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The Effect of Artificial Intelligence Tools on Mathematics Performance among IB MAA HL Students

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Abstract

This study examines the effects of implementing artificial intelligence (AI) in IB Mathematics: Analysis and Approaches Higher Level at Kolej MARA Banting on student learning when guided by educators. The intervention aimed to incorporate AI technologies and assist students, particularly those requiring further support, in learning to assess AI-generated responses critically and utilise them responsibly to enhance their mathematical skills beyond the classroom. In the third semester of Year 2, students either went to regular classes with no scheduled AI support or structured activities led by a teacher with AI support on five specific subtopics. Independent-samples t-tests showed no statistically significant differences between groups on four of the five quizzes. However, there was a significant improvement in the Maclaurin Series topic ($p < .05$), which suggests that AI integration may work better for some topics than others. Subgroup analysis indicated that lower-achieving students exhibited significant improvement after AI-supported intervention, as evidenced by significant improvement on subsequent similar evaluations following guided elucidations of solution methodologies. Additionally, the AI-integrated group exhibited markedly superior performance in the Semester 3 examination, $t(90) = -3.15$, $p = .002$, despite similar baseline performance in Semester 2. In Semester 3, structured AI guidance was used to help students understand the pros and cons of AI. In Semester 4, however, the focus was on independent thinking and on talking to teachers rather than using AI tools. Data from students showed that AI-supported activities prompted them to determine whether their answers were correct and to reflect on how to use algebraic methods or graphical display calculators (GDCs) correctly. This aligns with the IB learner profile, which includes critical thinking and reflective learning. A comparison of the IB May 2024 and May 2025 exam results shows that AI-assisted instruction may help students learn more in the short term, but its overall effect on their performance on external exams is only moderate and varies by subject. The findings indicate that teacher-facilitated AI integration can serve as an effective educational support tool, especially for structured procedural subjects, although its efficacy varies across mathematical domains and student proficiency levels.

Keywords: Artificial Intelligence in Education, Teacher-Guided AI Integration, IB Mathematics, Analysis and Approaches HL, Mathematics Learning. AI-Supported Learning.

Introduction

The International Baccalaureate Diploma Programme (IBDP) prioritises the purposeful integration of technology to enhance teaching and learning, with a particular focus on mathematics education. In IB Mathematics: Analysis and Approaches Higher Level (MAA HL), students consistently employ technological tools, such as graphical display calculators and digital platforms, to enhance mathematical modelling, visualisation, and intricate problem-solving. This integration of technology is consistent with the IB philosophy of cultivating reflective, principled, and independent learners, as outlined in the IB Learner Profile. Inquiry-based learning and investigative tasks, such as the Mathematics Exploration, encourage students to critically evaluate methods, justify their reasoning, and apply mathematical concepts in authentic contexts. At the national level, Malaysia's Higher Education Blueprint (2015–2025) emphasises the value of digital transformation in education and advocates for the strategic integration of emerging technologies, including artificial intelligence (AI), to enhance learning environments. These initiatives reflect a broader shift toward Education 4.0, a paradigm that prepares learners for the digital age by emphasising technology-driven, personalised, and flexible education to develop critical thinking, creativity, collaboration, and communication skills. The IB educational framework aligns with these principles through its focus on inquiry-based pedagogy, conceptual understanding, and the purposeful use of technology to foster higher-order thinking. Advancements in AI technologies have expanded the role of digital tools in mathematics education beyond traditional computation and visualisation to include adaptive feedback, generative explanations, and problem-solving support. Recent studies suggest that AI-assisted learning environments can improve student engagement and academic performance in mathematics and other STEM disciplines [1].

Nevertheless, most existing research focuses on general mathematics education, and there is limited empirical evidence on the structured use of AI in academically rigorous programs such as IB MAA HL. Due to the abstract and conceptually demanding nature of the MAA HL curriculum, careful pedagogical integration of AI is essential to ensure these technologies support, rather than supplant, students' reasoning and analytical thinking. In response to the growing presence of AI tools in education, the International Baccalaureate issued official guidance on AI use in March 2025, emphasising that AI should be integrated to promote responsible and ethical learning practices. The guidelines stress the importance of maintaining academic integrity and ensuring that students remain active participants in the learning process, rather than passive recipients of AI-generated outputs. To make AI work well in IB classrooms, teachers need to provide clear guidance so students can think critically about AI-generated explanations, check how solutions are reached, and understand the limits of AI tools. In response to these developments, this study examines the effects of teacher-guided AI integration on student performance in IB Mathematics: Analysis and Approaches Higher Level. Rather than presuming that AI inherently enhances learning outcomes, the research investigates whether structured AI-supported instruction results in measurable differences in student achievement across selected mathematical subtopics. By situating AI integration within the pedagogical principles of the IB and the broader Education 4.0 framework, this study seeks to offer empirical considerations regarding the responsible and effective use of AI to support learning in advanced secondary mathematics education.

