INTERNATIONAL JOURNAL OF ACADEMIC RESEARCH IN BUSINESS & SOCIAL SCIENCES

Vol 15, Issue 01, (2025) E-ISSN: 2222-6990

Examining Secondary Students' Calculator Competency and its Relationship to Higher-Order Thinking Skills (HOTS) in Mathematics Problems

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To Link this Article: http://dx.doi.org/10.6007/IJARBSS/v15-i1/24167 DOI:10.6007/IJARBSS/v15-i1/24167

Published Date: 06 January 2025

Abstract

Scientific calculators are intended to be effective tools for enhancing and broadening mathematical skills. However, many students continue to face challenges in solving mathematics problems requiring Higher-Order Thinking Skills (HOTS), even with access to scientific calculators. This study investigates the competency of secondary students in using calculators for mathematical problem-solving and examines its relationship with their performance in HOTS mathematics problems. Using a quantitative research approach, the study involved administering tests and surveys to 55 Form Four students from a school in the Johor district. Data collection assessed students' calculator skills and their ability to solve HOTS problems related to quadratic functions. The analysis showed a significant positive correlation between students' proficiency in using calculators and their performance in HOTS problems. Students with stronger calculator skills achieved higher scores in HOTS problem-solving. The findings provide valuable insights for improving educational strategies to enhance students' calculator skills. By exploring the connection between calculator use and HOTS performance, this study aims to guide educators and policymakers in improving mathematical learning experiences and outcomes for secondary students.

Keywords: Scientific Calculators, Higher-Order Thinking Skills, Quadratic Functions

Introduction

In today's rapidly evolving world, the ability to solve complex problems is vital for success in both academic and professional spheres. Mathematics, a cornerstone of education, plays a crucial role in fostering these skills. Higher-Order Thinking Skills (HOTS), such as analyzing, evaluating, and creating, are integral to this process, as they encourage students to move beyond rote memorization and engage in critical and creative thinking. Recognizing this, the Malaysian Ministry of Education has integrated HOTS into the national curriculum through the Malaysian Education Blueprint (2013–2025). This initiative aims to prepare students for the demands of the 21st century by equipping them with critical thinking and problem-solving skills essential for global competitiveness.

In October 2011, the Ministry of Education (MOE) launched a comprehensive evaluation of the Malaysian education system, leading to the development of the Malaysian Education Blueprint (2013–2025). This initiative aims to prepare both educators and students for 21st-century challenges. A central focus of the new curricula, namely the Kurikulum Standard Sekolah Menengah (KSSM) and the Kurikulum Standard Sekolah Rendah (KSSR), is the incorporation of Higher-Order Thinking Skills (HOTS). Introduced in 2012 and fully implemented by 2017, these curricula are designed to equip students with the ability to think critically, apply knowledge to new situations, analyze information, and communicate effectively with the skills essential for thriving in a modern learning environment.

Scientific calculators are increasingly acknowledged as transformative tools in mathematics education. Beyond merely simplifying computations, these devices enable students to focus on understanding mathematical concepts and solving higher-level problems. Research has shown that effective use of calculators enhances not only computational accuracy but also students' engagement and attitudes toward mathematics, ultimately fostering deeper conceptual understanding (Ellington, 2003; St. John & Lapp, 2000). Despite this potential, many students struggle to utilize calculators effectively, particularly when tackling HOTS problems. This study explores secondary students' proficiency with calculators and its relationship to their performance in solving HOTS questions, with a focus on quadratic functions.

The significance of this study lies in its potential to inform educational practices and policies. By identifying gaps in students' calculator competencies and their impact on problem-solving skills, this research provides valuable insights for educators and policymakers. It highlights the need for targeted interventions, such as teacher training and curriculum adjustments, to optimize the use of calculators in enhancing mathematical understanding and HOTS development. Ultimately, this study seeks to bridge the gap between procedural fluency and conceptual mastery, ensuring students are better prepared to meet contemporary challenges.

