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Boosting Student Motivation and Science Understanding in the GCE 'O' Level Combined Science through AT-TPACK Framework

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Abstract: The particular study examined the impact of science boost camp interventions, utilizing the activity theory and TPACK (AT-TPACK) framework, on the achievements of sixty-eight Year 11 combined science students following the new Cambridge 5129 syllabus, including Paper 3 components, in Muara, Brunei. These students, learning combined science in English as their second language for three years, scored below 60% in their SPE Year 8 science exams, placing them in the Applied Secondary Education Programme (one class of 20 students) and the Special Applied Program (three classes of 48 students). The study used a pre-test-post-test and delayed post-test experimental design to evaluate the effectiveness of the proposed three-phase AT-TPACK model. The primary goal was to enhance students' combined science achievement and reduce the number of students receiving ungraded (below 30%) grades in the GCE O-Level examinations. After the mock exams, the sixty-eight students were randomly assigned to fourteen intervention groups based on their academic performance. Each group, led by a higher achiever (HA) student, participated in science interventions. This study examines the impact of science boost camp interventions, utilizing the activity theory and TPACK (AT-TPACK) framework, on the achievements of sixty-eight Year 11 combined science students following the new Cambridge 5129 syllabus, including Paper 3 components, in Muara, Brunei. The students were selected through purposive sampling, involving 20 students from Year 11A (General Applied Program) and 48 from Year 11B to 11C2 (Special Applied Program). These students, learning combined science in English as their second language for three years, scored below 60% in their SPE Year 8 science exams, placing them in the Applied Secondary Education Programme. The aspects measured in this study included students' motivation, conceptual understanding, and collaborative learning performance. The results revealed significant improvement in achievement scores postintervention and a reduction in ungraded grades, with thematic analysis indicating sustained retention of scientific concepts even after the 20-week intervention period. Students' GCE O-level exam performance improved, with the school achieving its 2023 target for combined science, increasing from 19% to 35%, placing the school in the second-highest rank in the country. These findings highlight the potential of targeted interventions in addressing challenges in combined science education, providing insights for educators seeking to enhance student outcomes in similar contexts.

Keywords: Activity theory, combined science, motivation, scientific conceptual understanding, science boost camp.

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INTRODUCTION

The study investigates the effectiveness of the Science Boost Camp intervention, designed using the Activity Theory (AT) and Technological Pedagogical Content Knowledge (TPACK) frameworks, to enhance Year 11 students' motivation and understanding of scientific concepts in preparation for their GCE O-Level Combined Science examination. The research targets students who have historically

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struggled with science due to language barriers, poor study habits, and low prior achievement, particularly those enrolled in the Applied Secondary Education Programme. To strengthen the scientific foundation and increase academic achievement, this study incorporated peer-based strategies and practical learning scenarios contextualized in local settings.

Using a pretest-posttest-delayed posttest experimental design, the study evaluates how structured peer-led learning, technology-enhanced instruction, and revision strategies impact student achievement, motivation, and knowledge retention over a 20 week. While initial findings indicate improved test scores and motivation, challenges such as exam pressure, sustainability of knowledge retention, and broader scalability remain areas for further investigation. As science education evolves globally, efforts must reflect student needs. Recent studies such as Aisy et al. (2024) and Irdalisa et al. (2024) highlight the benefits of innovative learning strategies in enhancing student performance and motivation in science.

Previous studies have revealed significant challenges in learning science for students in learning a second language, especially when they have previously underperformed in foundational subjects. In Brunei Darussalam, where English is the medium of instruction for science, many Year 11 students enrolled in the Applied Secondary Education program face difficulties with motivation, mastering content, and preparing for exams. These students, often scoring below 60% in earlier assessments, encounter further obstacles, such as language barriers and limited study habits, compounding their challenges in understanding scientific concepts. To address these issues, intensive revision sessions known as the "Boost Camp" have been developed as promising interventions to support students in preparing for their General Certificate of Education (GCE) O-level examinations.

Research emphasizes the need for students to grasp 'overloaded' abstract concepts in science. Science literacy encompasses understanding scientific concepts, evaluating evidence, and applying knowledge to real-world situations (Irdalisa et.al., 2024). Studies done by Evagorou, Erduran & Mäntylä (2015) suggested that in teaching science, the emphasis in visualization should shift from cognitive understanding—using the products of science to understand the content—to engaging in the processes of visualization. Furthermore, in the same research, it suggests that it is essential to design curriculum materials and learning environments to create a social and epistemic context and invite students to engage in the practice of visualization as evidence, reasoning, experimental procedure, or a means of communication and reflect on these practices (Evagorou, Erduran & Mäntylä, 2015). Scientific reasoning is crucial for students to analyze data and solve problems effectively (Irdalisa et.al., 2024).

However, fostering higher scientific literacy requires helping students in visualizing accurate concepts to prevent misconceptions. Technology and carefully designed instructional strategies offer a solution for supporting students in visualizing abstract scientific ideas (Fan, Salleh & Laxman, 2018). In addition to enabling simple tasks such as internet searches and document creation, technology can bridge language gaps and enhance students' understanding of scientific concepts (Fan, Salleh & Laxman, 2018).

This struggle is not unique to Brunei; other countries whose students take the GCE O Level Combined Science examination also report low performance. Table 1.1 summarizes cumulative grades worldwide over the past ten years, showing that a significant percentage of students score above a 'C', the threshold for credit and distinction for the subject 5129 Combined Science.

Table 1.1: GCEs' percentages of cumulative grades worldwide for 5129 combined science subjects. Note: In addition to SAG, 2020, 2021, and 2022 followed the moderated thresholds, as per the Cambridge press release, and should be ignored.

Year	**Percentage of students obtaining grade C and above** *(Grade C or above = Credit and Distinction)*
Nov 2023	24.5
Nov 2022	24.4
Nov 2021	38.3 (SAG)
Nov 2020	27.2
Nov 2019	20.3
Nov 2018	20.0
Nov 2017	21.0
Nov 2016	62.0

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Year	**Percentage of students obtaining grade C and above** *(Grade C or above = Credit and Distinction)*
Nov 2015	21.0
Nov 2014	24.0
Nov 2013	24.0

Note. Adapted from https://www.cambridgeinternational.org/programmes-and-qualifications/cambridge-uppersecondary/cambridge-o-level/results-statistics/ Copyright (2019) by UCLES 2021.