Research Problem Statement

The mathematics: Analysis and Approaches Higher Level (MAA HL) course within the International Baccalaureate Diploma Programme (IBDP) is recognised for its academic rigour, characterised by abstract concepts, advanced reasoning, and complex problem-solving. Many students frequently struggle to master these concepts, especially when required to apply mathematical reasoning in unfamiliar contexts. Although artificial intelligence (AI) tools are increasingly accessible and widely adopted to support mathematics learning, empirical evidence regarding their effectiveness in rigorous programmes such as IB MAA HL remains limited. Determining whether AI can substantively support student comprehension, academic performance, and learning behaviours consistent with the IB philosophy is therefore essential. The integration of AI in mathematics education presents both opportunities and challenges. AI tools offer step-by-step explanations, immediate feedback, and continuous learning support, which may benefit students requiring additional assistance outside of classroom hours. Nevertheless, the effectiveness of AI depends on its implementation. Without appropriate guidance, students may rely on AI-generated answers without critically evaluating their accuracy, methodological suitability, or alignment with the IB syllabus. As a result, unrestricted AI use may foster passive learning and diminish opportunities for independent mathematical reasoning. These challenges are particularly evident in the structure of the MAA HL examination. Many AI tools primarily generate algebraic solutions, which are most applicable to Paper 1 questions. By contrast, Paper 2 requires the use of graphical display calculators (GDC), and Paper 3 emphasises investigative and extended problem-solving tasks.

As a result, students who rely heavily on AI-generated algebraic methods may employ inappropriate strategies when using calculators or in investigative questions, resulting in inefficient or incorrect solutions. This misalignment between AI-generated approaches and examination requirements has been noted in IB examiner reports. Many students also frequently encounter challenges when initiating the Mathematics Exploration, an internal assessment that requires independent investigation and original mathematical thinking. Many struggle to generate initial ideas or select appropriate mathematical approaches. While AI tools can offer useful starting points or inspiration, excessive reliance on AI-generated content raises concerns regarding academic integrity, plagiarism, and superficial understanding. Given these opportunities and challenges, it is necessary to investigate how AI can be integrated into mathematics classrooms to support meaningful learning while upholding academic integrity and independent reasoning. Specifically, there is a need to determine whether teacher-guided AI integration can help students critically interpret AI-generated solutions, evaluate the suitability of problem-solving methods, and improve mathematical performance across the MAA HL curriculum. Accordingly, this study aims to assess the impact of structured, teacher-guided AI use on student learning and performance in IB Mathematics: Analysis and Approaches Higher Level.

Research Questions

This study investigates how teacher-guided integration of artificial intelligence (AI) affects student performance in the International Baccalaureate Mathematics: Analysis and Approaches Higher Level (MAA HL) course. It examines whether students receiving AI-integrated instruction perform differently on quizzes compared to those without structured AI guidance. The study also compares pre-test and post-test results within the AI-integrated group to assess improvement following a guided AI-supported intervention. It explores the benefits of teacher-guided AI integration for lower-achieving students and examines performance differences across grade bands based on prior achievement. Additionally, the study examines whether AI-supported learning influences performance on major assessments, such as semester exams and IB external examinations, including Paper 1 and Paper 2. Finally, it considers students' perceptions of AI's role in supporting mathematical reasoning, problem-solving strategies, and learning behaviour, especially those aligning with the International Baccalaureate (IB) Learner Profile, which outlines the attributes and values that IB students should develop.

Hypothesis

To examine the statistical differences between groups, the following hypotheses were

Formulated

H_0: There is no statistically significant difference in mean quiz scores between students receiving teacher-guided AI-integrated instruction and those receiving conventional instruction.