1. Scientific Calculators in Mathematics Education

Scientific calculators play an essential role in engaging students and providing immediate feedback during mathematics lessons (Kamarulhaili & Sim, 2005; Leng, 2011). To maximize their potential, both students and teachers must develop the skills required to use this technology effectively in the classroom (Nabie & Yidana, 2001; Ebal et al., 2019). In today's technology-rich environment, students should be proficient in utilizing the functionalities of scientific calculators. At all educational levels, calculators can expand mathematical understanding, facilitate access to mathematical information, and improve computational fluency, provided their use is guided by knowledgeable educators.

2. Previous Studies on Calculator Use

Research consistently demonstrates the positive impact of calculators on students' mathematical learning, particularly in developing HOTS. Advanced calculators, including those powered by artificial intelligence, have been shown to enhance students' performance in subjects like Basic Calculus by enabling deeper engagement with abstract concepts (Afidchao et al., 2023). Furthermore, studies indicate that calculators support conceptual learning by allowing students to concentrate on problem-solving rather than repetitive calculations, leading to improved achievement and attitudes toward mathematics (Bray et al., 2017). These findings align with earlier research, which highlights the educational benefits of traditional calculators (Liang, 2017).

3. Higher-Order Thinking Skills (HOTS)

Higher-Order Thinking Skills (HOTS) are critical for developing creative and analytical thinking. These skills require students to apply, analyze, evaluate, and create, going beyond rote memorization. Based on Bloom's Taxonomy, HOTS encompass the higher levels of cognitive processes, including complex reasoning, decision-making, and problem-solving (Kementerian Pendidikan Malaysia, 2013; Ministry of Education, 2019). The revised taxonomy by Anderson and Krathwohl categorizes cognitive processes into six levels—remembering, understanding, applying, analyzing, evaluating, and creating—with the top three levels classified as HOTS (Bloom et al., 1956; Schultz, 2005).

The Malaysian education system emphasizes the integration of HOTS to improve learning outcomes, particularly in national and international assessments like PISA and TIMSS, which highlight the need for stronger cognitive skills among students (Malaysia Education Blueprint, 2013–2025). Incorporating HOTS into teaching practices encourages students to explore concepts, effectively use calculators in exams, and develop analytical and creative thinking skills, ensuring they are prepared to meet the demands of the 21st century. Research shows that calculator use enhances problem-solving and analytical skills, fostering a deeper understanding of complex mathematical ideas (Kastberg & Leatham, 2005; Ellington, 2003).
This study seeks to explore the relationship between secondary students' calculator competency and their performance in HOTS, emphasizing the need for collaboration among educators and stakeholders to strengthen these skills. HOTS are essential for fostering critical, analytical, and logical thinking, which are crucial for addressing modern challenges (Hassan et al., 2012; Jacob et al., 2012; Prusak et al., 2013; Lee et al., 2001).

Problem Background

Despite the recognized benefits of scientific calculators in mathematics education, their integration into teaching practices remains inconsistent, particularly in developing countries like Malaysia. The National Council of Teachers of Mathematics (NCTM) has long advocated for calculators as essential tools for enhancing mathematical understanding (NCTM, 2000). However, studies reveal that students often lack the proficiency to use calculators effectively for complex problem-solving, leading to missed opportunities for fostering HOTS (Higgins et al., 2019; Kerslake et al., 2013). This gap is evident in international assessments such as the Trends in International Mathematics and Science Study (TIMSS) and the Programme for International Student Assessment (PISA), where Malaysian students consistently score below the global average in higher-order cognitive tasks (OECD, 2018).

Quadratic functions, a fundamental topic in secondary mathematics, exemplify these challenges. Many students struggle with misconceptions about variables, graph interpretation, and algebraic representations, which hinder their ability to solve HOTS problems (Zaslavsky, 1997; Ellis & Grinstead, 2008). Scientific calculators, with their advanced features, have the potential to address these issues by providing visual and numerical insights. For instance, modern calculators enable students to explore the effects of coefficients on the vertex and shape of a graph, promoting a deeper understanding of quadratic functions (Kissane, 2016).

However, the effective use of calculators demands specific skills, such as accurately entering functions, interpreting outputs, and applying results to real-world problems. Research shows that while calculators can enhance mathematical reasoning, their misuse or underutilization often exacerbates students' difficulties in solving higher-order problems (Didis et al., 2011; Díaz & Poblete, 2018). In Malaysia, this issue is compounded by limited instructional support and an overemphasis on content mastery at the expense of critical thinking (Hassan et al., 2012).

