



FLIPPED CLASSROOM IN SCIENCE EDUCATION: CORRELATING STUDENT EXPERIENCE WITH ATTITUDES

Chau Ping Lam, Nyet Moi Siew

University Malaysia Sabah, Malaysia

E-mail: lam_chau_bp20@iluv.ums.edu.my, sopiah@ums.edu.my

Abstract

Despite the growing adoption of the Flipped Classroom (FC) model in higher education, there is limited exploration of its impact on secondary education and students' attitudes toward science. Thus, this study aimed to examine the correlation between secondary school students' perceptions of the Flipped Classroom experience in learning science and their attitudes towards the subject. The research focused on five perception constructs: Collaborative Environment, Self-Directed Learning, Learning Impact, Motivation and Enjoyment, and Technology Integration. Students' attitudes towards science were measured across five constructs: Importance of Science, Practical Work in Science, Learning Science in School, Science Outside School, and Future Participation in Science. The study utilized a quantitative survey methodology, collecting data from a sample of 100 Form Four students at School A, Sabah, Malaysia as of the year 2024. Through the analysis of the survey, the study found a significant positive correlation between students' positive perceptions of the FC experience and their attitudes towards science. Notably, high ratings for 'Motivation and Enjoyment' indicated enhanced student engagement, while lower ratings for 'Technology Integration' highlighted areas needing improvement. The findings underscore the potential of the FC to positively influence students' attitudes towards science. This research implies that educators should seek ways to enhance student engagement and foster a positive attitude towards science through innovative teaching methods such as Flipped Classroom.

Keywords: attitude towards science, Flipped Classroom (FC), perceptions of the FC experience, science education, secondary education

Introduction

The World Economic Forum's 2023 Future of Jobs Report predicts that by 2027, the most in-demand jobs will be in Science, Technology, Engineering and Mathematics (STEM) fields. The consistent predictions with previous reports from 2016, 2018, and 2020, highlight the long-term shift towards technology adoption and automation as key drivers of structural change (Di Battista et al., 2023). Despite this trend, the relatively low enrollment in science programs underscores the urgent need for attention and intervention. Lau et al. (2022) warn of a future shortage of human capital in science fields, as annual enrollment targets are not being met. This shortfall illustrates a growing gap between the demand for STEM-related jobs and student interest in science education.

In Malaysia, the Education Ministry reported that STEM enrollment was 45.73% in 2023. Not only was this considerably low, but it also deviated significantly from the 60:40 policy set by the Malaysia Education Blueprint 2013-2025, which aims for 60% of students to be in the STEM field. To assess students' views on their STEM learning environments, the Ministry of Education Malaysia conducted the STEM Pupil Index study. The 2023 findings indicate an overall index of just 44.09%, suggesting that students have a less positive assessment of their learning environment and unfavorable attitudes towards learning STEM (Ministry of Education Malaysia, 2023).

This implies a need for innovative teaching methods to address these issues, bringing us to the Flipped Classroom model. The Flipped Classroom gained popularity through the efforts of educators like Jonathan Bergmann and Aaron Sams, who started using it in their high school chemistry classes around 2007. Its effectiveness in leveraging technology to enhance learning, alongside the rise of online learning platforms and the push for student-centered environments, particularly during the COVID-19 pandemic, contributed to its widespread adoption (Divjak et al., 2022).

Several studies affirm that the Flipped Classroom model positively impacts tertiary level students' academic performance and motivation (Chou et al., 2021; Mshayisa & Basitere, 2021; Palazón-Herrera & Soria-Vílchez, 2021; Pattanaphanchai, 2019). Research also showed that students in flipped classrooms perceive formative assessments better (Ruiz-Jiménez et al., 2022), and engage in highly personalized learning activities (Aburayash, 2021; Colomo-Magaña et al., 2020; Narihan et al., 2023). Although there is a foundation of research on pedagogy and academic outcomes, there is a lack of extensive research on student perceptions of the learning experience during flipped learning for science subjects and the correlation between this variable with their attitudes toward science. Thus, this study hopes to fill the current research gap by specifically seeking to examine how students' perceptions of the flipped classroom experience in learning science are associated with their attitudes towards science. Will the positive perception of the flipped classroom experience in learning science result in positive attitudes toward science or vice versa?