H_1: There is a statistically significant difference in mean quiz scores between students receiving teacher-guided AI-integrated instruction and those receiving conventional instruction.

Research Methodology

The study sample comprised 92 Kolej MARA Banting students (Batch 2023–2025) enrolled in IB Mathematics: Analysis and Approaches HL for the May 2025 session. Participants were assigned to two groups: 41 received conventional instruction, while 51 engaged in teacher-guided AI-integrated learning, which involves using artificial intelligence tools to enhance the learning experience. Both groups followed an identical syllabus, schedule, and assessments aligned with the IB MAA HL curriculum. In Semester 3, Group 2 received structured AI-integrated instruction focused on five subtopics, utilising tools such as ChatGPT, Desmos, and Photomath to support conceptual understanding and problem-solving. For topics outside these subtopics, both groups received comparable instruction without structured AI integration, indicating that AI was applied selectively rather than throughout the semester.

During classroom activities on the selected subtopics, the teacher monitored and guided the use of AI tools to ensure appropriate and purposeful application. Many students were encouraged to analyse, verify, and reflect on AI-generated solutions rather than rely on them passively. This approach aimed to foster independent reasoning, critical thinking, and responsible use of technology. However, public accessibility made it impossible to fully control students' independent use of AI tools outside the classroom. This situation reflects authentic educational conditions in which independent access to AI is possible, but structured teacher guidance remains the primary distinguishing factor in instructional practice.

The data collection included quiz scores from the five selected subtopics, pre- and post-quiz assessments in the AI-integrated group, scores from the Semester 3 exam, and scores from the IB May 2025 exam. Additional analyses were performed across achievement levels, categorised by Semester 2 performance (grades 4 and below, grade 5, and grades 6 and 7), to evaluate the impact of AI integration on students with varying academic abilities. Statistical analyses, including independent-samples t-tests, paired-samples t-tests, and ANOVA F-tests, were conducted to determine whether significant differences existed between groups and across achievement levels.

This study employed a quasi-experimental design, recognising that AI integration was limited to selected instructional topics and that students' independent use of AI outside the classroom could not be controlled. Nevertheless, structured, teacher-guided AI integration within specific lessons enabled a meaningful evaluation of its impact on student performance while maintaining alignment with IB pedagogical principles, including Approaches to Learning (ATL) skills and the IB Learner Profile. For example, in a kinematic subtopic, students in the AI-integrated group used ChatGPT to plan a step-by-step approach to a complex problem, then managed their own workflow as they compared various solution paths suggested by the AI. The teacher facilitated reflection activities that prompted students to identify the most reliable sources and set personal targets for growth in self-management skills, such as time planning and error tracking. This classroom practice exemplified the learner-centred nature of the intervention by giving students agency over their learning process, while teacher prompts and a structured activity design supported the explicit development of ATL skills such as self-management and critical thinking.

Research Background

Recent advancements in Intelligence (AI) have created new opportunities to enhance mathematics education by facilitating personalised learning, conceptual understanding, and problem-solving. AI-powered tools deliver step-by-step explanations, generate alternative solution strategies, and provide immediate feedback to students. These features allow learners to revisit challenging concepts and explore multiple approaches to mathematical problems beyond classroom hours. Previous research indicates that AI-assisted learning environments support student engagement and improve understanding when learners actively interact with AI-generated explanations rather than merely copying solutions [2].

Beyond AI-based explanation tools, digital mathematical platforms such as GeoGebra and Desmos have demonstrated the value of technology in supporting students' visualisation of abstract mathematical relationships. These platforms enable learners to dynamically manipulate graphs and mathematical models, facilitating deeper exploration of concepts that are often challenging to grasp through symbolic manipulation alone. Research suggests that technology-supported visualisation enhances analytical reasoning, critical thinking, and creativity, which are essential skills for advanced mathematics learning [3].

Within the International Baccalaureate Diploma Programme, technology integration is essential for supporting inquiry-based learning and conceptual understanding. In IB Mathematics: Analysis and Approaches Higher Level (MAA HL), students are required to apply advanced mathematical reasoning, analyse complex problems, and communicate their thinking effectively. The curriculum focuses on self-directed learning, critical thinking, and ethical technology use, which are all traits of the IB Learner Profile [4].