This study draws on two key theoretical frameworks: activity theory (AT) and technological pedagogical content knowledge (TPACK). Activity theory (Engeström, 1987) provides a lens to examine the social and cultural contexts of learning, focusing on how tools, rules, and community interactions mediate learning processes. In addition, TPACK (Mishra & Koehler, 2006) emphasizes integrating content, pedagogy, and technology to create more effective and engaging learning environments. Together, these frameworks offer a comprehensive approach to addressing the unique challenges that low-achieving students face in an English as a second language (ESL) context.

Students in the Applied Secondary Education Programme in Brunei Darussalam face persistent challenges in mastering GCE O-Level Combined Science, particularly due to language barriers, cognitive overload, and limited access to effective instructional strategies. Despite the importance of scientific literacy, many students struggle to visualize abstract concepts, leading to low exam performance and a high percentage of ungraded scores. Meanwhile, previous research highlights the benefits of technology-enhanced learning, there is limited empirical evidence on how structured interventions, such as Boost Camps, can improve science achievement for low-performing, ESL students. This study addresses this gap by investigating whether a peer-led, AT-TPACK-based intervention can enhance student motivation, engagement, and long-term knowledge retention in science learning.

To create meaningful learning experiences, teachers must possess strong content knowledge (CK) and pedagogical knowledge (PK). However, scholars such as Mishra and Koehler (2006) and McCrory (2008) argue that technological knowledge (TK) is equally essential. When combined, these three domains—CK, PK, and TK—form the TPACK framework, guiding technological inclusion in educational settings. In science education, it is crucial for teachers to continuously increase their content, pedagogical and technological skills to enhance student learning outcomes.

Activity theory (Figure 1) contextualizes technology usage within a broader framework, considering the interaction between learners and tools and the larger social and cultural contexts of these interactions. The theory explores how individuals engage in goal-directed behaviour, which is mediated by tools and shaped by community norms, rules, and divisions of labour (Yamagata-Lynch, 2010). The use of technology in education is therefore seen not only as a tool for instruction but also as a facilitator of collaborative, goal-oriented activities that align with broader educational objectives.

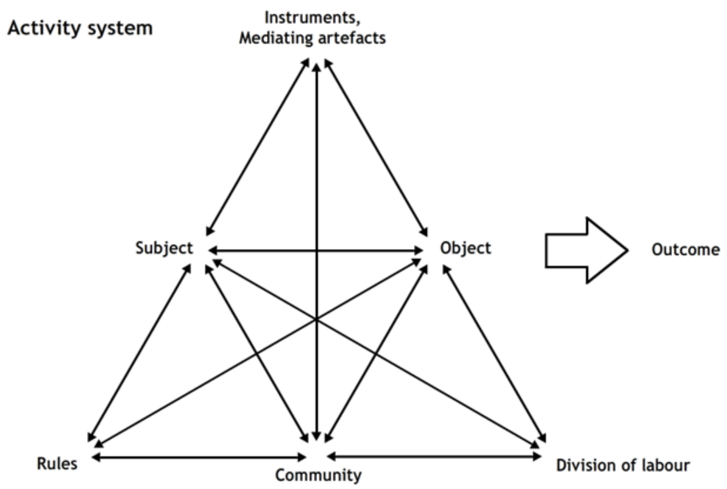

Figure 1: Activity system diagram

Diagram illustrating connections between subjects, instruments, objects, and outcomes, along with rules, communities, and the division of labor (Engeström, 2000).

The activity theory in Figure 1 is incorporated into the TPACK framework, which fits into the context of this study, as shown in Figure 2.

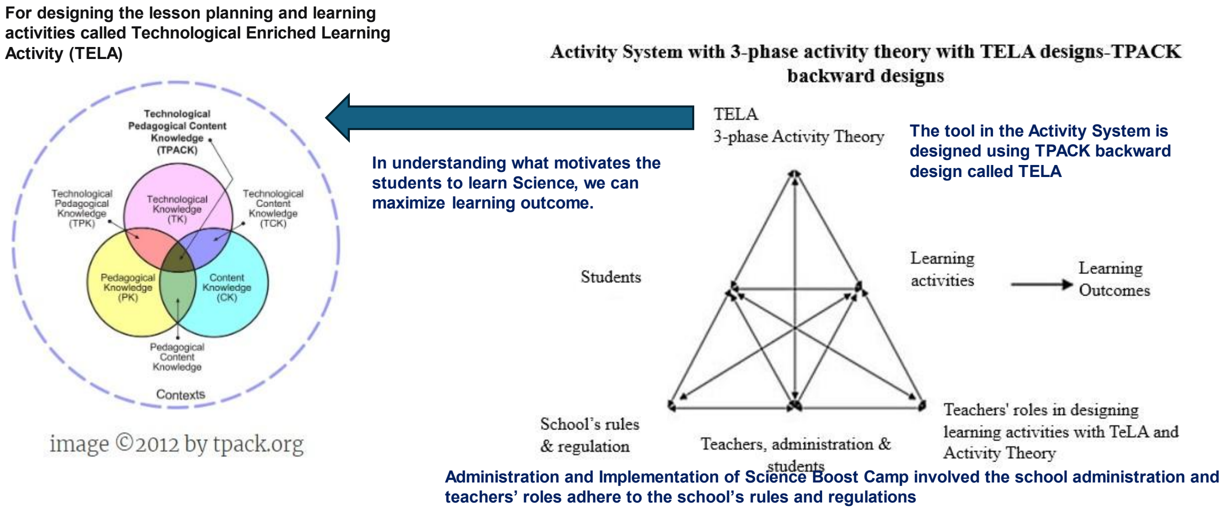

Figure 2: AT-TPACK framework of this study

The primary aim of this research is to evaluate the effectiveness of the Boost Camp, which was designed with the AT-TPACK framework, in improving student motivation and understanding of scientific concepts. Specifically, the study aims to determine whether these interventions can improve students' combined science test scores and reduce the number of students receiving ungraded scores.

The short-term objectives (Immediate Impact & Feasibility within the Study's Scope)

1. Improve Science Achievement
   o Enhance students' understanding of science concepts, particularly those struggling with language barriers.
   o Reduce the number of students receiving ungraded (U) scores in the GCE O-Level Combined Science exam.
2. Enhance Motivation and Engagement
   o Implement structured, technology-enhanced Boost Camp interventions to foster student motivation.
   o Use peer-led learning to build collaborative and supportive learning environments.
3. Validate the Effectiveness of the AT-TPACK Framework
   o Assess whether the integration of Activity Theory (AT) and Technological Pedagogical Content Knowledge (TPACK) improves science education outcomes.
   o Use a mixed-methods approach to measure knowledge retention and motivation.
4. Identify Student Learning Barriers
   o Examine how second-language learners struggle with scientific terminology and abstract concepts.
   o Analyze student feedback on stress and motivation to refine future interventions.