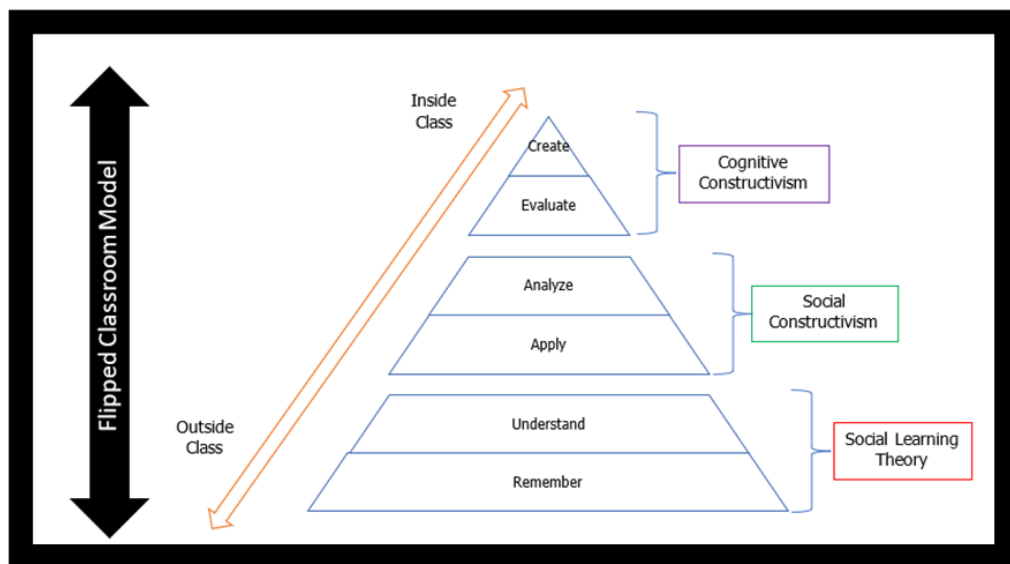
Literature Review

Theoretical Framework

Conventional lectures have largely invested classroom time in promoting lower-level cognitive work, while the flipped classroom allows students to engage in higher-order cognition. The flipped classroom model aligns with various learning theories as outlined in Bloom's taxonomy. The foundational skills of remembering and understanding are associated with social learning theory, as students independently review materials outside the classroom, observing and imitating others' learning strategies. The middle levels of analyzing and applying correspond with social constructivism, where students engage in collaborative discussions and practical applications during in-class sessions. The higher-order skills of evaluating and creating are linked to cognitive constructivism, emphasizing the active construction of knowledge and the development of critical thinking skills. This theoretical framework supports the flipped classroom's ability to cultivate a range of cognitive skills, enhancing the overall learning experience.

Figure 1 visually represents this theoretical framework, demonstrating how the flipped classroom model in science education correlates with students' attitudes toward science, as structured through Bloom's taxonomy.

Figure 1
Research Theoretical Framework



Past Research on Flipped Classroom

The increasing adoption of flipped classrooms in Malaysia, though still relatively new, demonstrates its practicality and positive impact across various disciplines. There have been growing studies that have explored the impact of the flipped classroom model on student learning outcomes and attitudes. For instance, Halili et al. (2021) examined the mobile flipped classroom approach in a private university in Malaysia, focusing on students' motivation, learning, and engagement. The study utilized homogenous purposive sampling with 40 undergraduate final-year students in a multimedia and computer animation course. The findings indicated that over half of the students agreed that the flipped classroom positively influenced their motivation and engagement.

Similarly, Narihan et al. (2023) assessed Year Two preclinical medical students' perceptions of the flipped classroom at University Malaysia Sarawak (UNIMAS). Using both qualitative and quantitative methods, the study revealed mixed responses, with some students preferring traditional classrooms while others appreciated the self-pacing aspect of the flipped classroom. These studies highlight the growing interest and mixed perceptions of the flipped classroom model in Malaysian tertiary education.

Internationally, studies by Pattanaphanchai (2019), Mshayisa and Basitere (2021), Palazón-Herrera and Soria-Vílchez (2021) showed that flipped classrooms can significantly enhance academic performance, with students achieving higher test scores than those in traditional settings. Yu et al. (2023) found that these benefits could persist for at least a year. Students in these studies valued the flipped classroom for enhancing their understanding through pre-class resources and in-class activities. Such findings suggest that the flipped classroom can be particularly effective in improving science learning and attitudes, a relatively underexplored area in the context of secondary education.

