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Analyzing students' mathematical conceptual understanding of functions in senior high school

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Abstract

This study aims to analyze students' mathematical concept understanding ability on function material in class XI of SMA Islam Sabilurrosyad Gasek Malang in the 2024/2025 academic year. The research method used is a qualitative approach with a case study. Data were collected through interviews with teachers and students, classroom observations, and concept understanding tests. Interviews were conducted to explore factors that influence student understanding, observations were used to see student interactions with the material and teaching methods applied, and tests were used to identify student misconceptions. The collected data were analyzed to determine the main themes related to students' difficulties in understanding the concept of functions and the misconceptions that occurred. The study results showed that there were difficulties for students in understanding the concept of functions, which were caused by factors such as ineffective teaching methods and a lack of practice. Based on these findings, it is recommended that teachers improve their teaching methods and provide more varied exercises to improve student understanding. The implications of this study show the importance of an interactive and contextual teaching approach in conveying mathematical concepts. As a practical recommendation, teachers are advised to use visual learning media and provide constructive feedback to help students build a deeper understanding of concepts.

Keywords: functions, gasek malang, sabilurrosyad islamic high school, understanding of mathematical concepts.

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INTRODUCTION

In advanced learning, students are required to have high-level thinking skills that include examination, assessment, and creativity in understanding problems. HOTS are the main focus of learning in schools. In the context of science, HOTS not only teaches students to memorize and apply equations, but also to think critically and find solutions to various complex and different problem situations (Abraham et al., 2021). Therefore, the application of HOTS-based questions is very important to develop students' creativity and problem-solving abilities. The importance of developing high-level thinking skills through HOTS questions has been widely discussed in various studies emphasizing the need for innovative assessment in the 21st century (Ichsan et al., 2020) teacher. Research shows that the application of HOTS in mathematics learning can significantly improve students' cognitive and affective skills. For example, HOTS questions can hone students' analytical skills, critical thinking skills, and creativity in solving problems that are not only routine but also those that require original solutions. However, the application of HOTS questions in the classroom does not always run smoothly. Many teachers and students have difficulty understanding and applying these concepts in the learning process.

One of the biggest challenges in implementing HOTS questions is from the teacher's side.

According to Arafah et al (2021), many mathematics teachers have difficulty in implementing HOTS-based questions, especially in learning planning. This study shows that teachers often have difficulty in compiling questions that truly challenge students' high-level thinking skills. This problem includes a lack of understanding of how to design questions that follow HOTS dimensions, as well as how to structure learning that encourages students to think critically and creatively. In addition, research conducted by Mardiana (2021) highlighted that many teachers are not accustomed to using learning methods or strategies that support the implementation of HOTS. Teachers tend to focus more on delivering material in a conventional way, where students are only invited to memorize formulas and procedures without really understanding the underlying concepts. This causes students to be unfamiliar with the types of questions that require thinking skills outside of routine procedures.

Therefore, it is necessary to improve teacher competence in implementing HOTS-based learning, including in designing questions that are more intellectually challenging often supported by teacher guidance programs (Izzati et al., 2020). From the student's perspective, difficulty in solving HOTS questions is also a crucial issue. Kairuddin (2020) stated that many students have difficulty understanding HOTS questions because they are not yet accustomed to the type of questions that require in-depth understanding and critical thinking. Students tend to be accustomed to routine questions that only require the application of procedures or formulas that have been taught, without having to think further to analyze more complex situations. This difficulty is not only related to the understanding of mathematical concepts, but also to the lack of skills in analyzing problems, evaluating solutions, and creating alternative solutions. For example, in questions that ask students to find the best solution from several alternatives, students often only apply one approach without considering the possibility of other, more efficient or creative solutions (Busyairi & Sinaga, 2015). This shows that students need more practice and guidance in dealing with HOTS questions that require high-level thinking skills.

Previous research states that PBL has been widely recognized as an effective strategy to improve students' high-level thinking skills and imagination. The application of PBL in mathematics learning allows students to participate effectively in the learning process by understanding real problems that are relevant to life. Thus, PBL empowers students to think fundamentally and creatively in finding solutions to the problems they face (Rahman, 2023). Research by Utami, (2023) shows that the application of PBL can advance students' creative thinking skills. In this study, students involved in problem-based learning were able to provide imaginative and unique solutions in understanding HOTS problems. Students also showed improvements in explanatory and evaluative skills, which are the basis for dealing with scientific problems. PBL not only encourages the development of students' cognitive abilities but also allows them to learn independently and be responsible for their learning preparation.