Additionally, the study explores the sustainability of knowledge retention beyond the intervention period, examining whether the increase in motivation and understanding can be maintained over time. The long-term objectives (Broader Educational Impact & Scalability):

1. Sustain & Scale Boost Camp Interventions
   o Expand Boost Camp to other schools or subjects beyond Combined Science.
   o Integrate into national education policies for supporting low-achieving students in science.
2. Enhance Teacher Professional Development
   o Train teachers on AT-TPACK integration to improve their technological, pedagogical, and content knowledge.
   o Promote a shift from rote learning to inquiry-based, technology-supported teaching.

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3. Develop Longitudinal Research on Knowledge Retention
   o Assess whether students retain conceptual understanding beyond the 20-week intervention.
   o Conduct follow-up studies on students' performance in higher-level science courses or STEM careers.
4. Reduce Exam Anxiety & Improve Learning Mindsets
   o Develop strategies that balance academic rigor with emotional well-being.
   o Investigate methods to help students manage exam stress and pressure effectively.

The research addresses the following questions:

1. Is there a significant change in students' test scores after the Boost Camp interventions?
2. Does the intervention have an impact on students' test scores?
3. How do these interventions improve students' motivation and learning outcomes?

This introduction sets the foundation for a deeper exploration of the relevant literature, further clarifying this study's context, significance, and theoretical underpinnings

LITERATURE REVIEW

Research into students' challenges in learning science in a second language has identified several barriers to success. In their study, Ramaila and Lazou (2022) highlight that learners encounter multiple challenges when studying science in a language different from their home language. These challenges include difficulties in comprehending scientific terminology, spelling, and pronunciation, which can hinder understanding of both the content and examination instructions. Such findings underscore the importance of addressing language barriers to enhance science education for ESL students. This is particularly problematic for low-achieving students, who may already have limited prior knowledge of science and weak study habits. Huang and Lin (2013) highlight the importance of targeted interventions that address both the cognitive and motivational aspects of learning, particularly for students at risk of underperforming in high-stakes exams, such as the General Certificate of Education (GCE) O-Level.

This issue is evident in Brunei Darussalam, where the medium of instruction for science is English, and students in the Applied Secondary Education Programme face difficulties in mastering content owing to language barriers and poor study habits, as highlighted in the introduction chapter. These challenges hinder students from developing the higher-order thinking (HOT) skills necessary to succeed in science. This study aims to investigate how boot camp, designed as an intervention using a combination of activity theory (AT) and the technological pedagogical content knowledge (TPACK) framework, can help students overcome these obstacles and improve their science exam performance.

Theoretical Frameworks: Activity Theory and TPACK

Activity theory (AT), initially introduced by Vygotsky (1978) and later expanded by Leont'ev (1978) and Engeström (1987), provides a robust framework for understanding the social and cultural dimensions of learning. It posits that learning is a mediated activity shaped by the tools available to the learner, the rules of the learning environment, and the broader community. In the context of this study, Boost Camp functions as a mediated activity, utilizing tools such as scientific materials and technology, with the community comprising peers and teachers collaborating to support learning. It aligns with the study’s aim of exploring how teacher-led interventions can enhance student motivation and understanding in a high-stakes examination environment.

The TPACK framework complements activity theory by integrating technology into the teaching process to enhance pedagogical and content knowledge. Mishra and Koehler (2006) emphasize that effective teaching requires understanding how to use technology to make content more accessible, particularly in subjects such as science, where interactive and visual tools can significantly aid comprehension. Sarkawi and Salleh (2016) reported that incorporating TPACK in English as a second language (ESL) classrooms improved student engagement and performance, particularly when technology was used to overcome language barriers. This is directly related to the study's focus on using technology to support students in understanding abstract scientific concepts, a key element of the Boost Camp intervention.

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Technology in Science Education

The integration of technology into science education has been shown to improve conceptual understanding. Studies by Fan et al. (2018) and Purwaningsih et al. (2019) demonstrate that hands-on, technology-driven learning activities enhance student outcomes, particularly for low-achieving students. This study builds on these findings by applying technology in exam preparation to improve cognitive and motivational outcomes through Boost Camp. These camps incorporate peer-led learning, technology-enhanced lessons, and structured revision sessions, directly addressing the challenges of cognitive overload and lack of motivation, as discussed in the introduction chapter.

While technology infrastructure has been established in the Bruneian context, studies indicate that many teachers may not fully understand how to integrate these technologies into their teaching practices (Ali et al., 2015). This study proposes a framework for empowering teachers to integrate technology via TPACK and the 21st-century learning design (21CLD) model. The aim is to equip teachers with the tools to support students in mastering both content and 21st-century skills, reinforcing the role of the teacher in the learning equation, as highlighted in the introduction.

Gaps in Research

Despite the increasing emphasis on technology integration, research into science education remains limited in certain areas. Yaki, Saat, Sathasivam, and Zulnaidi (2019) argued that more research is needed to explore the impact of technologically enriched lesson designs. Similarly, Amin, Smith, and Wiser (2014) noted that while research on conceptual understanding has been conducted, few studies have investigated how students' conceptions change after instruction.

Teacher Empower and Pedagogical Practices

A significant barrier to student progress in science education is the reliance on traditional teaching methods that focus on content mastery rather than on developing skills such as problem-solving and critical thinking (Zongyi, 2019). Research suggests that teachers often hesitate to implement constructivist pedagogies, which foster conceptual understanding and higher-order thinking (HOT) skills. This reluctance is driven by pressure to prepare students for exams, leading to a preference for more didactic teaching methods. However, as Deng (2019) argues, traditional pedagogy is inadequate for preparing students for the demands of the 21st-century economy.

