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A Comparative Study of Pedagogical Orientations among Natural Sciences Pre-Service Teachers at Two South African Universities

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A Comparative Study of Pedagogical Orientations among Natural Sciences Pre-Service Teachers at Two South African Universities

Abstract

In university teacher education, the most critical aspect is introducing pre-service teachers to different methods of teaching science for learner conceptual understanding. However, universities in South Africa still face challenges in their science methodology modules, which hinders pre-service teachers’ exposure to diverse teaching methods for science topics. Successful science instruction requires teachers not only to possess solid content knowledge but also the ability to translate that knowledge into appropriate teaching approaches for specific topics. This paper investigates the pedagogical orientations of Natural Sciences pre-service teachers at two South African universities. The term 'orientation' here represents teachers' knowledge and beliefs regarding the teaching of science. Existing literature indicates various classifications of pedagogical orientations, with two primary approaches: direct approaches (Direct Didactic and Direct Active modes) and inquiry approaches (Guided Inquiry and Open Discovery). A quantitative method was used to determine the pedagogical orientations of Natural Sciences pre-service teachers. A questionnaire was administered to one hundred and fifteen final-year undergraduate Natural Sciences pre-service teachers at the two universities to achieve the aim of the study. The questionnaire comprised of ten items, referred to as the ‘Pedagogy of Science Teaching Test (POSTT). Each POSTT item portrayed an authentic teaching scenario for a particular Natural Sciences topic and presented four alternative teaching methods. The pre-service teachers were expected to select the most appropriate choice. The findings of this study indicate that the most selected pedagogical orientation among Natural Sciences pre-service teachers was the inquiry pedagogical orientation, aligning with Guided Inquiry. Some of the pre-service teachers opted for a teacher-centred pedagogical orientation, aligning with Direct Active approaches.

Keywords: Pedagogical orientations, Guided Inquiry, Pre-service teachers.

Introduction and Background

To achieve quality education, teacher training institutions must produce competent pre-service teachers, as the quality of an educational system is determined by the quality of its teachers (Schleicher, 2016). South Africa faces challenges with its current teacher workforce, particularly in Sciences and Mathematics, largely due to the legacy of its pre-1994 educational system, which favoured certain racial groups over others. Prior to democracy in 1994, education was segregated: White communities had separate schooling systems, while Black, Indian, and Coloured communities had their own systems. Compulsory education was limited mainly to Whites, Indians, and Coloureds, while it was not compulsory for Black people to study until their exit grade which is grade 12 (Bunting, 2006).

These inequalities extended into higher education, with universities designated for specific racial groups. Around 1985, South Africa had 19 higher education institutions for Whites, 2 for Coloureds, 2 for Indians, and 6 for Blacks (Bunting, 2006). This segregation resulted in lasting inequalities, as former white universities still benefit from better resources, private donations, and research output compared to former black universities. Post-1994, the South African government merged universities to address past injustices, resulting in 26 public universities: 12 traditional universities (academic focus), 8 universities of technology (vocational focus), and 6 comprehensive universities (combining both).

This study was conducted in two comprehensive universities: one is formerly white, urban, and resource-rich, while the other is formerly black, rural, and resource-poor, with 98% of students funded by the National Student Financial Aid Scheme (NSFAS). The paper aims to investigate whether the pedagogical orientations of final-year pre-service teachers from these two universities differ due to their distinct contexts. The hypothesis is that differing environments and teaching methods might influence their pedagogical orientations. Based on the aim, the research question is:

> What are the pedagogical orientations of Natural Sciences Pre-service Teachers at two the South African comprehensive universities?

Theoretical Framework and Literature Review

This paper is underpinned by pedagogical content knowledge (PCK) as a theoretical framework and pedagogical orientations as a conceptual framework. PCK is a key competency for teachers, emphasising how to teach specific content rather than general content (Sahingöz &

Cobern, 2020). PCK combines pedagogy and content knowledge to create the most effective, teachable formats to make concepts understandable to learners (Shulman, 1987). Pedagogical orientations refer to different beliefs and approaches to teaching and learning at different grade levels (Grossman, 1990; Magnusson et al., 1999). These authors incorporated pedagogical orientations into their PCK models, believing that orientations play a role in teachers' PCK (Sahingöz & Cobern, 2020).

