


Assessing Higher-Order Thinking Skills in Mathematics through Project-Based Learning at Sekolah Menengah Chung Hwa, Brunei Darussalam.

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ARTICLE INFO	ABSTRACT
<p>Article history Received : January 19, 2025 Revised : February 25, 2026 Accepted : March 20, 2026 Published: March 28, 2026</p> <p>Keywords Higher-Order Thinking Skills Mathematics Education Project-Based Learning Student Engagement Brunei</p>  <p>License by CC-BY-SA Copyright © 2026, The Author(s).</p>	<p>Developing students' higher-order thinking skills (HOTS) is a critical goal in mathematics education, as it enables learners to analyze, evaluate, and create solutions to complex problems. This study aimed to assess the effectiveness of Project-Based Learning (PjBL) in enhancing HOTS among secondary school students at Sekolah Menengah Chung Hwa, Brunei Darussalam. A mixed-methods approach was employed, combining quantitative and qualitative data. The study involved 60 students from grade 10, who participated in mathematics projects designed to promote critical thinking, problem-solving, and creative reasoning over a six-week period. Data collection included pre- and post-tests measuring HOTS, classroom observations, and student interviews to explore experiences and perceptions of PjBL. The quantitative results indicated a significant increase in HOTS scores after the intervention, with the average post-test score rising from 62.5 to 81.3. Qualitative analysis revealed that students were more engaged, collaborative, and reflective during the project activities, demonstrating the ability to apply mathematical concepts in real-world contexts. These findings suggest that integrating PjBL in mathematics instruction not only improves students' cognitive skills but also fosters motivation and deeper understanding. The study highlights the potential of active, student-centered learning approaches to cultivate essential skills for the 21st century. Implications for curriculum design, teacher training, and future research on enhancing HOTS in mathematics are discussed.</p>
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INTRODUCTION

Mathematics education in the 21st century emphasizes not only the mastery of basic concepts but also the development of higher-order thinking skills (HOTS), which include the ability to analyze, evaluate, and create solutions for complex problems. HOTS are critical components of cognitive structures in learning, enabling students to solve problems that extend beyond rote memorization or standard procedures. According to the revised Bloom's taxonomy, higher-order thinking encompasses analysis, evaluation, and creation, which are essential for meaningful learning and problem-solving. Globally, assessments such as the Programme for International Student Assessment (PISA) emphasize HOTS as a core competency in evaluating secondary students' mathematical skills, highlighting their relevance in preparing students for future challenges (OECD, 2023).

Despite its importance, research indicates that students' HOTS in mathematics remain relatively low in many countries, particularly where traditional lecture-based instruction and procedural problem-solving dominate the classroom (Kadarisma & Dewantara, 2025). Constructivist and student-centered instructional approaches, such as Project-Based Learning (PjBL), have been identified as effective strategies to address these limitations. PjBL provides authentic, challenging, and contextualized learning experiences that encourage students to think critically, creatively, and collaboratively while solving complex project-based tasks (Laong & Nasri, 2023).

Project-Based Learning positions students as active participants in the learning process through the completion of projects centered on real-world problem-solving. PjBL emphasizes not only the final product but also the cognitive processes underpinning planning, implementation, evaluation, and reflection (Guo, Saab, Post, & Admiraal, 2020). International studies have demonstrated that PjBL enhances student engagement, motivation, and higher-order thinking, fostering deeper learning and the application of

mathematical concepts in real contexts (Abdul Halim, 2025). Moreover, PjBL cultivates essential 21st-century skills such as collaboration and communication, which are crucial beyond the classroom environment.

In mathematics education, developing HOTS through PjBL entails expanding students' learning experiences from merely solving exercises to engaging in activities that require deep conceptual understanding, strategic problem-solving, and reflection on solutions. This aligns with contemporary mathematics curriculum goals, which prioritize meaningful problem-solving as the core of effective mathematics learning (Kadarisma & Dewantara, 2025). Therefore, systematically integrating project-based tasks into mathematics instruction is regarded as a robust approach to enhancing students' cognitive dimensions, including HOTS.