The survey used to measure student motivation is called the Academic Motivation Scale (AMS). The Academic Motivation Scale (AMS, AMS-C-28; Vallerand et al., 1992) is a 28-item, Likert-scaled measure of motivation toward education. The AMS is based on the tenets of self-determination theory and comprises 28 items, subdivided into seven subscales that assess three types of intrinsic motivation, three types of extrinsic motivation, and overall motivation. It asks the following question: "Why do you go to college?" The items represent the possible answers to that question, thus reflecting the different types of motivation. The seven-factor structure: 1. Intrinsic Motivation-to-Know, 2. Intrinsic Motivation-toward Accomplishment, 3. Intrinsic Motivation-to Experience Stimulation, 4. Extrinsic Motivation Identified, 5. Extrinsic Motivation-Introjected, 6. Extrinsic Motivation-External Regulation, and 7. Motivation (4 items each). By integrating AMS approaches, educators can understand in greater detail which factors motivate students to learn more and teachers to create a more dynamic learning environment that encourages exploration and critical thinking. This study contributes to the call for a shift towards more innovative and creative lesson designs, empowering teachers to adopt instructional practices that promote deeper learning and adaptability in science education. Hence, the AMS survey helps teachers emphasize in greater detail what factors motivate students to learn based on their feedback, aligning the principles of constructivist pedagogy (Davis et al., 2020).

Empowering teachers is crucial, as they are best positioned to understand their students' needs. Deng and Gopinathan (2016) assert that teacher empowerment significantly affects student learning outcomes. This study aligns with this perspective, offering a framework for teachers to plan and integrate technology into their classrooms innovatively, thereby enhancing both student motivation and achievement.

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METHOD

This study employed an explanatory sequential mixed-method design, integrating both quantitative and qualitative approaches to assess the impact of the Boost Camp intervention on students' academic performance and motivation. The sample comprised 68 Year 11 combined science students from one of the secondary schools in Brunei who were enrolled in the Applied Secondary Education Programme or the Special Applied Programme. These students, having previously scored below 60% in their Year 8 School Progress Examination (SPE) science examinations, needed intervention to increase their GCE O Level science exam scores through improved conceptual understanding and motivation.

The scientific topics addressed in the intervention include Physics, including Newtonian mechanics, energy conversion, Biology, such as osmosis, cells, respiration, and Chemistry, including matter, chemical bonding, and energy conversion, all of which are aligned with fifty-three topics in the GCE O-Level 5129 syllabus. The intervention materials were drawn from CIE past papers and practical-based questions tailored to the updated curriculum. Validity and reliability were ensured by using standardized examination papers from the Cambridge International Examinations (CIE) archives. A Cronbach's alpha test was performed on the survey instrument and yielded a value of 0.81, indicating high reliability.

The Boost Camp intervention was structured via the Activity Theory (AT) and Technological Pedagogical Content Knowledge (TPACK) frameworks and was implemented over 20 weeks. The students were divided into 14 groups, each led by a higher-achieving peer, facilitating the revision sessions. The intervention followed a three-phase model: pre-test, post-test, and delayed post-test. The pre-test assessed students' baseline knowledge, the post-test measured immediate improvements following the Boost Camp, and the delayed post-test evaluated knowledge retention over time.

Quantitative data were collected through the students' test scores across all three phases. The scores were analysed via paired-sample t-tests to determine whether the intervention led to statistically significant improvements in academic performance.

For the qualitative component, student’s feedback on motivation was gathered through surveys administered before and after the intervention. These surveys were based on the Academic Motivation Scale (AMS) developed by Vallerand et al. (1992), which assesses different dimensions of motivation: intrinsic motivation (motivation driven by interest in the task itself), extrinsic motivation (motivation based on external rewards), and motivation (a lack of motivation or purpose). The AMS was selected for its robust ability to capture varying levels of student motivation in academic contexts. Thematic analysis of the survey responses identified critical themes related to the impact of the Boost Camp on student motivation and learning experiences. Figure 3 shows the study’s methodology.

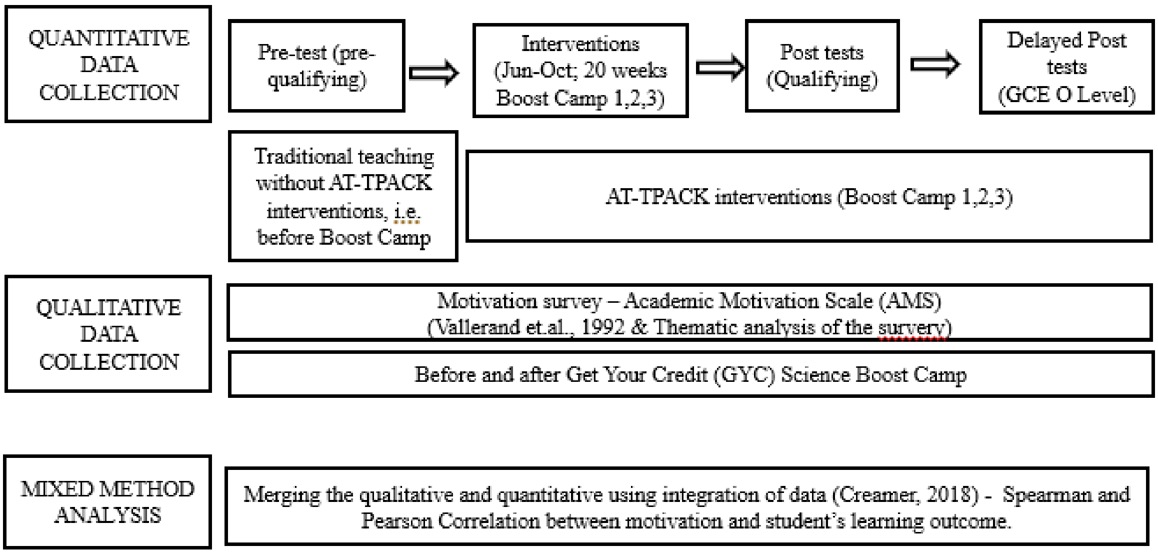

Figure 3: The process of pre-test and post-test administration to the students

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The study samples included sixty-eight year 11 students who took combined science for their GCE O-level examination. They have different learning abilities, ranging from 20 students from the General Programme to 48 from the Applied Programme, as shown in Figure 4.

Group/Class	Pre-test	Treatment	Post-test
Year 11A – 20 Year 11B1 – 21 Year 11C1- 14 Year 11C2 – 13	Pre-Qualifying test scores	AT-TPACK interventions called Science Boost Camps 1,2 & 3	Qualifying test scores
Mixed abilities students total of 68 Divided into 14 groups of 5			

Figure 4: Study samples

By incorporating both quantitative test scores and qualitative motivational data, this mixed-method study explored how technologically enriched learning activities (TELAs) affect students' conceptual understanding of atomic structures and their learning experiences. This approach follows Vygotsky's (1978) theory of learning, which emphasizes constructing new knowledge by integrating prior understanding, making the Boost Camp intervention ideal for shaping and developing students' scientific concepts.