Pedagogical orientations influence teacher's PCK (Magnusson et al., 1999), for example, a teacher who believes in inquiry-based approaches often focuses on helping learners make connections between prior knowledge and new content. Conversely, a teacher's PCK can also influence their pedagogical orientation. Barendsen and Henze (2019) noted that a teacher with a strong understanding of how learners grasp a certain concept may modify their teaching approach to be more learner-centred, incorporating inquiry-based methods. Therefore, pedagogical orientations and PCK are closely related, influencing each other and both being crucial for effective teaching. Teachers must possess a good balance of both to deliver content effectively and provide meaningful learning opportunities for their learners. Cobern et al. (2014) grouped pedagogical orientations into four categories:

i. Direct Didactic (DD) is where the teacher presents science concepts directly and explains them, and there are no student activities though the teacher answers questions from the students.

ii. Direct Active (DA) is where student activity follows, for example, verifying a law after the teacher's direct presentation of the concepts. Both DD and DA orientations are presented as factual knowledge, and these two orientations are regarded as teacher-centred methods.

iii. Guided Inquiry (GI) is where the teacher introduces a topic through student exploration, and the teacher guides the students to the desired science principle or concept resulting from the activity.

iv. Open Inquiry (OI) is where students have the freedom to explore a phenomenon or an idea as they choose. Both GI and OP orientations are developed through scientific inquiry.

The first two pedagogical orientations are referred to as direct approaches or teacher-centred, and the last two pedagogical orientations are referred to as inquiry approaches or learner-centred. The four pedagogical orientations are used as conceptual framework in this paper.

Sciences Pre-service teachers’ pedagogical orientations

Several studies have explored pre-service teachers' pedagogical orientations in science education, focusing on their beliefs and approaches to teaching and how these impact their ability to teach science effectively. For example, Sizer, Tharp, Wrigley, Al-Bataineh, and Park (2021) investigated how pre-service elementary teachers’ orientations towards science inquiry affect their implementation of inquiry-based instruction. Thirty-one pre-service teachers participated, with data collected using a survey and three vignettes. The results showed: (a) a moderate relationship between pre-service teachers’ views on inquiry-based instruction and their willingness to implement it; (b) increased confidence in implementing inquiry-based instruction as they gained experience through coursework; (c) a preference for inquiry methods, though they felt more comfortable with a teacher-centred approach. Şahingöz and Cobern (2020) aimed to understand how taking a science methods course correlated with the science teaching preferences of pre-service science teachers. Twenty K-8 teacher education students participated, with some interviewed to explain their responses to the POSTT items. Results indicated that many participants favoured an inquiry science teaching orientation, though their reasons varied. Bansal, Ramnarain, and Schuster (2019) examined the pedagogical orientations of pre-service science teachers in a two-year Bachelor of Education program in India. All these studies used a POSTT to identify pre-service teachers’ pedagogical orientations, with interviews probing the reasons behind them. Their findings showed that pre-service teachers developed varying pedagogical orientations, from direct instruction to open inquiry. These studies show that pre-service science teachers often select a Guided Inquiry while others also indicated that pre-service science teachers might adopt multiple pedagogical orientations depending on the context.

Methodology

This paper adopted quantitative method, which is the process of collecting and analysing numerical data (Cresswell, 2014). In this paper, numerical data and statistical analysis was used to understand and explain the pedagogical orientations of Natural Sciences pre-service teachers at the two comprehensive universities in South Africa. A ten-item scenario-based POSTT (Pedagogy of Science Teaching Test) questionnaire was administered to 115 Natural Sciences pre-service teachers, with 66 participants from an urban university and 49 from a rural university. POSTT is a standardized assessment tool used to evaluate the knowledge and skills of pre-service teachers in relation to teaching science (Cobern et al., 2014). The POSTT administered included ten case-based scenario items showing realistic teaching situations. Figure 1.1 shows an example of POSTT items.

General wrap-up of unit

Mr. Nelson's 6th grade students have just completed a unit in their earth science class. As a "wrap-up," Mr. Nelson would like students to re-examine the three learning objectives that served as the focus for this entire unit.