Moreover, the disparity in calculator usage proficiency among students highlights a critical issue in educational equity. Students from underprivileged backgrounds often lack access to quality teaching resources, including calculators, which further widens the achievement gap in HOTS-related tasks (Radzuan et al., 2021). These inequities are particularly concerning in light of Malaysia's performance in TIMSS and PISA assessments, which underscore the urgent need for educational reforms to enhance critical thinking and problem-solving skills (OECD, 2018). For example, Malaysia's TIMSS 2019 scores in mathematics and science at the Grade 8 level were 461 and 471, respectively but still below the international average of 500. While PISA 2022 revealed improved scores in reading, mathematics, and science compared to 2018, they remain below OECD averages, reflecting persistent challenges in higher-order cognitive tasks. Educational reforms, such as the introduction of Hot Topics (HOTs), aim to shift from rote memorization toward critical thinking and analytical problem-solving (Tee et al., 2012).

Research also indicates that inadequate teacher training contributes to the ineffective integration of calculators into classrooms. Teachers often lack the confidence or expertise to utilize calculators as tools for developing HOTS, focusing instead on basic computational functions (Chan et al., 2023). This shortfall not only limits students' exposure to advanced calculator features but also reduces opportunities for them to develop higher-order cognitive skills through technology-assisted learning. Addressing this gap requires targeted professional development programs to equip educators with the necessary skills and strategies for integrating calculators effectively (Tan & Tan, 2022).

Finally, the rapid advancement of technology presents both opportunities and challenges for education systems. As calculators evolve with features such as graphing capabilities and AI-powered tools, ensuring their effective use in classrooms becomes increasingly complex. Educators must balance the benefits of these technologies with the need to maintain a strong foundation in conceptual understanding, particularly in critical topics like quadratic functions (Afidchao et al., 2023). This study aims to address these challenges by exploring the relationship between students' calculator proficiency and their performance in HOTS, providing actionable insights for enhancing mathematics education in Malaysia.

Objectives

The objectives of this study are as follows:

1) To assess the competency of Form Four students in using calculators for the topic of quadratic functions.

2) To evaluate the competency of Form Four students in solving HOTS problems related to quadratic functions.
3) To understand students' perspectives on their competency in using calculators for quadratic functions.
4) To investigate the relationship between calculator competency and performance in solving HOTS problems among Form Four students in the topic of quadratic functions.

Method

Research Design and Sampling

This study adopts a quantitative research approach to evaluate secondary students' calculator competency and their ability to solve Higher-Order Thinking Skills (HOTS) problems. Utilizing a correlational framework, the research examines the relationship between two primary variables: calculator competency (independent variable) and HOTS problem-solving ability (dependent variable). Data collection involves administering tests and questionnaires. The instruments include a demographic survey (Part A), assessments on quadratic functions (Parts B and C), and a 10-item questionnaire (Part D). The sample comprises 55 Form Four students from Kulai, Johor, selected through purposive sampling. These students, having been exposed to mathematics examinations since Form One, possess the foundational knowledge required for the study. Data analysis, performed using the Statistical Package for the Social Sciences (SPSS), seeks to provide insights into the influence of calculator usage on students' higher-order thinking capabilities.

Research Instruments

The study employs a structured tool comprising four sections to evaluate students' proficiency in calculator usage and HOTS problem-solving:
Part A: Collects demographic data about the participants.
Part B and Part C: Feature tests on quadratic functions with seven open-ended questions. These questions assess calculator skills, with a maximum of 12 marks allocated based on question complexity. Part B focuses on fundamental calculator tasks, including basic operations and simpler mathematical problems, with lower marks for less complex tasks. Part C evaluates HOTS competencies through more advanced problems that require application, analysis, evaluation, and creation, with higher marks awarded for demonstrating advanced calculator skills.

Part D: Contains a 10-item, closed-ended questionnaire exploring teacher strategies, student confidence in using calculators, and success rates in solving problems. The questionnaire uses a four-point Likert scale for straightforward response analysis and classifies calculator competency into low, moderate, or high categories.
The instrument, refined through pilot testing, ensures reliability and validity, providing a robust assessment aligned with the study's objectives.