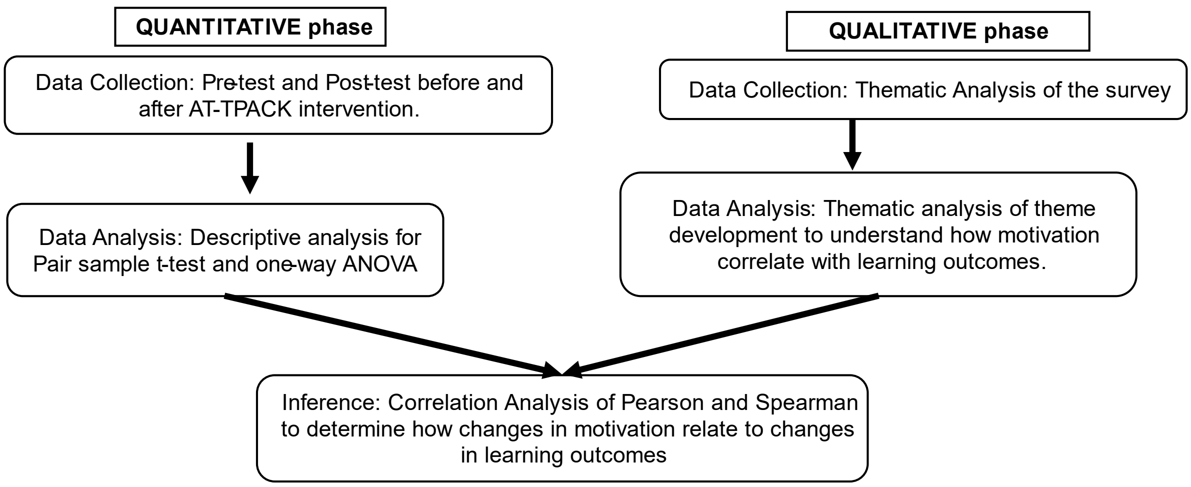

Diagram process adapted from Sondergeld, 2013
Figure 5: Data analysis process of this study

The answers to the quantitative and qualitative research questions were collected before and after the interventions; the data were based on quantitative and qualitative scores, respectively. These results were presented in numerical data form and analysed via independent sample t-tests and paired-samples t-tests (for the test score data) and repeated-measures ANOVA (for survey and interview data) via SPSS statistical software. The data were collected on two different occasions: i) before the interventions (pre-test as the prequalifying exam score) and ii) after twenty weeks of the interventions (post-test as the qualifying exam score). The delayed post-test (GCE O-Level exam grades) was collected in February of the following year when Cambridge, United Kingdom, released it. The GCE O-Level percentile is a weighted average that is not proportional to the internal examinations by schools (in this case, the quantitative data from the pre- and post-test); hence, the scores from the GCE O-level examination cumulative grade percentage are only used to mark students' performance in general.

With respect to the use of the same samples, Pallant (2013) suggested that paired-sample t tests can be used when the same person is measured during continuous observation at different times after the participants are exposed to some experimental manipulation or intervention.

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This study adopted the process of mixing data for mixed-method research, a strategy developed by Creamer (2018), to fully understand the effects of TELA intervention lessons on students' motivation and conceptual understanding of science and their learning experiences. The process of data mixing is summarized in Table 1.2.

Table 1.2 – The process of mixing used in this study

Stages in this study	Strategies used to apply mixing
Research questions	The research questions are divided into two quantitative questions, one qualitative question, and one mixed-method research question, which is denoted as a mixed-method research question.
Data collection	The quantitative data analysis in the first phase shapes the data collected in the second phase using a sequential mixed method (Creamer, 2018).
Sampling	Both the quantitative and qualitative samples are from the same sample. Stratified probability sampling is used.
Analysis	We are merging both the quantitative and qualitative methods to answer the mixed-method research questions.
Interpretation and conclusions	Use of meta-inference or integration to explain particular phenomena discovered during analyses of both strands. Inconsistencies and consistencies are explained.
Reporting	The results of data analyses are linked to the literature.

Creamer (2018) developed the strategy of mixing quantitative and qualitative data during the analysis and interpretative stage to complement mixed methods research. It mentioned that both types of data can be integrated to produce a meta-inference that shows the whole phenomenon of the study. Meta-inferences are produced by finding links in quantitative and qualitative data that can be integrated in an explanatory way (Tashakkori, Teddlie & Johnson, 2020). For example, students who scored below 30% and thus failed the post-test after the intervention were interviewed to determine the reasons behind the failure. In this way, teachers can help those students identify problematic areas and guide them to learn the correct concepts for the future. Meta-inferences show that mixing quantitative and qualitative data articulates an understanding of the phenomenon that does not exist if treated as separate parts (Bazeley & Kemp, 2012; Tashakkori, Teddlie & Johnson, 2020).

RESULT AND DISCUSSION

Motivation scores and test performance showed statistically significant improvements ($p < 0.05$) between pre-test and post-test scores. This suggests a moderate level of learning improvement. The findings align with previous research highlighting the role of contextualized interventions in improving student learning outcomes in science. These results are supported by similar findings in other contexts. For example, Aisy, M. R., Trisnowati, E., & Siswanto, S. (2024) demonstrated that using problem-based learning (PBL) integrated with socio-scientific issues significantly improved critical thinking skills among students. This mirrors our finding that student motivation and understanding increased when science instruction was made relevant to real-world applications through Boost Camp sessions.

Likewise, Irdalisa, I., Paidi, P., Panigrahi, R. R., & Hanum, E. (2024) found that STEAM-based project learning with eco-print techniques enhanced students' scientific reasoning and creativity. These outcomes align with our intervention's emphasis on experiential, peer-supported, and technology-enhanced learning, which helped students conceptualize the science context. Moreover, the structure of the Boost Camp intervention—where high-achieving peers led small study groups—resonates with the group investigation learning model reviewed by Solikah, A. A., Saputro, S., Yamtinah, S., & Masykuri, M. (2024), who found this approach effective in strengthening students' critical thinking skills. Similarly, the results showed that collaborative, student-led environments increased both engagement and retention of scientific knowledge.

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Descriptive and Inferential Data Analysis

To evaluate the effectiveness of the science Boost Camp intervention, a comparative analysis was conducted on students' test scores before and after the intervention. Descriptive and inferential statistics were computed using SPSS (Version 21). The theory explains why and how the intervention might work, and the empirical data show whether it worked and to what extent (See Table 1.3).