The application of HOTS questions in mathematics learning is very important to foster critical thinking and problem-solving skills. Nursyifa et al, (2020) showed that the development of HOTS-based teaching materials can significantly improve students' ability to solve mathematical problems. These teaching materials require students to analyze problems, make hypotheses, and assess various possible answers before determining the most appropriate answer. In addition, HOTS learning based on critical thinking skills for mathematics teachers also has a positive impact on classroom learning (Khotimah & Sari, 2020). Teachers who are trained in compiling HOTS questions will be better able to motivate students to think critically and imaginatively. Thus, the application of HOTS questions not only affects students' cognitive learning outcomes but also fosters their emotional abilities, such as motivation and interest in learning.

Overall, the application of HOTS questions in mathematics learning has a significant impact on

the development of students' creativity and problem-solving abilities. However, the challenges in its implementation, both from the teacher and student side, need to be overcome by providing appropriate training and coaching. Teachers need to be better prepared in designing HOTS-based learning, and students need more practice to get used to questions that require high-level thinking skills. Thus, further research needs to be conducted to examine in more depth the effectiveness of the application of HOTS questions in various learning contexts.

METHODS

The method used in this study is qualitative library research, which aims to strengthen students' spiritual conditions through Islamic mathematics learning. This study refers to the qualitative data analysis strategy of Miles and Huberman, which includes three stages, namely data reduction (filtering and selecting relevant data), data presentation (arranging data in narrative or visual form), and drawing and verifying conclusions (formulating and ensuring meaningful findings). Qualitative research itself is a process of understanding human or social phenomena comprehensively and complexly through the expression of words (Walidin et.al, 2015). The data collection strategy is carried out by tracing and analyzing various written sources such as books, scientific journals, research articles, illustrated stories, and other scientific works. The literature review process is carried out systematically using keywords such as "HOTS mathematics questions", "student creativity", and "mathematics problem solving" through trusted sources such as Google Scholar, DOAJ, and accredited national journals. The stages of implementing the literature study follow Zed's opinion (Fadli, 2021), namely planning research instruments and materials, planning workbook indexes, arranging study time, and the process of reading and recording research materials. The inclusion criteria in this study were articles that discussed the application of HOTS questions in mathematics learning, published in the last ten years, and used a qualitative or conceptual approach, while irrelevant articles, only discussed technical aspects of mathematics, or were not available in Indonesian or English, were excluded from the analysis. The research flow in this article is explained through Figure 1.

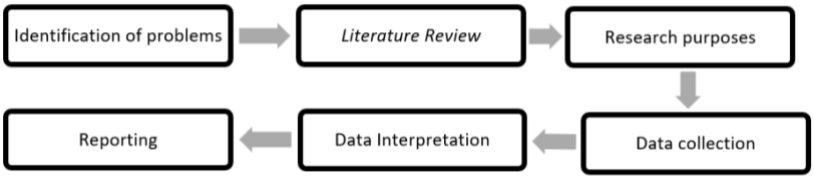

Figure 1. The research flow

The provided flowchart illustrates a standard research methodology, commencing with the Identification of Problems, where the research question or gap in knowledge is pinpointed. This is followed by a comprehensive Literature Review to contextualize the problem within existing knowledge and theories. Subsequently, clear Research Purposes are formulated to guide the study's objectives. The core of the investigation then proceeds with Data Collection, employing suitable methods to gather relevant information, which is then thoroughly processed and analyzed during Data Interpretation to derive meaningful insights. Finally, the findings, analyses, and conclusions are formally presented in the Reporting phase, completing the research cycle.