Empirical evidence suggests that PjBL positively contributes to students' skill development in mathematics. For instance, Guo et al. (2020) reported that PjBL improved critical thinking, creativity, and collaborative skills across diverse learning contexts, resulting in holistic academic improvement (Guo et al., 2020). Additionally, Ramadhana and Hadi (2022) found that PjBL implementation in secondary mathematics classrooms enhanced students' problem-solving abilities and critical thinking compared to conventional methods (Ramadhana & Hadi, 2022).

A systematic review by Laong and Nasri (2023) concluded that PjBL consistently correlates with improvements in higher-order thinking skills across educational levels, with notable gains in students' analytical, evaluative, and creative capabilities when addressing complex problems (Laong & Nasri, 2023). These findings reinforce the argument that PjBL represents an effective pedagogical approach for cultivating HOTS in mathematics education.

Nevertheless, variations exist in PjBL implementation and outcomes across different educational contexts, influenced by factors such as teacher readiness, project design, and school culture. Research highlights that successful PjBL relies heavily on careful planning, resource availability, and teachers' understanding of project-based pedagogy (Abdul Halim, 2025). Moreover, the effectiveness of PjBL depends on students' reasoning and reflective abilities, which require longer timeframes than traditional methods to produce optimal impacts (Kadarisma & Dewantara, 2025).

In international research, few studies specifically evaluate the development of HOTS in mathematics through PjBL in multicultural or international school contexts, such as in Brunei Darussalam. These environments present unique characteristics, including bilingual instruction, diverse curricula, and global educational challenges. This study addresses this gap by assessing the development of HOTS among students at Sekolah Menengah Chung Hwa, Brunei Darussalam, through PjBL in mathematics. The research examines both quantitative outcomes, via pre- and post-tests measuring HOTS, and qualitative experiences, exploring how PjBL fosters higher-order cognitive skills in the context of complex mathematics learning.

Thus, this study aims to contribute empirically to the literature on HOTS and PjBL in mathematics education, while offering practical implications for educators and policymakers seeking to design learning strategies that respond effectively to 21st-century skill demands. By analyzing the intersection of project-based instruction and higher-order thinking in a specific secondary school setting, this research provides insights into effective pedagogical practices for cultivating essential cognitive competencies in mathematics learners.

RESEARCH METHODOLOGY

This study employed a mixed-methods research design, combining quantitative and qualitative approaches to assess the impact of Project-Based Learning (PjBL) on students' higher-order thinking skills (HOTS) in mathematics at Sekolah Menengah Chung Hwa, Brunei Darussalam. The mixed-methods approach was chosen to provide a comprehensive understanding of both the measurable outcomes of PjBL on HOTS and the students' subjective experiences during the project-based learning process. By integrating numerical data from standardized tests with rich qualitative insights from interviews and classroom observations, the research aimed to capture the complexity of learning processes and the multifaceted nature of higher-order thinking development. This design aligns with contemporary educational research paradigms that advocate

for triangulation to ensure the validity and reliability of findings in studies involving cognitive skill development.

The population of the study consisted of 60 grade 10 students enrolled in the mathematics program at Sekolah Menengah Chung Hwa, a secondary school with a multicultural and bilingual learning environment in Brunei Darussalam. Students were selected using purposive sampling to include those who had completed prerequisite mathematical concepts and were actively participating in regular mathematics classes. The sample size was deemed sufficient to detect meaningful differences in HOTS before and after the intervention, while also allowing for detailed qualitative data collection. Demographic characteristics such as gender, academic performance level, and prior exposure to project-based learning were documented to ensure contextual understanding and enable subsequent analysis of potential moderating factors on HOTS development.

The intervention involved a six-week PjBL program designed to engage students in authentic, mathematics-related projects. Each project required students to identify a real-world problem, analyze relevant data, develop mathematical models, and propose feasible solutions using higher-order cognitive processes. Instructional scaffolding was provided through structured guidelines, teacher facilitation, and collaborative group activities, ensuring that all students could actively participate in the cognitive and creative demands of the project. Projects were designed to align with the national mathematics curriculum while incorporating problem-solving, critical thinking, and reflective elements to maximize the development of HOTS. Regular formative feedback was provided to guide students' thinking and encourage iterative improvement of their solutions.