Nevertheless, as AI tools become more accessible, concerns have arisen regarding overreliance on AI-generated answers, potential misuse, and the possibility that students may bypass essential reasoning processes [5]. In response to these challenges, the International Baccalaureate issued guidance on the use of AI in March 2025, emphasising that AI should support learning while ensuring that students remain active thinkers and critical evaluators of AI-generated information. To use AI effectively, teachers need to provide clear guidance to help students understand AI-generated explanations, verify that the solutions are valid, and assess whether these methods align with the IB syllabus and exam standards. Despite increasing interest in AI-supported learning, empirical research on the role of structured, teacher-guided AI integration in advanced programmes such as IB MAA HL remains limited. Most existing literature addresses general secondary mathematics or broader STEM contexts, with fewer studies examining how AI can support conceptual understanding without supplanting students' reasoning processes. Additionally, limited research has investigated the impact of AI-supported learning on student achievement across various mathematical topics, particularly regarding procedural reasoning, conceptual understanding, and examination performance [6]. This study addresses the identified research gap by examining the impact of teacher-guided AI integration on student performance in selected topics within the IB MAA HL curriculum. Specifically, it investigates whether structured AI-supported instruction results in measurable differences in quiz performance, semester examination outcomes, and learning achievements among students with varying prior achievement levels. By evaluating AI as a guided-learning support tool rather than a direct problem-solving substitute, this research aims to offer empirical observations about the effective integration of AI in advanced secondary mathematics classrooms [7].

Data and Analysis

A questionnaire administered to 92 MAA HL students (Batch 2023–2025) at Kolej MARA Banting revealed a high level of familiarity with artificial intelligence (AI) tools, with 83.3% of students reporting familiarity [8, 9]. Nevertheless, this familiarity did not consistently correspond to frequency of use; some students who were familiar with AI used it infrequently, while some less familiar students reported frequent use. Approximately half of the cohort actively used AI in class, indicating widespread but varied adoption. Among specific tools, ChatGPT was the most commonly recognised AI platform, followed by PhotoMath. By contrast, fewer students reported familiarity with specialised mathematical tools such as Wolfram Alpha or GeoGebra. This pattern indicates a tendency among students to rely on accessible AI tools that provide textual explanations rather than platforms designed for symbolic computation or mathematical visualization [10]. In terms of purpose, 60% of students reported using AI to complete homework problems, 40% to understand difficult topics, and 23% to obtain detailed solutions to MAA HL questions. These findings suggest that AI is primarily used as a support tool for immediate problem-solving rather than long-term conceptual development. Supporting this, only 40% of students believed AI significantly aided their learning in class, while 33% felt it improved their understanding of the syllabus, and 45% considered it somewhat helpful for challenging topics. Four students reported that AI did not assist them at all, highlighting that AI's effectiveness may depend on individual learning styles and engagement levels. Taken together, the data suggest a high level of AI familiarity, moderate actual usage, and selective perception of its usefulness among MAA HL students. Fewer students report that AI significantly improves their understanding of concepts, despite its frequent use for homework and problem-solving [11, 12]. This aligns with broader concerns in mathematics education that AI can support immediate performance but does not automatically foster deep or long-term learning. These patterns will be further examined in relation to academic outcomes measured through quizzes, semester examinations, and the IB May 2025.

Table 1: Comparison of Quiz (%) Performance Between Non-AI and AI-Integrated Groups Across Five Selected Subtopics

		QUIZ 1(AREA AND VOLUME)	QUIZ 2 (KINEMATIC)	QUIZ 3 (EULER METHOD)	QUIZ 4(MACLAURIN SERIES)	QUIZ 5 (INTERSECTION OF 3D PLANES)
G1	CLASS1	79.28	45.34	57.07	51.80	85.43
	CLASS2	78.05	46.15	55.00	46.32	75.62
	CLASS3	78.03	42.05	53.08	35.96	72.12
	MEAN	78.45	44.52	55.05	44.69	77.72
	SD	24.79	25.00	18.86	16.01	14.00
G2	CLASS4	66.89	53.10	69.76	69.94	79.55
	CLASS5	68.06	50.96	65.77	43.27	79.64
	CLASS6	75.11	54.84	40.00	52.76	74.18
	MEAN	70.02	52.97	58.51	55.32	77.79
	SD	20.67	19.73	24.95	17.63	21.00