Further, Ruiz-Jiménez et al. (2022) highlighted the importance of formative assessment in the flipped classroom and its positive impact on students' attitudes towards science. The study found that students' attitudes were crucial in achieving better academic results, supporting the

flipped classroom's efficacy at the university level. This reinforces the potential of the flipped classroom to foster a positive learning environment, which is critical for subjects like science that often require active and engaging instructional methods.

Moreover, research by Colomo-Magaña et al. (2020) and Aburayash (2021) emphasized the flipped classroom's role in developing self-learning skills. Aburayash noted a positive correlation between students' attitudes toward the flipped classroom and their academic motivation and self-learning skills. These studies underscore the flipped classroom's potential to enhance digital competence, creativity, and independence among students. These skills are particularly relevant in science education, where critical thinking and problem-solving are essential.

Webb and Doman (2020) explored the flipped classroom's impact on students' attitudes in diverse cultural contexts, including the USA, Macau, and Colombia. They found that engaging in online activities before class improved students' attitudes towards technology-enhanced learning, reducing anxiety and enhancing their perception of the learning process. This international perspective suggests that the flipped classroom model can positively impact students' attitudes across various subjects and cultural contexts, making it a versatile and valuable instructional strategy.

The existing literature underscores the flipped classroom's potential to positively influence students' academic performance and attitudes, primarily at the tertiary level and in various international contexts. However, a notable gap exists as most research has focused on tertiary education, leaving secondary education, particularly science subjects, underexplored. This gap is significant because secondary education is a critical stage for shaping students' attitudes towards subjects like science, which can influence their future academic and career choices. Overall, this study hopes to contribute to the broader academic discourse by addressing the underexplored area of the flipped classroom's impact on secondary education, particularly in science. It also offers practical implications for educators and policymakers looking to implement or refine flipped classroom strategies in similar educational settings.

Research Question

This study aimed to bridge the gap by examining the relationship between secondary school students' perceptions of the Flipped Classroom experience in learning science and their attitudes toward the subject while also measuring the level of students' perceptions along with their attitudes in these areas. Thus, the research question for this study was 'Is there a significant linear relationship between students' perceptions of the Flipped Classroom experience in learning science and their attitudes toward science' with the null hypothesis (H_0) of 'There is no significant linear relationship between students' perceptions of the Flipped Classroom experience in learning science and their attitudes toward science'.

Understanding this correlation at such a critical educational stage can provide valuable insights for educators and policymakers to tailor teaching methods that better resonate with younger learners and foster positive attitudes toward science from an early age. This focus is vital as it corresponds with the formative years of students' academic journeys, where nurturing positive attitudes and interests toward science can have a lasting impact on their educational and career trajectories.

Research Methodology

Design

This research employed a quantitative survey research design. According to Karatoprak et al. (2015), a survey method is a practical and systematic way to collect data and is easy to administer and score. Furthermore, a survey method provides researchers with an opportunity to gain broader and more comprehensive feedback from respondents, which best suits the aim of the study.

Sample

The sampling method employed is purposive sampling. This study specifically targeted secondary school students in Form Four who took science subjects with the flipped learning experience as they had a substantial amount of exposure to the flipped classroom approach, providing them more experience than their lower secondary grades counterparts. Selecting participants from specific grades helps in narrowing down the sample to a relevant and homogeneous group. This ensures that participants share similar educational backgrounds and have been exposed to the Flipped Classroom approach during their respective grade levels.

Based on the data provided by School A, a total of 135 Form Four students were enrolled in science subjects in 2024, which constituted the entire population. According to the Krejcie and Morgan (1970) formula, the suitable sample size for a population of 135 is 100. Selecting 100 participants randomly from School A in Sabah, Malaysia, ensures that the study focuses on a specific educational setting. Limiting the sample to students from the same school creates a more cohesive and consistent sample, as participants are likely to share similar school environments, resources, and teaching practices. This can help in minimizing potential confounding factors related to school-level differences.

Instrument

The instruments used were a combination of 'Student Perceptions of the Flipped Classroom Survey' (SPFC) originally by Johnson (2013), and the 'Attitudes Towards Science Measures' (ATSM) by Kind et al. (2007) where both were slightly modified after the pilot study to better align with the specific objectives of this study before being administered to the selected participants. The researcher consulted with subject matter experts familiar with Flipped Classroom methodologies and science education to assess the validity and appropriateness of the items in measuring the intended constructs. The researcher modified the instruments as suggested until their validity was confirmed by the assigned parties to ensure the instrument was usable for the study. Both instruments were considered to have high reliability as their overall Cronbach's alpha values are .907 (SPFC) and .891 (ATSM), exceeding the benchmark of .600.