Table 1. List of Journals from the Las 10 Years

No.	Year	Title

1	2015	Strategi Pembelajaran Creative Problem Solving (CPS) Berbasis Eksperimen untuk Meningkatkan Kemampuan Kognitif dan Keterampilan Berpikir Kreatif
2	2018	Pengembangan Bahan Ajar Matematika Berbasis Higher Order Thinking (HOTS) untuk Meningkatkan Kemampuan Pemecahan Masalah Mahasiswa PGSD.
3	2019	Menilik Konsep Kemampuan Berpikir Tingkat Tinggi (Higher Order Thinking Skills) dalam Pembelajaran Matematika
4	2021	Analisis Minat dan Motivasi Belajar, Pemahaman Konsep, dan Kreativitas Siswa Terhadap Hasil Belajar Selama Pembelajaran Dalam Jaringan
5	2022	Profil Tingkat Kesulitan Guru Matematika dalam Penerapan Pembelajaran Berbasis HOTS Ditinjau dari Dimensi Perencanaan
6	2023	Efektivitas Pendekatan Open-Ended pada Pembelajaran Matematika untuk Meningkatkan Kemampuan Berpikir HOTS Matematis Siswa SMP
7	2023	Investigasi Kesulitan Siswa dalam Menyelesaikan Masalah HOTS Matematika
8	2023	Penerapan Model Pembelajaran Problem Based Learning dalam Meningkatkan Keterampilan Berpikir Tingkat Tinggi (HOTS)
9	2024	Pelatihan Soal HOTS (Higher Order Thinking Skills) Berbasis Kemampuan Berpikir Kritis Bagi Guru Matematika Kota Sungai Penuh
10	2024	Pengajuan Masalah Berorientasi HOTS: Kreativitas Calon Guru Matematika

RESULTS AND DISCUSSION

Characteristics of HOTS Mathematics Questions

HOTS is a complex thinking ability that includes problem solving, critical thinking, and creativity and innovation (Alam, 2019). Indonesia's educational achievement in the international arena is still low, as evidenced by the 2018 PISA ranking, which was in 74th position out of 79 countries for reading ability, and 73rd and 71st for mathematics and science (Sujadi et al., 2021). According to Saraswati and Agustika (2020), Indonesian students still have difficulty in solving HOTS questions, which indicates the need to improve high-level thinking skills. The research article of the Indonesian Ministry of Education and Culture revealed that the level of questions and subject matter affects students' thinking skills (Huda et al., 2021). However, improving high-level thinking skills is not enough just by using HOTS questions and materials. More specific learning strategies are needed to develop critical thinking skills (DIKDAS, 2021). Facing the complex challenges of the 21st century, the potential of Indonesian students to master HOTS is very large. One of the learning models that can improve analytical thinking skills is PBL (Busdayu et al., 2023). This model encourages students to be sensitive to environmental problems and formulate solutions according to the learning material. According to Untari et al. (2018), PBL is an authentic problem-based learning that is unstructured and open, aimed at developing students' critical thinking skills.

Impact on Student Creativity

Based on further research, the progress of students' imaginative numerical thinking skills through Higher Order Thinking Aptitudes (HOTS) questions showed significant progress. According to Runisah et al. (2019), scientific creative thinking skills include four main indicators, namely familiarity, adaptability, elaboration, and creativity. In the study conducted, there was an increase in the average creativity score from 62.3 to 78.6, which indicates an increase of 26.2% after the implementation of HOTS questions (Desti et al., 2020). The developing creativity indicators show significant changes. Fluency of thinking increased from 58.5% to 75.3%, flexibility of thinking from 55.7% to 72.4%, elaboration from 60.2% to 79.1%, and originality from 52.9% to 69.5% (Siswono, 2018).

Comparison of creativity before and after the implementation of HOTS questions shows a significant transformation in students' mathematical abilities. Before the intervention, students tended to

use a conventional approach with limited solution variations. After the implementation of HOTS questions, there was an increase in the complexity of thinking, the diversity of problem-solving strategies, and the ability to transform mathematical concepts (Sidiq et al., 2021). This is by Usodo's research (2024), which emphasized that HOTS questions can stimulate the development of mathematical creativity through divergent thinking stimuli and conceptual challenges. Nindiasari et al., (2024) added that the HOTS approach encourages students to explore multiple solutions, which in turn increases their creative thinking capacity. In conclusion, the application of HOTS questions provides a substantive contribution to developing students' mathematical creativity, opening up space for innovative approaches in mathematics learning (Harjo et al., 2019).

Impact on Problem-Solving Ability

Based on various studies, the development of students' mathematical problem-solving strategies through HOTS questions shows complex dynamics. According to Polya (in Hendriana et al., 2018), mathematical problem-solving strategies include four key stages, namely understanding the problem, planning a solution, implementing the plan, and re-checking the results. The level of student success in solving HOTS questions varies. Research by Sari et al. (2019) revealed that, in general, student success ranges from 65-75%, with variations based on the complexity of the questions and the characteristics of the mathematical material. Factors that influence success include students' initial abilities, motivation, and conceptual understanding. The obstacles faced by students in the problem-solving process are quite diverse. The main challenges include: Difficulty identifying key information in problems, Limited ability to transform problems into mathematical models, Difficulty choosing the right solution strategy, and Low ability to make mathematical arguments. These obstacles are consistent with findings from other studies, such as the analysis of student errors in solving mathematical word problems (Gulvara et al., 2023).