Table 2: Comparison of Quiz Performance Between Non-AI and AI-Integrated Groups (p-values and Cohen's d)

Quiz	p-value	Cohen's d	Interpretation
Quiz 1	0.985	0	No effect
Quiz 2	0.07	0.38	Small–Medium effect
Quiz 3	0.46	0.15	Small effect
Quiz 4	0.0036	0.62	Medium–Large effect
Quiz 5	0.987	0	No effect

To evaluate the instructional impact of teacher-guided AI integration, quiz performance across five MAA HL subtopics was compared between the non-AI group (Group 1) and the teacher-guided AI-integrated group (Group 2). Descriptive statistics for the quizzes are provided in Table 1, and statistical comparisons, including p-values and effect sizes, are summarised in Table 2. An independent-samples t-test indicated that four of the five quizzes showed no statistically significant differences between the two groups. For Quiz 1 (Area and Volume) and Quiz 5 (Intersection of 3D Planes), mean scores were nearly identical, and effect sizes were negligible. Similarly, Quiz 3 (Euler Method) demonstrated no meaningful difference in performance between instructional approaches. (Maclaurin Series) demonstrated a statistically significant difference in Favor of the AI-integrated group. Many students receiving teacher-guided AI support achieved higher mean scores, and the effect size indicated a moderate practical impact. The results of this experiment may indicate that teacher-guided AI integration may be particularly beneficial for topics involving symbolic manipulation and analytical reasoning [13].

For Quiz 2 (Kinematics), the AI-integrated group also achieved higher mean scores, although the difference did not reach statistical significance. Nevertheless, the effect size indicated a small-to-moderate practical advantage, suggesting potential instructional benefits from modelling-related tasks.

Table 3: Scores among 12 students (weak or grade 4 and below in semester 2 examinations)

		QUIZ1 (AREA AND VOLUME)	QUIZ 2 (KINEMATIC)	QUIZ 3 (EULER METHOD)	QUIZ 4 (MACLAURIN SERIES)	QUIZ 5 (INTERSECTION OF 3D PLANES)
GROUP1	MEAN	69	32	50	45	72
	SD	26	18	21	13	14
GROUP 2	MEAN	54	50	49	53	74
	SD	24	27	22	18	26
	p value	0.9374	0.01403	0.5368	0.07706	0.3522
	t value	1.5771	-2.3084	-0.09329	1.4655	-0.383
		ACCEPT NULL	REJECT NULL	ACCEPT NULL	REJECT NULL	REJECT NULL

Further analysis focused on students who scored Grade 4 or below in the Semester 2 examination, as shown in Table 3. Only the Kinematics topic showed a statistically significant improvement among these lower-achieving students due to teacher-guided AI integration. For the remaining quizzes, no statistically significant differences were detected. Taken together, the findings suggest that AI-supported instruction may provide targeted support for weaker students in structured procedural contexts but does not consistently improve performance across all mathematical topics [14].

Table 4: Mean and Standard Deviation of Quiz Scores in Group 2 Categorised by Semester 2 Achievement Bands

		(AREA AND VOLUME)	QUIZ 2 (KINEMATIC)	QUIZ 3 (EULER METHOD)	QUIZ 4 (MACLAURIN SERIES)	QUIZ 5 (INTERSECTION OF 3D PLANES)
GRADE 4 & BELOW (n=21)	MEAN	79	49	49	53	74
	(n=21)	16	18	22	18	24
GRADE 5 (n=23)	MEAN	80	74	66	57	83
	(n=23)	28	19	24	15	14
GRADE 6&7 (n=7)	MEAN	79	99	71	73	89
	(n=7)	15	11	21	18	14

Table 5: Anova result

Quiz	F (2 48)	p-value	Conclusion (α = 05)
Quiz 1 (Area & Volume)	0.013	0.987	Not significant
Quiz 2 (Kinematics)	23.921	0.000000062	Significant
Quiz 3 (Euler Method)	4.043	0.0238	Significant
Quiz 4 (Maclaurin Series)	3.791	0.0296	Significant
Quiz 5 (Intersection of 3D Planes)	2.158	0.1266	Not significant

Within the AI-integrated group, a one-way ANOVA was conducted to examine the influence of prior academic achievement on quiz performance. Many students were categorised into three achievement bands based on Semester 2 examination results, as shown in Table 4, and the ANOVA results are presented in Table 5. Significant differences were observed in kinematics, the Euler method, and the Maclaurin series, with students of higher prior achievement consistently obtaining higher mean scores [15, 16]. By contrast, no significant differences were observed for area, volume, and the intersection of 3D planes. Spearman's rank correlation further confirmed a strong positive relationship between prior achievement level and quiz performance ($\rho = .68$, $p < .001$), indicating that prior academic ability remained a key predictor of student performance.