The research instrument was a 4-point Likert scale questionnaire form where the responses are from 1 (strongly disagree) to 4 (strongly agree) and have 50 items in total, with 20 questions in the first part for SPFC focusing on students' perceptions of the Flipped Classroom experience in learning science, and 30 questions in the second part for ATSM measuring their attitudes toward science. All the negatively worded items (*) were scored by reversing the numeric values for analysis purposes. Both instrument items were organized into five subsequent constructs to provide a comprehensive understanding of students' experiences with the Flipped Classroom approach and their attitude towards science during the analysis. The following Table 1 and 2 displayed the distribution of items for SPFC and ATSM.

Table 1
Distribution of Items in SPFC

Constructs	Item Number	Total items
Collaborative environment (SPFC_A)	1, 3, 17	3
Self-directed learning (SPFC_B)	5, 8*, 14, 16	4
Learning Impact (SPFC_C)	7, 10*, 12, 15*, 18, 19	6
Motivation and Enjoyment (SPFC_D)	2*, 9, 11, 20	4
Technology integration (SPFC_E)	4, 6*, 13	3

(*) *Negatively worded items***Table 2**
Distribution of Items in ATSM

Constructs	Item Number	Total items
Learning science in school (ATSM_A)	1, 2, 3, 4, 5, 6*	6
Practical work in science (ATSM_B)	7, 8, 9, 10, 11, 12, 13, 14*	8
Science outside of school (ATSM_C)	15, 16, 17, 18, 19, 20	6
Future participation in science (ATSM_D)	21, 22, 23, 24, 25	5
Importance of science (ATSM_E)	26, 27, 28, 29, 30	5

(*) *Negatively worded items*

Flipped Classroom

In this research context, Flipped Classroom (FC) refers to a pedagogical model in which the traditional in-class teaching and learning and homework components of Science subject are reversed. It is a form of blended learning where it incorporates both face-to-face and online components. The participants had all experienced this type of learning in the aftermath of the Covid-19 post-lockdown phase in previous years. Students participate in Science learning activities both inside and outside the classroom. Outside the classroom, students participate in learning activities such as watching pre-recorded videos before class, and reading material, usually as homework. During actual class time, students participate in active learning activities such as problem-solving exercises, group discussions, simulations, and experiments.

Data Collection and Analysis

Before conducting the survey, a short briefing was given to the participants regarding the purpose of the survey and instructions for completing the questionnaire. This was to ensure that participants clearly understood what their involvement entails, and that they could question and seek clarification before participating. The briefing serves to establish transparency, informed decision-making, and mutual understanding between the researcher and the participants.

The collected data were manually keyed in for analysis using "Statistical Package for Social Science (SPSS)" version 29.0. The analysis involved two types of statistical methods:

descriptive and inferential statistics. Descriptive statistics measures such as means, standard deviations, frequencies, and percentages were used to describe the characteristics of the variables. The level of students' perceptions and attitudes were determined by calculating their mean scores from the SPFC and ATSM questionnaires, respectively. Those scores were categorized into four hierarchical levels: 0.99 – 0.00 'Very Negative' (VNe), 1.99 – 1.00 'Negative' (Ne), 2.99 – 2.00 'Positive' (Po), and 4.00 – 3.00 'Very Positive' (VPo).

Pearson product-moment correlation analysis was conducted to investigate these two variables' relationship and test the research hypothesis at the predetermined significance level (0.01). To interpret the Pearson correlation coefficient value in this study, the following scale was used: 0.80 – 1.000 (Very Strong); 0.600 – 0.799 (Strong); 0.400 – 0.599 (Moderate); 0.200 – 0.399 (Weak); 0.000 – 0.199 (Very Weak). The null hypothesis is rejected if and only if the p-value is less than 0.01, indicating evidence of a significant relationship between the variables.

Research Results

Level of Students' Perceptions of Flipped Classroom Experience in Learning Science

Based on Table 3, the students had an overall positive level of perceptions of the Flipped Classroom experience in learning science, with a mean of 2.92 and a standard deviation of 0.54. The distribution of responses indicated that the majority of students rated their experience as either 'Positive' (51.00%) or 'Very Positive' (45.00%), with only a small percentage reporting a 'Negative' experience (4.00%) and none reporting a 'Very Negative' experience.