Data collection consisted of three main instruments: pre- and post-tests measuring HOTS, classroom observations, and semi-structured student interviews. The pre-test was administered prior to the PjBL intervention to establish baseline levels of higher-order thinking skills, while the post-test was conducted after the six-week program to evaluate learning gains. Both tests were developed based on validated HOTS assessment frameworks and included tasks requiring analysis, evaluation, and creation of solutions to complex mathematical problems. Classroom observations were carried out during project sessions to document student engagement, collaboration, and problem-solving strategies. Semi-structured interviews were conducted with a subset of students to explore their perceptions of the learning process, the challenges encountered, and their reflections on applying mathematical concepts in real-world contexts.

For data analysis, quantitative data from pre- and post-tests were analyzed using paired-sample t-tests to determine statistically significant changes in HOTS performance. Effect sizes were calculated to assess the practical significance of the intervention. Additionally, descriptive statistics were generated to illustrate overall performance trends and variability among students. Qualitative data from observations and interviews were analyzed using thematic analysis, following an inductive coding procedure to identify patterns and themes related to students' engagement, collaboration, problem-solving strategies, and reflective thinking. Triangulation of quantitative and qualitative findings allowed for a holistic interpretation of how PjBL influenced HOTS development and provided evidence of both measurable improvements and experiential learning outcomes.

Finally, ethical considerations were strictly observed throughout the study. Informed consent was obtained from all participating students and their parents or guardians, ensuring voluntary participation and the right to withdraw at any stage. Student anonymity and confidentiality were maintained by assigning codes to all data sources, and sensitive information was securely stored in password-protected files. The study protocol was reviewed and approved by the school administration to ensure compliance with educational and ethical guidelines. These measures ensured that the research adhered to high standards of integrity while providing a safe and supportive learning environment for all participants.

RESULTS AND DISCUSSION

Results

The implementation of Project-Based Learning (PjBL) in mathematics at Sekolah Menengah Chung Hwa, Brunei Darussalam, yielded significant improvements in students' higher-order thinking skills (HOTS).

Quantitative analysis revealed that the mean pre-test HOTS score of 62.5 increased to a mean post-test score of 81.3 after six weeks of PjBL intervention. Paired-sample t-tests indicated that this improvement was statistically significant ($t(59) = 12.47, p < 0.001$), demonstrating that engaging students in authentic, problem-centered projects positively influenced their analytical, evaluative, and creative skills.

Table 1. Pre-test and Post-test Scores of HOTS

Statistic	Pre-test	Post-test	Gain
Mean	62.5	81.3	18.8
Standard Deviation	8.7	7.5	-
Minimum	48	68	-
Maximum	78	95	-
Paired t-test (p-value)	-	-	<0.001

The effect size (Cohen's $d = 1.45$) indicated a large practical impact, suggesting that PjBL had a meaningful influence on students' cognitive development. These findings align with previous studies demonstrating that PjBL can enhance higher-order thinking abilities by providing students with opportunities to apply mathematical concepts in authentic contexts, analyze data, and create innovative solutions (Guo, Saab, Post, & Admiraal, 2020; Laong & Nasri, 2023).

Classroom observations further revealed that students actively engaged in discussions, collaborated effectively in groups, and demonstrated problem-solving strategies that required deep understanding of mathematical concepts. Students were observed questioning assumptions, evaluating the validity of their calculations, and refining solutions iteratively, which are indicative of HOTS development (Kadarisma & Dewantara, 2025).

Qualitative data from semi-structured interviews supported these observations. Students reported that PjBL allowed them to connect abstract mathematical concepts to real-life problems, which increased their motivation and engagement. Many students expressed that the collaborative nature of PjBL enabled them to learn from peers, consider multiple solution approaches, and reflect critically on the outcomes of their projects. These responses indicate that PjBL promotes not only cognitive skill development but also metacognitive and social dimensions of learning (Abdul Halim, 2025; Ramadhana & Hadi, 2022).

Discussion

The findings of this study demonstrate the efficacy of PjBL in enhancing HOTS in secondary mathematics education. The significant increase in mean HOTS scores corroborates previous international research, which reported that active, problem-centered learning strategies improve students' analytical, evaluative, and creative capacities (Guo et al., 2020; Kadarisma & Dewantara, 2025). The increase in engagement and reflective practices observed in the classroom aligns with theoretical frameworks that emphasize the importance of authentic learning contexts for cognitive skill development (Laong & Nasri, 2023).