Table 6: Pre-Test and Post-Test Results of Many students Who Initially Failed in Each Quiz

QUIZ 1	PRE TEST	POST TEST
	7	18
	10	15
	10	10
	9	20
	5	15
	9	15
	3	13
	9	14
	10	13
	6	12
	P value	0.0001461
	t value	5.7057
		reject Null

QUIZ 2	PRE TEST	POST TEST
	7	14
	8	14
	10	7
	9	18
	6	17
	7	15
	8	18
	9	10
	9	16
	7	17
	9	9
	10	16
	9	10
	5	19
	P value	0.0001669
	t value	4.8213
		Reject Null

QUIZ 3	PRE TEST	POST TEST
	17	26
	11	18
	15	11
	16	18
	15	22
	13	21
	14	20
	11	6
	17	19
	16	22
	13	22
	9	12
	4	11
	17	17
	17	21
	18	13
	17	21
	12	9
	18	18
	14	17
	14	22
	19	9
	9	6
	P value	0.02092
	t value	2.1612
		reject Null

QUIZ 4	PRE TEST	POST TEST
	5	8
	8	10
	10	9
	6	7
	9	14
	9	4
	9	12
	7	5
	5	11
	3	5
	3	7
	2	6
	P value	0.03472
	t value	2.0114
		Reject Null

QUIZ 5	PRE TEST	POST TEST
	5	5
	5	7
	6	9
	4	8
	5	8
	6	7
	6	10
	3	13
	5	5
	3	12
	5	10
	6	6
	5	13
	4	8
	5	12
	6	14
	1	9
	5	9
	6	10
	3	3
	6	10
	6	9
	5	5
	2	10
	3	13
	3	9
	4	6
	5	6
	8	8
	8	5
	P value	6.764e-7
	t value	6.0596
		reject Null

An additional analysis examined post-test results for students who initially failed a quiz within the AI-integrated group. After receiving guided AI-supported feedback, these students completed a second assessment with similar questions. As shown in Table 6, most students improved their post-test scores, indicating that AI tools may be effective as a remedial support mechanism. The improvement was particularly evident in procedural questions, where AI assistance enabled students to verify solution steps and identify calculation errors [17-19].

Table 7: Comparison of Semester 2 and Semester 3 Examination Results Between Group 1 and Group 2

		second semester	**third semester**
Group 1	Mean	57	43
	SD	11	10
Group 2	Mean	59	50
	SD	12	11
	t value	-0.820	-3.1500
	p value	0.4100	0.0022

Table 8: Comparison of Semester 3 Examination Results Between Group 1 and Group 2

		P1	**P2**	**P3**
G1	MEAN	50.6982456	39.89298246	25.37836257
	SD	11.5270109	11.25297244	8.133968039
G2	MEAN	60.1024205	44.07440925	25.97773468
	SD	14.8768381	13.77854223	8.658436967
	t value	-3.32	-1.57	-0.34

	p value	0.0013	0.12	0.73
		significant	not significant	not significant

Semester examination results were analysed to assess broader academic outcomes. As shown in Table 7, no statistically significant difference was observed between groups in Semester 2, indicating comparable baseline performance [20]. In Semester 3, however, the AI-integrated group achieved significantly higher mean scores than the non-AI group. Although both groups experienced a decline in overall performance during the semester, the reduction was smaller in the AI-integrated group, suggesting that teacher-guided AI activities may have helped mitigate the extent of performance decline during a more demanding academic period.

Performance across examination components is presented in Table 8. The results indicate that the AI-integrated group performed significantly better on Paper 1, while no statistically significant differences were observed in Papers 2 and 3.