Data Collection

The study employs a correlational design to simultaneously gather data using tests and questionnaires. Participants were informed of the study's purpose and assured of confidentiality before completing the survey. Test and questionnaire items were constructed based on relevant literature and adapted to suit the research context. To accommodate potential language barriers, the survey questions were presented in both English and Bahasa

Melayu. Students were given 60 minutes to complete the test and questionnaire. Responses were submitted anonymously, with no incentives provided or identifying information collected.

Data Analysis

A correlational method is used to assess the relationship between the independent variable (calculator competency) and the dependent variable (HOTS problem-solving skills). This approach quantifies the degree of correlation between the variables, as outlined in Table 1. The analysis provides valuable insights into the impact of calculator use on students' performance in HOTS-related tasks.

Table 1
Summary of Data Analysis

RESEARCH OBJECTIVES	RESEARCH INSTRUMENTS	DATA ANALYSIS
RO 1: To assess the competency of Form Four students in using calculators for the topic of quadratic functions.	Test	Score
RO 2: To evaluate the competency of Form Four students in solving HOTS problems related to quadratic functions.	Test	Score
RO 3: To understand students' perspectives on their competency in using calculators for quadratic functions.	Questionnaires	Interval data
RO 4: To investigate the relationship between calculator competency and performance in solving HOTS problems among Form Four students in the topic of quadratic functions.	Test	Spearman Correlation

Research Findings

Students' Calculator Competency

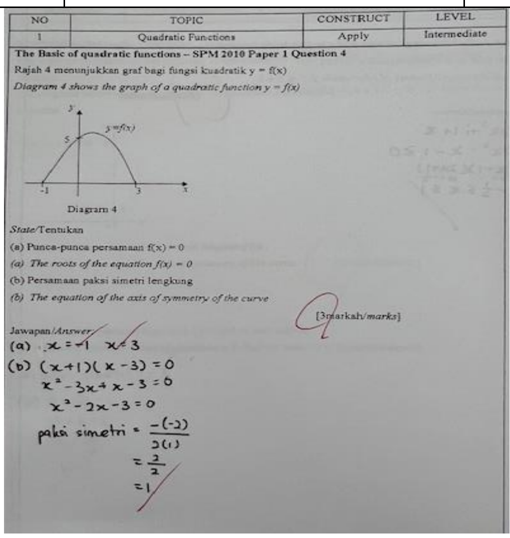
The analysis of calculator proficiency, as outlined in Table 2, reveals that a significant portion of students (56.36%) fall into the "High" competency category, demonstrating strong skills in using calculators for quadratic functions. However, 29.09% of students were categorized as having "Low" competency, while 14.55% exhibited "Moderate" competency. This distribution highlights a notable disparity in calculator skills, suggesting that while many students are proficient, a substantial number face challenges that could be addressed through targeted instructional support.

A deeper examination of this issue is illustrated in Figures 1 and 2, which depict two approaches to solving the quadratic inequality $2x^2 \leq 1 + x$. In Figure 1, the solution focuses on the equivalent inequality $x^2-x-3>0$. The quadratic expression is correctly factored as $(x-3)(x+1)>0$, and the critical points identified are $x=3$ and $x=-1$. The intervals satisfying the inequality are accurately determined, concluding that x<−1 or x>3 represent the solution intervals. This approach reflects a sound understanding of factoring and interval testing.

In contrast, the solution shown in Figure 2 attempts to solve the same inequality but exhibits errors in either the comprehension or application of the factoring and testing method. While the quadratic expression is also factored as (x−3)(x+1)>0, the intervals identified as solutions x<−1 or x>3—are incorrect. The process indicates confusion in evaluating the intervals, likely due to a lapse in manually verifying the signs of the intervals or incorrect use of the calculator to test the signs at specific points. This type of error underscores the need for improved instruction on integrating manual checks and calculator usage in solving inequalities.