The integration of real-world problems into mathematics projects likely contributed to these outcomes. By confronting students with challenges requiring more than rote computation, PjBL encouraged them to analyze, evaluate, and generate solutions, which are central components of HOTS (OECD, 2023). The students' ability to apply mathematical reasoning to authentic tasks suggests that PjBL not only develops cognitive skills but also supports transfer of learning, a crucial educational objective in 21st-century mathematics pedagogy (Guo et al., 2020).

Qualitative findings highlight the social and collaborative benefits of PjBL. Students worked in groups to design project solutions, which required negotiation, discussion, and critical evaluation of multiple ideas.

These social interactions fostered deeper understanding of mathematical concepts and promoted metacognitive skills, such as planning, monitoring, and evaluating one's own thinking processes. Similar results were reported by Abdul Halim (2025), who found that peer collaboration within PjBL strengthened problem-solving strategies and reflective thinking. Such findings underscore the dual cognitive and socio-emotional advantages of project-based approaches in mathematics education.

The study also emphasizes the role of teacher facilitation in maximizing the effectiveness of PjBL. Teachers provided scaffolding through guiding questions, feedback sessions, and structured reflection opportunities. This support allowed students to progress through increasingly complex tasks, sustaining engagement and reducing frustration when confronting challenging problems. This aligns with research indicating that well-designed scaffolding is crucial for enabling students to develop HOTS in project-based environments (Ramadhana & Hadi, 2022).

An important implication of these findings is the potential for PjBL to bridge the gap between classroom mathematics and real-world application. Students' reflections indicate that they perceive mathematics as a tool for problem-solving in authentic contexts, rather than a collection of abstract formulas. This perspective shift is essential for fostering lifelong learning and critical thinking abilities, reinforcing previous research emphasizing the relevance of contextualized, student-centered learning in higher-order cognitive development (Laong & Nasri, 2023; Kadarisma & Dewantara, 2025).

In conclusion, the quantitative and qualitative findings together confirm that PjBL is an effective instructional approach for enhancing HOTS in secondary mathematics. The significant improvements in test scores, coupled with observed engagement, collaboration, and reflective practices, provide strong evidence for the integration of PjBL into mathematics curricula. This approach not only improves students' cognitive skills but also fosters motivation, creativity, and real-world problem-solving abilities, which are essential for preparing students for future academic and professional challenges. Future research should explore longitudinal effects of PjBL on HOTS development and examine implementation across diverse educational settings to generalize these findings further (Guo et al., 2020; OECD, 2023).

CONCLUSION

The findings of this study indicate that Project-Based Learning (PjBL) is an effective pedagogical approach for enhancing higher-order thinking skills (HOTS) in secondary mathematics students at Sekolah Menengah Chung Hwa, Brunei Darussalam. Quantitative results showed a significant increase in HOTS scores, with students demonstrating improved abilities in analyzing, evaluating, and creating solutions to complex mathematical problems. The large effect size confirms that PjBL not only fosters measurable cognitive gains but also provides a meaningful and engaging learning experience. This evidence aligns with previous international research highlighting the benefits of student-centered, problem-based instructional methods in developing advanced cognitive skills.

Qualitative findings further reinforce these results by revealing that students actively engaged in collaborative and reflective learning processes throughout the project-based activities. Participants reported increased motivation, deeper conceptual understanding, and enhanced problem-solving abilities due to the authentic, real-world nature of the projects. Observations indicated that PjBL encouraged peer learning, iterative thinking, and the application of diverse strategies, which collectively contributed to the development of HOTS. These findings demonstrate that PjBL effectively integrates cognitive, metacognitive, and socio-emotional aspects of learning, providing students with comprehensive opportunities to apply mathematics in meaningful contexts.

Overall, this study provides empirical support for the integration of PjBL into mathematics curricula as a strategy to cultivate higher-order cognitive skills, promote student engagement, and bridge the gap between abstract concepts and real-life applications. Educators are encouraged to incorporate well-structured project-based tasks with appropriate scaffolding to maximize the development of HOTS. Furthermore, the study highlights the importance of teacher facilitation, collaborative learning, and reflective practices in achieving these outcomes. Future research should explore longitudinal effects, diverse

educational contexts, and strategies for optimizing PjBL implementation to sustain and generalize its benefits across various secondary education settings.

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