Tabel 1.3 - The types of data collected and analysed in this study

Component	Examples in Your Study
Theoretical	TPACK-AT framework guiding the intervention
Empirical	Student test scores and effect size from SPSS

A total of 68 students participated in the study. Table 1.3 presents the descriptive statistics of students' test scores before and after the science Boost Camp intervention. The pre-intervention mean score from the Qualifying Examination was M = 36%, while the post-intervention mean score from the GCE O-Level Examination increased to M = 43%. A paired-samples t-test was conducted to determine whether the observed difference in mean scores was statistically significant. The results indicated a statistically significant improvement in students' performance following the intervention.

The effect size, calculated using Cohen's *d*, was 0.697, suggesting a moderate effect of the intervention on student achievement. According to Cohen (1988), an effect size of 0.5 is considered moderate, and 0.8 is large; therefore, this result demonstrates that the Boost Camp had a meaningful and educationally relevant impact on students' test scores. These findings address Research Questions 1 and 2, confirming that the intervention significantly improved students' academic performance in science. Motivation scores and test performance showed statistically significant improvements ($p < 0.05$) between pre-test and post-test scores. This result suggests a moderate level of learning improvement.

A comparison of students' performance in the Qualifying Examination and the GCE O-Level Examination was conducted to assess the impact of the Boost Camp intervention. The descriptive statistics, illustrated through a boxplot (see Figure 6), show a noticeable increase in overall student achievement post-intervention.

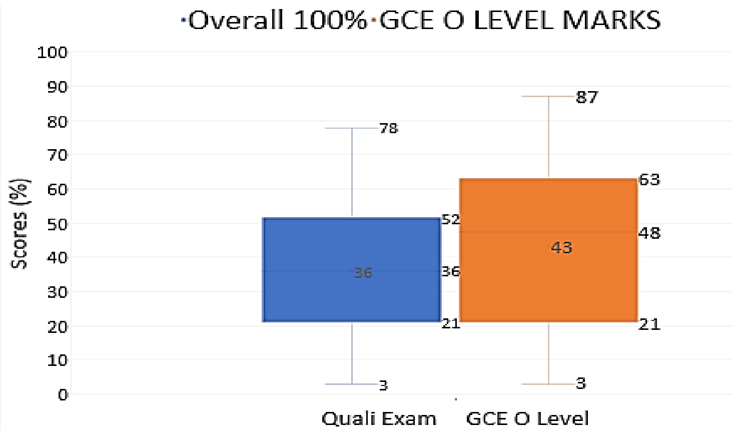

Figure 6: The box plots of the descriptive statistics show a noticeable increase in overall student achievement post-intervention.

The mean score in the Qualifying Exam was 36%, with a median of 36%, a lower quartile of 21%, and an upper quartile of 52%. The maximum observed score was 78%, and the minimum was 3%. In contrast, post-intervention results showed a mean score of 43% in the GCE O-Level Examination, with a median of 43%, a lower quartile of 21%, and an upper quartile of 63%. The maximum score reached 87%, with the same minimum of 3% (See Table 1.4).

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Table 1.4 - Descriptive statistical analysis

	Prequalifying exam scores	Qualifying exam scores
MEAN	36	43
SD.P	9	11
STDEVA	19	24
TTEST PAIRED 1 TAILED	.024256217 (p > .05)	
EFFECT SIZE	.697	

Skewness and kurtosis values for both datasets fall within acceptable ranges, suggesting no significant deviation from normality (pre-intervention: Skewness = 0.187, Kurtosis = -0.850; post-intervention: Skewness = -0.161, Kurtosis = -1.325) (See Table 1.5).

A paired-samples t-test conducted in SPSS revealed a statistically significant improvement in test scores from pre- to post-intervention. The effect size (Cohen's *d*) was 0.697, indicating a moderate effect of the intervention on student performance.

These results suggest that the Science Boost Camp had a significant and positive impact on students' academic outcomes in the GCE O-Level Combined Science examination. The spread and upward shift in the distribution, particularly in the upper quartile and maximum scores, further support the intervention's effectiveness in elevating student performance.

Table 1.5 - Descriptive statistical analysis

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Marks obtained in the prequalifying examination	68	3	78	35.84	19.224	.187	.291	-.850	.574
Marks obtained in the qualifying examination	68	3	87	43.24	23.854	-.161	.291	-1.325	.574
Valid N (listwise)	68								

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Marks obtained in the prequalifying examination	35.84	68	19.224	2.331
	Marks obtained in the qualifying examination	43.24	68	23.854	2.893

These results support the hypothesis that the Boost Camp intervention had a positive effect on students' test outcomes, addressing Research Questions 1 and 2:

- *Is there a significant change in students' test scores after the science boost camps intervention?*
- *Does the intervention have an impact on students' test scores?*

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For the qualitative data analysis, themes emerged from the thematic analysis of the interview transcripts. They grouped into similar themes to answer the third research question on the basis of the AMS survey.

Thematic Analysis of Qualitative Responses

To address the third research question: "How did the Boost Camp affect students' motivation and exam preparedness?", a thematic analysis was conducted on the interview transcripts. The analysis was complemented by findings from the Academic Motivation Scale (AMS) survey, which provided a framework for interpreting students' intrinsic and extrinsic motivational orientations. The qualitative data revealed recurring patterns of experience and perception among students who participated in the Boost Camp, which were grouped into four overarching themes: **structured motivation, peer support and collaboration, stress and emotional pressure, and confidence in exam preparedness**.

Theme 1: Structured Motivation and Self-Efficacy

Several students expressed that the structured nature of the Boost Camp sessions contributed significantly to their motivation and ability to focus on exam preparation. A clearly defined study schedule offered direction and reduced cognitive overload, fostering a sense of control and purpose in their revision process.

> *"Having a set schedule helped me focus. I knew when to study, and it made everything less overwhelming. It is like I had a roadmap, and I felt more motivated to stick to it."*

(Student A, Transcript 1)
Code: *Set schedule*

Theme: *Increased motivation through structure*

This finding aligns with the concept of **self-efficacy**, where belief in one's ability to organize and execute actions influences motivation and achievement (Bandura, 1997).

Theme 2: *Social Support and Peer Motivation*

Students consistently highlighted the benefits of peer collaboration during the intervention. Working in groups fostered a sense of accountability and emotional support, contributing to sustained motivation and a positive learning environment.