Of the following, which is most similar to how you would like to conduct the wrap-up?

A. I would ask the students what the main things are that they have learned in the unit, according to their own ideas of what is important or interesting, and have them list these as the unit wrap-up.

B. I would restate the three learning objectives for the students, and then relate each of them to the specific concepts that arose in the unit.

C. I would ask the students to reflect back on their work, and identify for themselves what the important central ideas of the unit were, then have them relate these to the original learning objectives.

D. I would restate the three learning objectives, then ask the students to say how the various concepts that arose in the lesson related to each of these.

Figure 1.1: An example of a POSTT item used in the questionnaire.

Participants were asked to analyse each scenario and select one of the four options that resonated with their pedagogical orientation: Direct Didactic, Direct Active, Guided Inquiry, or Open Inquiry. The data were then analysed using a scoring system: 1 point for Direct Didactic, 2 points for Direct Active, 3 points for Guided Inquiry, and 4 points for Open Inquiry, with a higher score indicating a preference for scientific inquiry (Ladachart, 2019; Cobern et al., 2014, & Schuster et al., 2007). To determine the reliability of the questionnaire, Cronbach's alpha results shows that the Natural Sciences questionnaire was 0.62. The Natural Sciences Cronbach's alpha reliability strength was moderate, and value is considered low compared to the normal standard in educational research (≥ 0.7). however, this POSTT instrument also yielded weak inter-item correlations in other studies conducted by Cobern et al. (2014), Schuster et al. (2007). Therefore, in this paper, a value of 0.62 is not considered a poor instrument result. For the purpose of data analysis, descriptive data statistics (percentages, mean scores, and standard deviations) were used to compare the POSTT scores between the pre-service teachers of the two universities.

Findings.

The overall Natural Sciences pre-service teachers preferred pedagogical orientations are presented in table 1.1.

Table 1.1: The overall mean scores of Natural Sciences pre-service teachers preferred pedagogical orientations between the two universities.

Question number	Labelling of university	Mean score	Std dev
Q1	Urban	2,74	,997
	Rural	2,65	,991
	Overall	2,70	,991
Q2	Urban	2,14	,943
	Rural	1,98	1,051
	Overall	2,07	,989
Q3	Urban	2,42	,895
	Rural	2,45	1,100
	Overall	2,43	,983
Q4	Urban	2,33	,934
	Rural	1,80	,935
	Overall	2,10	,968
Q5	Urban	2,98	,920
	Rural	2,84	,921
	Overall	2,92	,919

Q6	Urban	2,91	1,119
	Rural	3,22	,941
	Overall	3,04	1,055
Q7	Urban	2,79	,920
	Rural	2,88	,992
	Overall	2,83	,948
Q8	Urban	2,33	1,181
	Rural	2,12	1,201
	Overall	2,24	1,189
Q9	Urban	2,59	,976
	Rural	2,61	,885
	Overall	2,60	,935
Q10	Urban	2,55	,948
	Rural	2,39	,953
	Overall	2,48	,949

The findings in Table 1.1 show the overall mean scores for urban and rural universities and the mean scores for each item for both universities. For item number 1 (Temperature and Solubility), the mean scores for both universities fell between Direct Active and Guided Inquiry. However, for item 6 (Predator and Prey), there were some differences. The overall mean score for this item was 2.91 at the urban university and 3.22 at the rural university. These scores indicate that urban university pre-service teachers' pedagogical orientations leaned towards Direct Active, while the rural university pre-service teachers preferred pedagogical orientation was Guided Inquiry.

Furthermore, most items did not differ significantly between the two universities. For item 4, urban university pre-service teachers they leaned towards Direct Active with a mean score of

2.33, while the rural university pre-service teachers' mean score was 1.80, indicating a preference for Direct Didactic. Overall, the Natural Sciences pre-service teachers preferred pedagogical orientations was between Direct Active and Guided Inquiry. However, rural university pre-service teachers selected some items that leaned between Direct Didactic and Direct Active, with an overall mean score of (M=2.49; SD=0.3). On the other hand, urban university pre-service teachers preferred Direct Active for most items, with an overall mean score of (M=2.58; SD=0.341). The overall preferred pedagogical orientation for both universities leaned towards Direct Active, with an overall mean score of (M=2.54; SD=0.32). Therefore, the findings indicate that Natural Sciences pre-service teachers from both universities overall preferred pedagogical orientation was Direct Active.