Table 3
Result of Descriptive Statistical Analysis for SPFC (n=100)

Level	<i>f</i>	%	<i>M</i>	<i>SD</i>
Very Negative	0	0.00	2.92	0.54
Negative	4	4.00		
Positive	51	51.00		
Very Positive	45	45.00		
Total	100	100.00		

According to Table 4, it was observed that all the constructs were rated at the 'Positive' level or higher. However, it was noteworthy that 'Motivation and Enjoyment' stood out as the only construct with a 'Very Positive' level, achieving a mean of 3.01 and standard deviation of 0.71. This was followed closely by 'Learning Impact' ($M = 2.97$, $SD = 0.60$), 'Collaborative Environment' ($M = 2.94$, $SD = 0.76$), and 'Self-directed Learning' ($M = 2.90$, $SD = 0.50$), all of which approached the 'Very Positive' threshold. Although 'Technology Integration' received the lowest mean score at 2.72 ($SD = 0.60$), it still reflected a generally positive perception among students.

Analyzing the distribution of responses, the 'Collaborative Environment' construct received the most 'Very Positive' ratings, with 60.00% of students indicating strong agreement about its benefits. Following closely, 'Motivation and Enjoyment' was highly rated, with 58.00% of students reporting 'Very Positive' experiences. 'Learning Impact' also garnered strong

approval, with 55.00% of responses in the 'Very Positive' category. However, 'Technology Integration' not only had the lowest percentage of 'Very Positive' responses at 46.00%, but it also had the highest rate of negative responses, with 9.00% of students indicating dissatisfaction.

Table 4
Descriptive Statistical Analysis for SPFC by Constructs (n=100)

Constructs	VNe	Ne	Po	VPo	M	SD
	(%)					
Collaborative environment	0.00	7.00	33.00	60.00	2.94	0.76
Self-directed learning	0.00	2.00	49.00	49.00	2.90	0.50
Learning Impact	0.00	6.00	39.00	55.00	2.97	0.60
Motivation and Enjoyment	0.00	5.00	37.00	58.00	3.01	0.71
Technology integration	0.00	9.00	45.00	46.00	2.72	0.60

Level of Students' Attitudes Toward Science

The overall attitudes of students toward science were generally very positive, as indicated in Table 5. The mean score was 3.04 ($SD = 0.46$), with a majority of students in the 'Positive' (58.00%) or 'Very Positive' (41.00%) categories. Only one student reported a 'Negative' attitude (1.00%), and none were in the 'Very Negative' category.

Table 5
Result of Descriptive Statistical Analysis for ATSM (n=100)

Level	f	%	M	SD
Very Negative	0	0.00	3.04	0.46
Negative	1	1.00		
Positive	58	58.00		
Very Positive	41	41.00		
Total	100	100.00		

By referring to Table 6, three out of the five constructs fall into the 'Very Positive' level where the construct 'Importance of Science' received the highest rating with a mean of 3.32 and standard deviation of 0.53, entailed by 'Practical Work in Science' ($M = 3.20$, $SD = 0.59$) and 'Learning Science in School' ($M = 3.13$, $SD = 0.56$). The remaining two constructs were in the slightly lower 'Positive' category, with 'Science Outside School' ($M = 2.99$, $SD = 0.57$) being quite close to squeezing into the higher level and 'Future Participation in Science' ($M = 2.47$, $SD = 0.74$) being the lowest among all.

It also illustrated the detailed breakdown of attitudes, highlighting that 'Importance of Science' with the most 'Very Positive' responses (81.00%) and was uniquely the only construct with no negative responses at all. The ranking was followed by 'Practical Work in Science' (74.00%), 'Learning Science in School' (60.00%) and 'Science Outside of School' (54.00%). Whereas, 'Future Participation in Science' was notably the lowest-rated construct in the 'Very

Positive' category, with only 26.00% of students showing strong enthusiasm. Additionally, this construct had the highest rate of 'Negative' responses at 18.00%, suggesting a significant concern regarding students' future engagement with science.