Table 2
Level of Calculator Competency in Quadratic Functions

Students' Calculator Competency	Range of Marks by Using Calculator Skills	Numbers of Students (%)
Low	1-4 Marks	16 (29.09)
Moderate	5-8 Marks	8 (14.55)
High	9-12 Marks	31 (56.36)



NO	TOPIC	CONSTRUCT	LEVEL
1	Quadratic Functions	Apply	Intermediate

The Basic of quadratic functions – SPM 2010 Paper 1 Question 4

Rajah 4 menunjukkan graf bagi fungsi kuadratik y = f(x)

Diagram 4 shows the graph of a quadratic function y = f(x)

State/Tentukan

(a) Punca-punca persamaan f(x) = 0

(a) The roots of the equation f(x) = 0

(b) Persamaan paksi simetri lengkung

(b) The equation of the axis of symmetry of the curve

[3 markah/*marks*]

Jawapan/*Answer*:

(a) x = −1 x = 3

(b) (x+1)(x−3) = 0

x² − 3x + x − 3 = 0

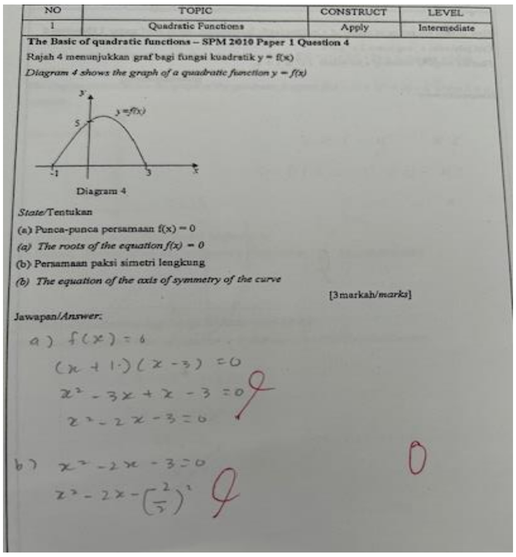
x² − 2x − 3 = 0

paksi simetri = −(−2) / 2(1)

= 2/2

= 1

Figure 1 Students' Correct Answer (Proper Calculator Used)



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(b) The equation of the axis of symmetry of the curve

[3markah/*marks*]

Jawapan/*Answer*:

Figure 2 Students' Incorrect Answer (Incorrect Data Entry, a Misunderstanding of How to Apply the Calculator's Outputs in Testing Interval Signs)

Competency in Solving Higher Order Thinking Skills (HOTS) Problems

The analysis of student performance on HOTS tasks reveals a decline in success rates as the complexity of problems increases. According to Table 3, students performed best on Level 4 (Analyze) tasks, with a success rate of 65.45%, but their performance dropped to 54.55% for Level 5 (Evaluate) tasks and 58.18% for Level 6 (Create) tasks. Overall, the competency distribution shows that 70.91% of students exhibited high proficiency in solving HOTS problems, while 29.09% were at a low proficiency level. These results highlight disparities in skill development, particularly at higher levels of cognitive tasks.

Table 3

Percentages of Students Answer Correctly in Higher Order Thinking Skills (HOTS) Problems

No of Questions in Part C	Level of HOTS	Numbers of Students (%)
C4	Analyse (Level 4)	36(65.45)
C5	Evaluate (Level 5)	33(60.00)
C6	Evaluate (Level 5)	30(54.55)
C7	Create (Level 6)	32(58.18)
Competency distribution for HOTS tasks	High	47(70.91)
	Low	8(29.09)

Students' Perspectives on Calculator Competency

Table 4 highlights significant challenges students face in using calculators effectively for solving HOTS problems. A lack of confidence is evident, as 100% of students provided negative responses to item 1, with similar trends observed in items 3, 6, and 10, where most students strongly disagreed or disagreed with feeling capable of using calculators proficiently. These findings suggest inadequate preparation or exposure to calculator-based problem-solving.

In terms of "Teachers' Effort," students expressed dissatisfaction with instructional support, with nearly half (49.09%) disagreeing and the remaining 50.91% strongly disagreeing those teachers provided adequate guidance in using calculators for complex tasks.

The "Ability to Get the Correct Answer" construct showed slightly better outcomes, but over 80% of students still reported negative responses to items 5, 7, 8, and 9. While a small number of students expressed some confidence in achieving correct answers, these results underscore the need for enhanced instructional strategies, professional development for educators, and opportunities for students to develop confidence and proficiency in calculator-based problem-solving.

