, and learning media can significantly contribute to improving students' HOTS. This study demonstrates that lecturers' knowledge of higher-order thinking skills is crucial in fostering these abilities in students, especially those who excel. Yusoff & Seman (2018) concur that the absence of educators' knowledge about higher-order thinking skills is a factor hindering the development of these skills.

The analysis of factors influencing HOTS in 50 outstanding students in the Master's program in Mathematics Education utilized a hierarchical approach. By examining three criteria and ten sub-criteria, it was found that Criterion 2, or students, is the most significant factor in determining students' HOTS, with a weight of 0.53. The second most influential factor is Criterion 1, or lecturers, with a weight of 0.13, and the least influential factor is the learning environment, with a weight of 0.07.

This study also elucidates that each criterion has sub-criteria indicating the priorities in decision-making. For the most influential criterion, namely students, the sub-criterion is student learning motivation. This is supported by previous research, which states that students' higher-order thinking skills (HOTS) are directly influenced by their motivation and learning style. The following section will elucidate the relevant factors influencing students' higher-order thinking skills in the context of smart classes and provide suggestions for improving these skills at the elementary school level (Gopalan & Gozali, 2019).

In the second priority criterion, namely lecturers, the sub-criterion with the most influence is the professionalism of teaching lecturers. The third influencing factor is the learning environment, with the most prioritized sub-criterion being the curriculum structure. Research by Ichsan et al. (2019) also emphasizes that enhancing the learning environment is crucial for developing students' HOTS. The study demonstrates that significant changes in curriculum and technological advancements play a pivotal role in HOTS. In today's technological era, students can easily access a wealth of information via the internet. However, they need to discern and utilize only valid information, which broadens their knowledge. Conversely, technology also presents the challenge that not all available information can be verified for accuracy.

Furthermore, this study revealed that appropriate teaching strategies from lecturers, a well-structured curriculum, students' achievement motivation, and internal self-control positively impact the development of higher-order thinking skills in high-achieving students. The hierarchical structure of this study facilitates systematic AHP analysis, allowing for accurate weighting and prioritization of the various factors that influence HOTS. These results provide a strong foundation for educational policy and practice recommendations aimed at improving higher-order thinking skills among high-achieving students.

Conclusion

Lecturers' competence in high-order thinking skills (HOTS) and their application in the classroom, along with students' motivation to practice analytical skills and the creation of a supportive curriculum structure, are crucial for developing high-level thinking skills among

high-achieving students. Teachers' self-efficacy in applying high-level thinking skills in the classroom, students' attitudes towards instilling analytical, evaluative, and creative skills, and the institution's curriculum structure greatly contribute to developing students' high-order thinking skills.

The study results indicate that there are three main criteria related to lecturers, students, and institutions (curriculum). All main criteria function as factors influencing the development of high-order thinking skills among outstanding students in the Master of Mathematics Education program at HKBP Nommensen University. Educators, academics, and researchers can implement various strategies such as curriculum revision and training for educators related to HOTS-based learning, facilitating the development of students' high-order thinking skills. Understanding the components that influence HOTS can help lecturers and curriculum designers create better learning opportunities and develop more effective assessment tools.

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