> *"Group work was great because we motivated each other. If someone was feeling down about an exam, we could lift each other. It created this supportive environment that made studying more enjoyable."*

(Student B, Transcript 2)
Code: *Group work*

Theme: *Social support and peer motivation*

This theme underscores the socio-cultural aspect of learning, where peer interactions play a crucial role in scaffolding knowledge and maintaining engagement (Vygotsky, 1978).

Theme 3: Emotional Pressure and Exam Stress

Despite the structured support, several students still reported experiencing heightened stress levels, particularly in the period leading up to the examination. The lack of effective coping strategies for managing pressure emerged as a concern.

> *"I often feel a lot of stress before exams. Sometimes I panic, and it truly affects my performance. I wish there were more strategies to help manage that stress."*

(Student C, Transcript 3)
Codes: *Panic, Exam pressure*

Theme: *Stress and emotional pressure*

This highlights the need for integrating stress management strategies within future Boost Camp sessions to support students' emotional well-being.

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Theme 4: Confidence and Exam Preparedness

Positive shifts in confidence levels and perceptions of academic readiness were prominent among student's post-intervention. Participants reported feeling more competent in tackling examination questions due to enhanced content understanding and targeted revision techniques.

"After the interventions, I feel much more prepared. My confidence has grown because I understand the material better. I believe I can tackle the exam questions."

(Student D, Transcript 4)
Codes: *Confidence, Preparedness*

Theme: *Confidence and exam preparedness*

This reflects the broader impact of the Boost Camp beyond academic scores, contributing to students' self-perception as capable learners.

Summary of Qualitative Findings

The qualitative data provided rich insights into the experiences of students, revealing that the Boost Camp intervention positively influenced their motivation, collaborative learning, and exam confidence, despite lingering challenges related to exam stress. These findings complement the quantitative results and provide a more holistic understanding of the intervention's effectiveness.

The overall results summarize that for each research question; the analysis and results are as follows:

1. **Research Question 1:** Is there a significant change in students' test scores after Boost Camp interventions?
    - The average test score increased from 36% to 43%, indicating a statistically significant improvement.
2. **Research Question 2:** Does the intervention affect students' test scores?
    - The moderate effect size of 0.697 further supports the conclusion that the Boost Camp intervention positively affects academic performance with a large effect size, according to Cohen (1988).
    - Motivation scores and test performance showed statistically significant improvements ($p < 0.05$) between pre-test and post-test scores. It suggests a moderate level of learning improvement.

3. **Research Question 3:** How do these interventions improve students' motivation and learning outcomes?
    - The thematic analysis of student feedback revealed several key themes related to motivation and learning outcomes. One prominent theme was the importance of structure in the Boost Camp sessions. Many students reported that having a structured revision schedule helped them focus their efforts and stay on track. As one student noted, "The Boost Camp gave me a clear structure for studying, which truly helped me stay focused." This finding aligns with previous research on the role of structure in promoting student motivation (Ainley & Ainley, 2015).
    - Another key theme was the role of peer support in fostering motivation. The peer-led nature of the Boost Camp created a sense of community among the students, with many reporting that working alongside their classmates helped them stay motivated. One participant explained, "Seeing my friends work hard during the Boost Camp made me want to do my best as well." This finding supports Vygotsky's (1978) theory of social learning, which emphasizes the importance of peer interaction in cognitive development.
    - While the Boost Camp was generally perceived as beneficial, some students reported increased pressure as the GCE O Level exams approached. One student stated, "I felt more stressed during the Boost Camp because I knew the exams were getting closer." This suggests that future interventions may need to balance academic rigour with emotional support to reduce exam-related anxiety.

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The summarized themes are shown in Figure 7.

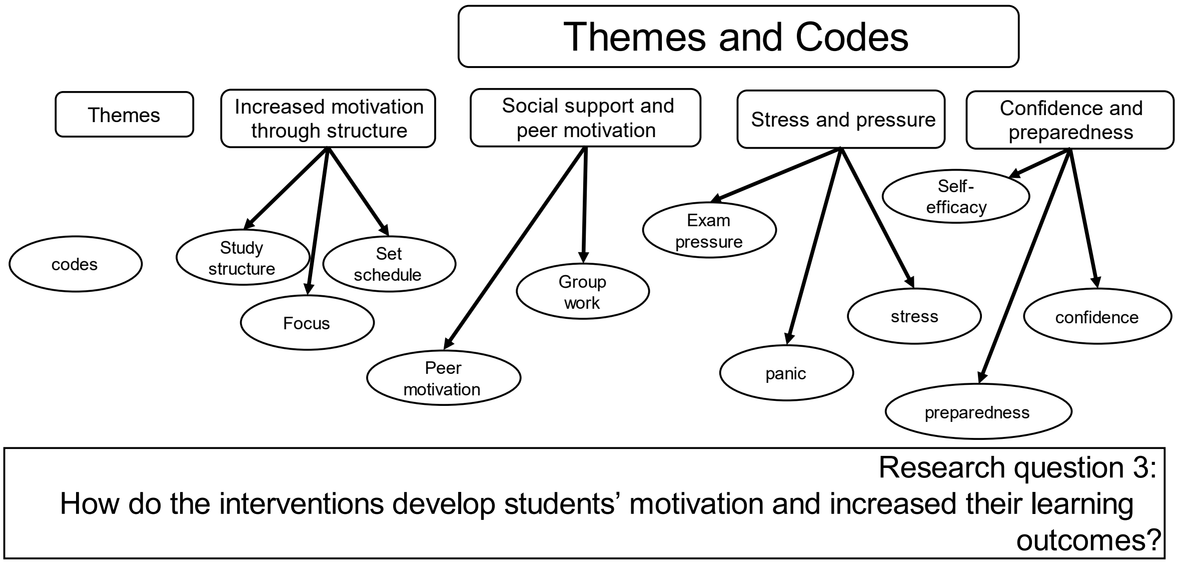

Figure 7: Data analysis from the thematic analysis of this study

Integration of Quantitative and Qualitative Findings: Correlational Analysis

To address the relationship between students' motivation and their learning outcomes, both quantitative and qualitative data were integrated. The triangulation of findings aimed to establish a deeper understanding of how motivational changes influenced academic performance following the Boost Camp intervention. Quantitative data were examined using Pearson and Spearman correlation coefficients, as summarized in Table 1.5.