Table 4
Percentage of Students Answered in Questionnaire of Competency of Using Calculator in Higher Order Thinking Skills (HOTS) Problems

No	Items	Construct	Strongly Disagree (SO), Numbers (%)	Disagree (D), Numbers (%)	Agree (A), Numbers (%)	Strongly Agree (SA), Numbers (%)
1	I enjoy of using scientific calculator in mathematics class.	SC	33 (60)	22 (40)	0	0
2	Teacher has teaching us how to using scientific calculator to solve the mathematics questions.	TE	27 (49.09)	28 (50.91)	0	0
3	I am increasingly using the scientific calculator in solving form four mathematic problems.	SC	27 (49.09)	28 (50.91)	0	0
4	I am competent to use scientific calculator in	SC	23 (41.82)	28 (50.91)	4 (7.27)	0

	mathematics class.					
5	Scientific calculator use is applicable to all topics in form four mathematic curriculum.	ACA	21 (38.18)	24 (43.64)	9 (16.36)	1 (1.82)
6	I prefer using scientific calculator in objective and subjective paper and in school.	SC	32 (58.18)	22 (40.00)	1 (1.82)	0
7	Using scientific calculator made the mathematics easier in learning process.	ACA	38 (69.09)	18 (27.27)	2 (3.64)	0
8	Having a scientific calculator which has multiple functions greatly increases your learning capacity.	ACA	35 (63.64)	17 (30.91)	3 (5.45)	0
9	Current functions of the scientific calculator is enough for form four mathematic curriculum.	ACA	29 (52.73)	24 (43.64)	2 (3.63)	0
10	I willing to learn how to using the calculator.	SC	37 (67.27)	18 (32.73)	0	0

Relationship between Calculator Competency and HOTS Problem-Solving

The study identified a moderate positive correlation between calculator competency and HOTS problem-solving, as indicated by a Spearman correlation coefficient of 0.632 ($p < 0.001$) in Table 5. This result suggests that students with higher proficiency in using calculators are more likely to excel in solving higher-order problems.

Table 5
Spearman Correlation of Relationship between Competency of Using Calculator and Solving Higher Order Thinking Skills (HOTS) Problems among Form Four Students in the Topic of Quadratic Functions

	HOTS	**Competency_of_Calculator**
Spearman Correlation	1	0.632
Sig. (2-tailed)		<0.001
N	55	55

Further analysis, represented by scatterplots in Figure 4, confirmed the correlation. The trendline equation y=0.74+1.01x and the coefficient of determination (R^2=0.497) indicate that approximately 49.7% of the variance in students' HOTS performance is explained by their calculator competency. This suggests that improvements in calculator skills are linked to better performance in solving HOTS problems.

However, the scatterplots also reveal variability in the data, indicating that other factors, beyond calculator competency, influence students' ability to solve HOTS problems. These findings emphasize the need to integrate calculator training with a focus on conceptual understanding and critical thinking skills. Educators should prioritize teaching strategies that combine calculator use with the development of analytical and problem-solving skills to enhance student performance in tackling HOTS problems.