These findings suggest that AI tools may be more effective for algebraic and procedural problem-solving tasks commonly assessed in Paper 1, whereas their effectiveness appears more limited for calculator-based or investigative questions

Table 9: IB result May 2025

Group		p1	p3	p2
G1	mean	58.68	39.95	55.29
	SD	11.05	8.35	11.56
G2	mean	60.47	38.82	57.2
	SD	14.04	10.5	15.17
t value		-0.683	0.574	-0.683
p value		0.4946	0.567	0.497

Performance in the IB May 2025 examination was compared between the two groups, as shown in Table 9. Independent-samples t-tests indicated no statistically significant differences between groups across the examination papers [21]. While the result suggests comparable overall performance, it does not necessarily imply that AI provided no instructional benefit.AI tools may help students understand solution strategies, but IB examination questions often require students to apply mathematical processes in unfamiliar contexts and present well-structured reasoning consistent with IB mark schemes [22]. Taken together, the results indicate that teacher-guided AI integration provides targeted benefits in specific mathematical domains, particularly those involving structured procedural reasoning. Nevertheless, its impact appears to be topic-dependent, and prior academic achievement remains a strong predictor of student performance [23].

Discussion

The findings of this study offer insights into the impact of teacher-guided integration of artificial intelligence (AI) on student learning within the International Baccalaureate Mathematics: Analysis and Approaches Higher Level (MAA HL) curriculum. The results in this cohort suggest that the effectiveness of AI integration depends on the specific topic and is more pronounced in areas that require structured procedural reasoning.

A comparison of quiz performance between the AI-integrated and non-AI groups revealed a statistically significant improvement exclusively in the Maclaurin Series topic. This outcome aligns with the topic's emphasis on symbolic manipulation and sequential algebraic reasoning. AI tools demonstrated particular effectiveness in generating and explaining these procedural processes, allowing students to review intermediate steps and verify calculations. Additionally, the kinematics topic showed a small-to-moderate practical effect, suggesting that AI could assist with modelling-based problems that involve a structured analytical procedure [24]. Several other topics, such as Area and volume, the Euler method, and the intersection of 3D planes, did not exhibit statistically significant differences. Taken together, the findings suggest that AI integration does not consistently enhance student performance across all mathematical domains [25]. Topics requiring spatial reasoning, graphical interpretation, or deeper conceptual understanding appear less likely to benefit from AI-generated explanations. This observation is consistent with previous research suggesting that AI can facilitate procedural learning but does not inherently improve conceptual understanding or higher-order reasoning without targeted instructional guidance. Further analysis of lower-achieving students indicated that teacher-guided AI integration yielded measurable benefits in the kinematics topic. This finding suggests that AI tools can serve as effective scaffolds for struggling learners by facilitating the review of problem-solving steps, the identification of calculation errors, and the reinforcement of procedural understanding [26]. Nevertheless, the lack of significant differences in other topics demonstrates that AI support alone is insufficient to address learning gaps among weaker students. Prior academic ability remained a strong predictor of performance, as shown by significant differences across achievement bands and a strong positive correlation between prior achievement and quiz scores. These results demonstrate the value of structured teacher guidance when integrating AI tools into mathematics classrooms.

The survey results showed that most students used AI to get answers or finish homework, not to learn more about the concepts. Without guidance, students may rely on AI-generated responses without critically evaluating the solution's correctness or the method's appropriateness within the IB syllabus. As a result, teacher-guided activities were implemented to encourage students to analyse AI-generated explanations, verify solution steps, and assess whether the approaches conformed to IB examination requirements.

Analysis of semester examination results provides additional support for this interpretation. While both groups experienced a decline in performance from Semester 2 to Semester 3, the AI-integrated group exhibited a smaller decrease. The survey results showed that most students used AI to get answers or finish homework, not to learn more about the concepts. Nevertheless, the absence of significant differences in final IB examination results indicates that AI integration did not lead to substantial long-term improvements in external assessment performance. One possible explanation is that IB examination questions often require students to apply familiar mathematical processes in unfamiliar contexts [27]. Although AI tools can assist students in understanding procedural solution strategies, they may not adequately prepare students for tasks that demand extended reasoning, mathematical communication, or proficient use of graphical display calculators (GDC). This phenomenon may account for the stronger performance of the AI-integrated group in Paper 1, which emphasises algebraic reasoning, but not in Papers 2 and 3, which focus on calculator-based analysis and investigative problem-solving. In summary, the findings indicate that AI integration should be regarded as a complementary instructional tool rather than a replacement for mathematical reasoning. When implemented with appropriate teacher guidance, AI can support procedural understanding, assist struggling learners, and offer additional learning opportunities beyond classroom hours. Nevertheless, its effectiveness depends on the manner of integration within the teaching process and the extent to which students are encouraged to evaluate AI-generated information critically. These findings suggest that AI should be viewed as a pedagogical support tool rather than a replacement for mathematical reasoning, particularly in advanced courses such as IB Mathematics: Analysis and Approaches HL.