Table 1.5: Correlation Between Motivation Changes and Learning Outcomes

	Motivation Changes	Learning Outcomes
Pearson's r	1.000	0.650**
Sig. (2-tailed)	—	< .001
N	68	68
Spearman's ρ	1.000	0.620**
Sig. (2-tailed)	—	< .001
N	68	68

Note: $p < .001$ (significant at the 0.001 level, two-tailed).

The Pearson correlation coefficient ($r = 0.65$, $p < .001$) indicated a moderate to strong positive correlation between changes in student motivation and their academic performance. Similarly, Spearman's rank-order correlation coefficient ($\rho = 0.62$, $p < .001$) confirmed this association, demonstrating consistency across parametric and non-parametric analyses. These findings suggest that increases in students' motivation were significantly associated with improvements in their learning outcomes.

Evidence from Examination Performance

To complement the statistical analysis, student achievement data from both prequalifying and qualifying examinations were evaluated. This performance data provided a concrete evidence of academic progress following Boost Camp.

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Table 1.6: Student Achievement in Prequalifying and Qualifying Examinations

Class	Prequalifying Results (% Credit C and Above)	Qualifying Results (% Credit C and Above)
Year 11A (n = 20)	85% (17/20)	85% (17/20)
Year 11B1 (n = 21)	24% (5/21)	38% (8/21)
Year 11C1 (n = 14)	14% (2/14)	21% (3/14)
Year 11C2 (n = 13)	0% (0/13)	8% (1/13)
Total (n = 68)	**35.3% (24/68)**	**43% (29/68)**
Ungraded (U)	49% (33/68)	37% (25/68)

The GCE O-Level results released in the subsequent academic year further substantiated the impact of the intervention. Notably, Year 11A, identified as the group of high achievers, sustained a 100% passing rate. Overall, there was an observable increase in students attaining Credit C and above, alongside a notable reduction in ungraded outcomes—from 49% in the prequalifying exam to 37% in the qualifying exam. These improvements align with the earlier reported correlations, reinforcing the notion that enhanced motivation positively influenced student performance.

Summary of Integration

The integration of statistical and qualitative findings revealed a coherent narrative: students who reported increased motivation—particularly in areas of structured revision, peer collaboration, and confidence—also demonstrated improved academic outcomes. This holistic understanding underscores the multifaceted value of the Boost Camp, both as a motivational scaffold and a mechanism for academic success.

DISCUSSION

The findings of this study provide strong evidence that the Science Boost Camp, when designed with the AT-TPACK framework, can significantly enhance both academic performance and motivation among low-achieving ESL students. The structured nature of the Boost Camp, combined with the peer-led approach, created a supportive learning environment that helped students stay focused and motivated throughout the intervention. These findings are consistent with previous research by Sarkawi and Salleh (2016), who reported that structured, technology-enhanced lessons improve student engagement and academic outcomes in ESL contexts. This aligns with broader evidence suggesting that inquiry- and project-based models—such as STEAM or PBL—promote meaningful engagement and cognitive skill development among science learners (Irdalisa et al., 2024).

The peer-led aspect of the Boost Camp also played a critical role in fostering motivation, as students felt a sense of responsibility to their peers and were encouraged by their classmates' efforts. This aligns with Vygotsky's (1978) theory of the zone of proximal development (ZPD), which posits that learning is most effective when individuals collaborate with more knowledgeable peers. The Boost Camp allowed higher-achieving students to take on leadership roles, providing support and guidance to their peers, which contributed to the overall success of the intervention. Similar collaborative models, such as the Group Investigation learning approach, have demonstrated efficacy in enhancing students' critical thinking and cooperative learning in science education (Solikah et al., 2024).

Integrating technology through the TPACK framework was another key factor in the success of the Boost Camp. By incorporating interactive and visual learning tools, teachers made complex scientific concepts more accessible to students, particularly those with language barriers. This finding supports Mishra and Koehler's (2006) argument that effective technology integration enhances both pedagogical and content knowledge, making learning more engaging and meaningful for students. Likewise, the use of real-world socio-scientific issues in a problem-based learning (PBL) context has been shown to foster higher-order thinking skills and meaningful connections to science content, particularly when engaging students in critical reasoning (Aisy et al., 2024).

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However, the increased stress reported by some students highlights the need for future interventions to consider the emotional impact of intensive revision sessions. While the Boost Camp successfully improved academic outcomes, the pressure of preparing for high-stakes exams may have increased anxiety among some participants. Future research could explore strategies for reducing exam-related stress while maintaining the benefits of structured revision programs.

LIMITATIONS

The study has several limitations that influence future research directions. One key limitation is the restricted sample size and context, as the research was conducted in a single school with a sample of 68 students. To enhance the generalizability of the findings, future studies should expand the sample size across multiple schools or different educational systems. Another limitation is the short-term measurement of knowledge retention. While the study included a delayed post-test over a 20-week , it does not provide insights into long-term impacts, such as university readiness. Future research should extend the tracking period beyond secondary education to evaluate the lasting effects of the intervention.

Additionally, the study has a limited focus on teacher implementation. Although it emphasizes technology integration, it does not primarily explore how teachers adapt to the AT-TPACK framework. Future research should investigate the effectiveness of teacher training programs and their impact on instructional quality in technology-enhanced learning environments.

Finally, the study follows an exam-oriented learning approach, primarily preparing students for standardized examinations. This focus may limit the development of broader scientific understanding. Future research should explore strategies to balance exam preparation with real-world applications of science knowledge, fostering deeper conceptual learning.

CONCLUSION

This study demonstrates the effectiveness of the Science Boost Camp, designed using the AT-TPACK framework, in enhancing both motivation and academic performance among Year 11 students preparing for the GCE O Level Combined Science examination. The intervention resulted in significant improvements in test scores and had a positive impact on students' motivation and confidence.

The findings underscore the importance of integrating motivational, collaborative, and practical strategies into science education. The AT-TPACK-based Boost Camp not only improved academic outcomes but also fostered deeper engagement and conceptual understanding. Differentiated instruction tailored to students' prior achievement and learning needs contributed to a reduction in the number of ungraded students in national assessments.

These outcomes are consistent with findings from recent studies in the *Jurnal Inovasi Pendidikan IPA*, which emphasize the impact of socio-scientific contexts (Aisy et al., 2024), STEAM-integrated worksheets (Irdalisa et al., 2024), and group investigation models (Solikah et al., 2024) in enhancing science learning outcomes. Future research should investigate the long-term effects on knowledge retention and consider implementing similar models across diverse science topics and educational contexts.

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