Table 6
Descriptive Statistical Analysis for ATSM by Constructs (n=100)

Constructs	VNe	Ne	Po	VPo	M	SD
	(%)					
Learning science in school	0.00	1.00	39.00	60.00	3.13	.56
Practical work in science	0.00	4.00	22.00	74.00	3.20	.59
Science outside of school	0.00	3.00	43.00	54.00	2.99	.57
Future participation in science	0.00	18.00	56.00	26.00	2.47	.74
Importance of science	0.00	0.00	19.00	81.00	3.32	.53

Relationship between Students' Perceptions of the Flipped Classroom Experience in Learning Science and their Attitudes Toward Science

The Pearson Product Moment Correlation Coefficient analysis in Table 7 showed that there was a significant and strong positive linear relationship between students' perception of Flipped Classroom experience in learning science and their attitudes toward science ($r = .649$, $p < .01$). Therefore, null hypothesis (H_0) was rejected at 99% confidence level. There exists adequate evidence to show that students' perception of Flipped Classroom experience in learning science had significant relationship with students' attitude towards science.

Table 7
The Correlation Analysis for the Relationship between Students' Perception of FC Experience in Learning Science and Attitudes Towards Science

Variables	Students' Attitudes Towards Science	
Students' Perception of FC classroom Experience	r	.649*

Note: * $p < .01$; $n = 100$

The Pearson Product Moment Correlation Coefficient Analysis (Table 8) indicates that there are statistically significant positive correlations between students' perceptions of the Flipped Classroom experience in learning science and their attitudes towards science by constructs. The strongest correlation was observed with the construct "Learning Science in School," which has a Pearson correlation coefficient of .716, significant at the $p < .01$ level, suggesting a strong positive relationship between these two at 99% confidence level.

The construct 'Practical Work in Science' and 'Importance of Science' showed significant positive correlation with a coefficient of .575 ($p < .01$) and .472 ($p < .01$) respectively, indicating a moderate relationship. Whereas, the construct 'Science Outside of School' and 'Future Participation in Science' with correlation coefficients of .389 ($p < .01$) and .346 ($p < .01$) respectively, both indicated weak but positive relationships.

Overall, the analysis demonstrated consistent and statistically significant positive correlations across all constructs, with each correlation being significant at 99% confidence

level. This highlights that better perceptions of the Flipped Classroom experience are associated with more favorable attitudes toward science, covering aspects such as learning science in school, practical work, science outside school, future participation in science, and the perceived importance of science.

Table 8

The Correlation Analysis for the Relationship between Students' Perception of FC Experience in Learning Science and Attitudes Towards Science by Constructs

Variable	Learning Science in School	Practical Work in Science	Science Outside of School	Future Participation in Science	Importance of Science
Students' Perception of FC Experience in Learning Science	<i>r</i> .716**	.575**	.389**	.346**	.472**

** $p < .01$; $n = 100$

Discussion

The findings of this study offer insights into students' perceptions of the Flipped Classroom experience in learning science and their attitudes toward the subject. Overall, students had a 'Positive' perception of the Flipped Classroom. This positive reception aligns with prior research (Hannan et al., 2023; Pattanaphanchai, 2019), which indicates that students across various educational settings, including secondary schools, tend to view the Flipped Classroom favorably. The consistency of these findings suggests that the Flipped Classroom model is not only adaptable but also well-received by students regardless of their education level, indicating its broad applicability and potential for integration into diverse educational contexts.

Students rated 'Motivation and Enjoyment' highly, highlighting the effectiveness of the Flipped Classroom in enhancing engagement and interest in learning science. This high level of engagement can be attributed to the active learning strategies and increased opportunities for interaction that the model provides during class sessions. Unlike conventional lecture-based teaching, the Flipped Classroom allows students to explore content at their own pace before class, freeing up class time for interactive, hands-on activities. This approach is consistent with Halili et al. (2021), who found that such engagement fosters a deeper understanding of the material and increases student motivation.

Furthermore, the positive ratings for 'Learning Impact,' 'Collaborative Environment,' and 'Self-directed Learning' underscore the comprehensive benefits of the Flipped Classroom. These aspects are crucial for fostering a deep understanding of content, as they encourage students to take an active role in their learning process. This aligns with the social constructivist theory, which emphasizes the importance of social interaction and collaboration in knowledge construction. Since students were already prepared with the foundational knowledge or the lower Bloom's Taxonomy levels' skills through pre-class materials, this allowed them to feel more included instead of detached from the activities with their friends during in-class meetings. This corroborates Mshayisa and Basitere (2021) and Ruiz-Jiménez et al. (2022), who emphasized the benefits of pre-class preparation, which facilitates more effective use of class time for advanced activities.