Limitation

This study investigated the effects of teacher-guided integration of artificial intelligence (AI) within five selected Mathematics: Analysis and Approaches Higher Level (MAA HL) subtopics during Semester 3Structured AI-supported instruction was implemented inconsistently throughout the academic year, with no guided AI activities in Semester 4. For this reason, the findings primarily reflect short-term instructional effects rather than long-term or sustained learning outcomes. The lack of continuous AI integration limits the ability to assess whether extended exposure to guided AI activities would lead to more consistent or lasting improvements in student performance.

Structured AI use was monitored during class sessions; however, students' independent access to AI tools outside of class could not be controlled. While this approach reflects authentic learning conditions, it introduces variability that may have influenced outcomes beyond the intervention. Many students likely engaged with AI tools at varying frequencies, for different purposes, and with differing levels of depth, potentially affecting the consistency of the results.

Moreover, AI integration was limited to five selected subtopics rather than being implemented across the entire MAA HL syllabus. The results suggest that the effectiveness of AI support may depend on the specific topic, particularly in procedural and symbolic reasoning tasks. As a result, these findings should not be generalised to all mathematical topics within the MAA HL curriculum. The comparison of International Baccalaureate (IB) external examination performance between the May 2025 and May 2024 cohorts was constrained by the fact that these cohorts comprised different student groups. Variations in student backgrounds, examination difficulty, and instructional contexts may have influenced the outcomes. For this reason, the cross-cohort comparison should be interpreted as a contextual reference rather than as causal evidence of AI integration's impact. Future research should employ longitudinal designs with larger sample sizes and sustained AI (artificial intelligence) integration across multiple topics. Such studies may offer more details about the long-term effects of teacher-guided AI on student learning, conceptual understanding, and performance in advanced mathematics.

Conclusion

This study examined the effects of teacher-guided integration of artificial intelligence (AI) on student performance in IB Mathematics: Analysis and Approaches Higher Level (MAA HL). The intervention aimed not only to enhance examination outcomes but also to promote responsible and critical use of AI as a learning support tool. Consistent with the International Baccalaureate's focus on independent thinking and academic integrity, the instructional approach required students to analyse AI-generated solutions, verify their accuracy, and assess whether the methods conformed to syllabus content and examination standards. The results demonstrate that the impact of AI integration differs substantially across mathematical topics. A statistically significant improvement was observed in the Maclaurin Series, where students experienced the greatest benefit, whereas a modest but practical advantage was found in Kinematics. Conversely, in topics such as area and volume, the Euler Method, and the intersection of 3D, no measurable differences were identified between the AI-integrated and non-AI groups. Taken together, the findings suggest that AI tools are particularly effective for topics involving structured procedural reasoning and symbolic manipulation, but their influence is more limited in other domains. Further analysis revealed that teacher-guided AI integration provided targeted support for lower-achieving students with modelling-based problems.

Prior academic achievement remained a strong predictor of performance. The AI-integrated group attained higher scores in the Semester 3 examination and performed better on Paper 1 components, which emphasise algebraic reasoning. Nevertheless, the advantages of AI integration were less evident in assessments requiring a graphical calculator, spatial reasoning, or extended investigative tasks. In summary, the findings indicate that teacher-guided AI integration can enhance instruction in advanced mathematics. With appropriate guidance, AI tools assist students in verifying solutions, identifying errors, and reinforcing procedural understanding. Nevertheless, AI should not substitute for independent mathematical reasoning. Instead, it should serve as a complementary resource that fosters analytical skills, problem-solving abilities, and responsible use of technology. Future research should investigate strategies to optimise AI integration across various mathematical topics and student profiles, while educators are encouraged to pursue ongoing professional development to ensure effective and ethical use of AI in the classroom.

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