Discussion and conclusions

To address the research question, "What are the pedagogical orientations of Natural Sciences Pre-service Teachers at two South African comprehensive universities?" the findings show that the overall preferred pedagogical orientation among Natural Sciences pre-service teachers was Direct Active (DA). In a Direct Active orientation, teachers prefer methods where student activities follow a direct presentation of concepts, such as verifying a law after the teacher's explanation. DA is characterised as factual knowledge and is considered a teacher-centred method.

These findings contrast with other studies, such as Nyirenda (2019) and Ladachart (2019), where pre-service science teachers preferred Guided Inquiry over Direct Active. Similarly, Ramnarain, Nampota, and Schuster (2016) found that the collective responses of Malawian and South African Physical Sciences teachers leaned towards Guided Inquiry, although township school teachers preferred Direct Active which was similar to this paper. The preference for Direct Active among Natural Sciences pre-service teachers shows a minimal influence from environmental or external factors or the context of the university. This was evident as pre-service teachers from both universities predominantly selected Direct Active as their preferred pedagogical orientation.

In conclusion, this study indicates that Natural Sciences pre-service teachers from the two universities were inclined towards Direct Active pedagogical orientation. Investigating these orientations across different contexts is important for aligning teacher education programs with curriculum goals and school reforms. This alignment ensures that teachers are prepared to implement the educational reforms frameworks, such as the inquiry-based learning approaches that is endorsed by the South African school curriculum know as Curriculum Assessment Policy Statement (CAPS). Furthermore, understanding pre-service teachers' pedagogical orientations allows university lecturers to identify strengths and weaknesses of pre-service teachers in their application of various teaching methods. However, this study only investigated the pedagogical orientations of Natural Sciences pre-service teachers and did not investigate whether these orientations are reflected in their actual classroom practices. Therefore, future studies should consider factors that influence pre-service teachers' pedagogical orientations and follow them into classrooms to observe if their stated orientations align with their teaching practices.

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Development and Evaluation of a Lesson Sequence in Heat and Temperature using Transformative Learning in a Blended- Online Setting: Effects on Students' Conceptual Understanding

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Development and Evaluation of a Lesson Sequence in Heat and Temperature using Transformative Learning in a Blended- Online Setting: Effects on Students' Conceptual Understanding

Abstract

The research investigated the effect of a TL (Transformative Learning) lesson sequence in Heat and Temperature on BSEd Science students' conceptual understanding of heat and temperature in a blended online learning setup, at a state university in Negros Occidental. It used a mixed embedded design of research. The instruments used were Heat and Temperature Conceptual Evaluation (HTCE), Interview questions, Journal Logs and the Lesson sequence itself. Results showed that after a two-week implementation of the lesson sequence, students did not practically pass the HTCE. However, on a positive individual observation, a significant increase on some students' post- test score performance reflected by $t(28)= 2.32$, $p=.04$ and medium effect size ($d=0.50$) was found. This indicates a medium and statistically significant increase among some students' HTCE post evaluation.These quantitative results were investigated further and were corroborated with qualitative data as reflected by selected interviews and journal logs from students who improved. Affordances and challenges were also noted in the implementation of the research. The challenges were internet connectivity, zoom platform cost, and teacher's and students' infamiliarity with the approach. For the affordances, data of the research show that TL promotes collaboration, interactivity and flexibility. The final findings show that TL can be integrated in science teaching in universities. To achieve conceptual development, relevant content and high appropriateness of TL themed activities should characterize a lesson plan and sequence. Also, the researcher is interested in investigating TL influenced classes for conceptual evaluation in a longer timeline rather than just two weeks, since conceptual development is a long process. The research further found out and recommends to the teachers and administrators who would like to use TL in their online courses the readiness of the students in terms of gadgets and technologies as the first consideration to support Blended Online Learning with TL.