However, 'Technology Integration' received lower ratings compared to other constructs. This discrepancy may be due to several factors, including limited access to high-quality technological resources, as highlighted by Aidoo et al. (2022). Despite being digital natives, students may still encounter barriers such as technical issues, inconsistent internet access, and

a lack of familiarity with the required software. Additionally, some students may find that the use of technology can sometimes feel disjointed or poorly integrated into the overall learning experience, which can subtract its perceived effectiveness. This suggests a need for better technological infrastructure and more effective integration strategies to ensure that technology enhances rather than hinders the learning process.

Regarding students' attitudes toward science, the study revealed a generally 'Very Positive' attitude, particularly in recognizing the 'Importance of Science,' 'Practical Work in Science,' and 'Learning Science in School.' These findings indicate that students not only value the role of science in society but also appreciate the hands-on, practical aspects of science education. This is consistent with previous research by Oonyu (2019) and Iwuanyanwu (2022), which found that practical experiences in science classes enhance students' understanding and appreciation of the subject.

The lower feedbacks for 'Science Outside School' and 'Future Participation in Science' suggest a disconnect between students' positive attitudes towards science in an educational context and their engagement with science outside the classroom or interest in pursuing science-related careers, which is concerning given the increasing demand for STEM professionals. This gap might be influenced by societal perceptions, limited extracurricular opportunities, and a lack of role models in STEM fields, as suggested by Yang et al. (2017). For instance, if the community places more value on other non-science professions, students may feel less inclined to pursue careers in science.

The significant positive correlation between students' perception of the Flipped Classroom and their attitudes toward science underscores the approach's impact on enhancing students' engagement and interest in the subject. Positive correlations found between flipped learning and the attitude towards science among students, highlight the importance of the flipped classroom strategy in developing scientific literacy among students (Alebous, 2021).

This correlation is strongest with 'Learning Science in School,' mirroring how the immediate relevance of flipped learning—through pre-class materials and interactive in-class activities—way of students learning science. This finding is consistent with earlier studies, such as those by Chou et al. (2021) and Aburayash (2021), which demonstrated a positive link between flipped learning strategies and various educational outcomes, including motivation and self-directed learning. Furthermore, increased student-teacher and peer interactions during class positively influence students' attitudes towards science, echoing Mshayisa and Basitere's (2021) findings on the impact of high-quality interactions in STEM education.

The moderate correlation between 'Practical Work in Science' and 'Importance of Science' suggests that while practical activities and the perceived value of science are enhanced by the flipped model, other factors like resource availability and societal values also play significant roles. For example, insufficient laboratory facilities can limit the effectiveness of practical work despite the flipped classroom setup, as noted by Shana and Abulibdeh (2020). Additionally, students' perceptions of science's role in addressing societal issues may affect their views on its importance. Responses to items like whether science and technology help the poor (ATSM Item 29) reveal that students might question the broader impact of science, influencing their overall perception despite positive classroom experiences.

The weaker correlations with 'Science Outside of School' and 'Future Participation in Science' indicate that the positive effects of the flipped classroom may not extend beyond the classroom or influence long-term career aspirations in science. Factors such as the availability and appeal of extracurricular science activities play a crucial role here. For instance, in schools like those in Kota Kinabalu, Sabah, where non-science clubs are more established and popular among the students, science-related activities may struggle to attract student participation. Chen et al. (2024) highlighted the importance of positive perceptions of STEM professionals, influenced by media and school opportunities, in shaping students' career aspirations. Thus, the

lack of visible role models and mentors in science can deter students from considering science as a viable career path, despite positive experiences in a flipped classroom setting.

Significance

This study adds to the growing body of literature on the efficacy of the Flipped Classroom model, particularly in secondary science education. The research not only confirms the positive reception of the model among students but also highlights areas needing improvement, such as technology integration. Moreover, it provides a comprehensive examination of the factors that link students' engagement with science both within and outside the school environment.

The findings suggest that while the Flipped Classroom can significantly enhance students' immediate learning experiences and attitudes toward science, additional strategies are needed to sustain and deepen their engagement with science beyond the classroom. This includes addressing technological challenges, promoting extracurricular science activities, and providing positive role models in STEM fields. These insights are crucial for educators, policymakers, and researchers aiming to improve science education and foster a sustained interest in the subject among students.