Aini (2025) found that these obstacles were largely rooted in students' lack of exposure to high-level reasoning problems. Continuous intervention and innovative pedagogical approaches are seen as being able to overcome these obstacles. The findings of Wijaya et al. (2023) show that with the right guidance, students can gradually develop mathematical problem-solving skills. Scaffolding strategies and providing constructive feedback are effective in helping students overcome difficulties in solving HOTS problems (Alayyubi et al., 2024). In conclusion, the development of mathematical problem-solving skills through HOTS problems is a complex process that requires a systematic and ongoing approach.

Synthesis of Results from Various Literature Sources

In the context of research on HOTS in mathematics learning, a meta-analysis study by Apriani et al. (2023) identified consistent findings that confirmed the important role of HOTS questions in improving students' mathematical thinking skills. These findings include the urgency of learning strategies that support HOTS, the importance of cognitively challenging question design, and encouragement of analytical and creative thinking. However, previous studies still show quite large methodological variations, ranging from differences in creativity measurement instruments, diversity of research settings (geographic context, education level), to non-uniform subject characteristics. The range of success of HOTS implementation also varies, with an increase in mathematical ability ranging from 52% to 78%, indicating inconsistencies in the interpretation of HOTS indicators and the effectiveness of the learning approaches used. Widodo et al. (2023) comprehensive findings emphasize that although there is a consensus that HOTS has a positive correlation with improving the quality of mathematical thinking, there are still gaps in the integration aspects of question design, learning strategies, and the role of teachers

as facilitators of higher-order thinking. This is where the scientific contribution of this article lies: not only reviewing previous findings descriptively as is common in systematic literature reviews (SLR) or meta-analyses, but also presenting an in-depth conceptual analysis of the relationship between HOTS question characteristics, active learning approaches such as PBL and inquiry, and the role of teachers in shaping students' intellectual independence. Thus, this article offers a new synthesis framework that can be used as a conceptual and practical basis in designing more transformative and contextual HOTS-based mathematics learning.

Practical Implications

The development of HOTS questions in mathematics requires a comprehensive and contextual approach, taking into account students' cognitive characteristics in depth. According to Susanto et al. (2023), HOTS questions ideally integrate real contexts, present complex problems, and encourage analytical, evaluative, and creative thinking skills according to the indicators in the revised Bloom's taxonomy. Implementation techniques can involve imaginative educational approaches such as PBL, inquiry-based learning, and collaborative learning, and even specific models like Predict-Observe-Explain (POE) (Sari et al., 2023), which are designed to actively stimulate students' reasoning skills. Furthermore, the development of blended learning models, such as flipped learning, has also shown promise in enhancing HOTS among students (Sari et al., 2021). The role of the teacher as a facilitator is also very important in providing gradual scaffolding, constructive feedback, and encouraging the development of independent problem-solving strategies. The scientific contribution of this article lies in the synergistic emphasis between HOTS question design and adaptive pedagogical strategies, and how both play a role in shaping students' creativity and problem-solving abilities. Unlike systematic literature reviews (SLRs) or other review articles that generally only map trends and main findings from many literatures, this article specifically examines the depth of the relationship between HOTS question characteristics, the learning approaches used, and the role of teachers, by identifying implementation gaps and providing conceptual direction for the development of more meaningful and transformative learning practices.

CONCLUSION

The implementation of HOTS questions in mathematics learning has a significant impact on the development of students' high-level thinking skills, especially in critical thinking, creativity, and problem solving. Creativity indicators such as fluency, flexibility, elaboration, and originality have increased substantially after the implementation of HOTS questions. However, there are several challenges in the implementation, including the limited competence of teachers in compiling and integrating HOTS questions into learning, as well as students' difficulties in understanding and solving questions that require in-depth analysis. Learning models such as Problem-Based Learning have proven effective in helping students overcome these obstacles by providing a more authentic and relevant learning experience. To ensure the successful implementation of HOTS questions, intensive training for teachers, ongoing professional development, and the adoption of innovative pedagogical approaches are needed. In addition, further research is recommended to explore the effectiveness of HOTS in various learning contexts to improve the quality of mathematics education as a whole.

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