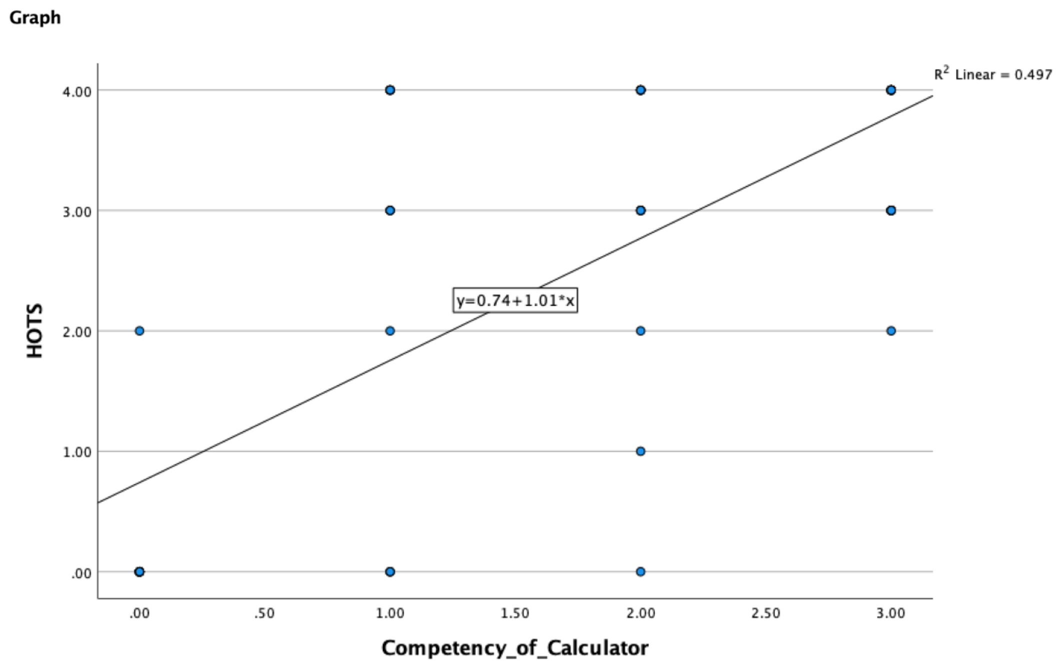

Figure 4 Scatterplot of Relationship between Competency of Using Calculator and Solving Higher Order Thinking Skills (HOTS) Problems among Form Four Students in the Topic of Quadratic Functions

Discussions and Results

Scientific calculators have become essential tools in mathematics education, significantly enhancing students' problem-solving abilities and Higher-Order Thinking Skills (HOTS). By shifting the emphasis from routine arithmetic tasks to advanced analytical problem-solving, calculators enable students to engage more deeply with challenging concepts such as quadratic functions. These functions, which involve both algebraic and graphical representations, are often difficult for students to master. Scientific calculators help bridge this gap by allowing students to visualize and manipulate quadratic equations, fostering a more profound conceptual understanding and improving overall efficiency in solving problems (Kissane, 2016; Sun & Li, 2021).

However, the integration of calculators into educational practice is not without challenges. A common obstacle is students' difficulty in navigating the advanced features of scientific calculators, particularly in solving HOTS-related problems. Research highlights that many students lack confidence and proficiency in using calculators for complex mathematical tasks, emphasizing the need for targeted instructional support (Kissane, 2016). Studies have demonstrated that workshops and seminars aimed at improving calculator skills can significantly enhance students' confidence and their ability to tackle higher-order mathematical problems (Tan & Tan, 2022).

Teachers play a pivotal role in addressing these challenges. To maximize the benefits of calculator usage, educators must go beyond using them as mere computational aids and integrate them as tools to support conceptual learning (National Council of Teachers of Mathematics, 2014). By guiding students in interpreting calculator outputs and connecting these results to the underlying mathematical principals, teachers can enhance students' understanding and problem-solving skills. Professional development programs are crucial in equipping educators with the strategies needed to effectively teach HOTS using scientific calculators (Chan et al., 2023).

Conclusion and Suggestion

Scientific calculators are indispensable in advancing students' problem-solving and HOTS abilities in mathematics education. Students with high calculator competency consistently outperformed their peers in HOTS tasks, as evidenced by the moderate positive correlation (Spearman $r=0.632, p<0.001$) between calculator proficiency and HOTS problem-solving ability. However, the study also revealed significant gaps in students' confidence and proficiency in using advanced calculator functions, pointing to the need for focused instructional interventions.

Teachers have a critical role in bridging these gaps by ensuring that calculators are utilized not just for calculations but as tools to deepen students' conceptual understanding. Professional development initiatives are essential to empower teachers with effective methods for incorporating calculators into HOTS instruction. Additionally, addressing common misconceptions in mathematics, such as those related to quadratic functions, requires a combination of effective teaching strategies and technological integration.

Future research should explore teachers' competencies in fostering HOTS and examine their impact on student performance. Expanding the scope to cover other mathematical topics and a broader range of student demographics could further validate the potential of calculators as tools to improve both procedural fluency and critical thinking in mathematics education.

Acknowledgement
The author wish to thank Dr Norulhuda Ismail from Faculty of Social Sciences and Humanities, Universiti Teknologi Malasyai (UTM), Malaysia, Email: p-norulhuda@utm.my

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