Limitations

The study presents several limitations that future research could address. Firstly, it offers a snapshot perspective of students' perceptions and attitudes towards the Flipped Classroom model, capturing only a momentary view without examining long-term changes. Secondly, the study indicated lower ratings for 'Technology Integration,' suggesting the presence of technological challenges that were not deeply explored. Additionally, the lower ratings for 'Science Outside School' and 'Future Participation in Science' highlight a gap in connecting classroom learning with real-world applications and career aspirations. Lastly, the study's focus on a specific school and grade level may limit the generalizability of the findings to other settings.

Suggestions

To address the limitations, future studies could consider conducting longitudinal research to explore the long-term effects of the Flipped Classroom model on students' attitudes, academic performance, and future engagement with science. Investigating specific technological challenges, such as access to resources and technical difficulties, would provide a clearer understanding of how to improve technology integration in this educational approach. Additionally, exploring ways to integrate science into extracurricular activities, like community service-based clubs, could help bridge the gap between classroom learning and real-world applications, fostering a deeper interest in science among students. Further research could also delve into the model's effectiveness across diverse demographics, including various socio-economic backgrounds, genders, and regions, would ensure the findings' broader applicability and inclusivity.

Conclusions and Implications

The primary finding of this study is the significant positive correlation between students' perceptions of the Flipped Classroom experience and their attitudes toward science. This highlights the potential of the Flipped Classroom model to positively influence students' engagement with science, thus providing compelling reasons for educators worldwide to

consider incorporating flipped learning strategies, especially in science education. Transitioning from conventional lecture-based teaching to more interactive, student-centered classroom learning environments can potentially improve educational outcomes on a global scale.

The challenges identified in this study, particularly related to technology integration within the Flipped Classroom model and varying levels of enthusiasm for science outside the classroom, underscore the need for comprehensive teacher training and professional development. Educators require targeted support to effectively implement flipped learning strategies. Addressing this need on a global scale will help prepare teachers to better engage students and improve learning outcomes across diverse educational contexts. Additionally, substantial investments in educational technology infrastructure are crucial to ensure that students worldwide can benefit from these innovative learning approaches. Bridging the digital divide is essential to making education more equitable and accessible, facilitating the successful integration of flipped learning across a variety of educational settings.

The observed variations in student enthusiasm highlight the importance of cultivating a sustained interest in science beyond the classroom environment. While the Flipped Classroom model may initially boost engagement, factors outside the classroom—such as access to resources, societal attitudes towards science, or a lack of extracurricular support—can affect students' long-term enthusiasm. To address this, a holistic approach to science education is required, one that connects in-class learning with real-world applications, promotes science-related extracurricular activities, and encourages parental and community involvement in science education.

On a policy level, this research provides empirical evidence supporting the incorporation of the Flipped Classroom model into national educational frameworks. Given the declining interest in science subjects and its potential impact on higher-order thinking and problem-solving skills, there is an urgent need for educational reform to meet the demands of the 21st century. The study's findings can guide policymakers in designing more engaging and effective science curricula that better integrate flipped learning elements favored by the students, thereby enhancing student experiences and attitudes toward science, ultimately shaping the future of education worldwide.

Finally, future research could expand the scope to include more diverse demographics, explore the long-term impacts of the Flipped Classroom on academic performance and career choices, and investigate the integration of emerging technologies such as artificial intelligence and virtual reality within this educational framework. Such studies could unveil new possibilities for enhancing student engagement and learning outcomes. This research could also be used to compare Flipped Classroom with other innovative teaching methods, providing valuable insights into the best practices for modern education. In essence, the presented research offers a springboard for future studies aimed at revolutionizing education and making learning more effective for students worldwide.

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Declaration of Interest

The authors declare no competing interest.

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Chau Ping Lam

B.Sc. Ed, Faculty of Education and Sport Studies, University Malaysia Sabah,
Jalan UMS, 88400, Kota Kinabalu, Sabah, Malaysia.
E-mail: lam_chau_bp20@iluv.ums.edu.my
ORCID: <https://orcid.org/0009-0003-2271-3220>

Nyet Moi Siew
(Corresponding author)

PhD, Professor, Faculty of Education and Sport Studies, University Malaysia
Sabah, Jalan UMS, 88400, Kota Kinabalu, Sabah, Malaysia.
E-mail: sopiah@ums.edu.my
ORCID: <https://orcid.org/0000-0002-0937-9729>