Keywords: *transformative learning, conceptual understanding, heat and temperature, blended online learning, lesson sequence, physics teaching and learning approach*

INTRODUCTION

Transformative Learning is allowing adult learners develop the ability to make their own sense of meaning independently away from pre-constituted facts and morals passed by religions, cultures, family beliefs, characters and life encounters (Sarver, 2012). This study focused on the implementation of a lesson sequence carefully structured using Transformative Learning (TL), a learning theory anchored vastly to the human's nature, which is to communicate. This theory is characterized partly as a developmental scheme, but more specifically as the understanding that learning makes use of prior knowledge to interpret significantly a fresh new idea or a revised illustration of meaning with someone's experience in order to be guided for future interpretations (Mezirow 1996, p. 162). It has three common themes, the centrality of transformative experience (TE), critical reflection and rational discourse. TL has been regarded as an approach which can be used in teaching (Garcia, 1998) and there is a possibility for transformative episodes to occur in an online learning environment (Boyer et al., 2006; Henderson, 2010; and Jackson & Chakraborty, 2014).

Studies have looked into the impact of TL with the retention of concepts (Walvoord, 2020), and physics concepts are generally one of the most challenging for students (McDermott, 2001; Engelhardt and Beichner, 2003). Especially on students' conceptual understanding of heat and temperature in a college Physics course, as these topics are considered one of the most abstract and with most misconception among students (Saparini, Murniati, Syuhendri, Widya Rahmatika Rizaldi, 2020; Ratnasari, Sukarmin and Suparmi, 2017). Explicitly exposed in a study was the misconception about perceiving water to boil at a temperature greater than 100 degree celsius when contained in some specific material (Baser, 2006). This is an example of a problem in the teaching of physics and these sorts of challenges according to Anderson, Krathwohl and Bloom (2001), can be confronted and can be improved by meaningful learning. Actual day to day life-experience about the concepts of heat and temperature are best tools to help the students to better understanding the phenomenon (Arnold & Millar, 1994). Likewise, transformative learning has its themes on centrality of experience, that can be delivered through transformative experience (TE) that is tied with learning goals on conceptual understanding (Pugh et al., 2010; Heddy & Sinatra, 2013). On the other hand, rational discourse and critical reflection, has its framework that is geared towards transformation of initial conceptions to a transformed and developed one. One important thing about TL's main theme is critical reflection (Taylor, 2017) which is basically essential in learning hard subject like physics, as it allows metacognition to happen, thus, making the learning experience meaningful and purposive.

Empirical studies that support TL includes the University of Central Oklahoma's use of their Student Transformative Learning Record (STLR) as a component of their undergraduate curriculum which gave a clear correlation between STLR and student's better retention of concepts and enhanced academic performance (King, 2018). Likewise, instructional materials for science education employing TL in higher education have been progressively developed in the said university (Walvoord, 2020). In Japan, TL was suggested to best be implemented in the higher education as it was believed to develop mature learners who can better participate in the resolution of complicated societal concerns (Enkhtur & Yamamoto, 2017). In the Philippines, though not much literature is sufficiently published regarding TL in instruction, De La Salle University (DLSU) in Manila had a case study on how TL is employed in their Instructional Video Production course. Findings of the study recommended that TL be integrated in University's courses (Espiritu & Budhrani, 2014) as it has the attributes of a meaningful and experience- centered approach in improving the conceptual understanding of the students.

Given the challenge of teaching physics concepts to students, and the fact that TL approach is not that much studied in the Philippine context, this research provides the body of knowledge with research-based results of new pedagogies in the teaching and learning approaches in improving the quality of physics instruction. To note, some of the teaching strategies applied in TL are present in most science or Physics teaching, what hinders the effective teaching in the Philippines is the lack of updating and trainings of teachers for new pedagogies that can be used in the present (Diate and Mordeno, 2021).

These current educational circumstances prompted and made the researcher develop and implement new and effective teaching approaches in teaching Physics especially on the topic of heat and temperature in higher education. This particular study carries significance as it adds to the body of literature in the area of Transformative Learning as basis for the development of a lesson sequence in developing the conceptual understanding of tertiary science education students. With this transformative learning setup, students were taught in a way that they are supplied with learning experiences that are worthwhile and effective.

It was employed in a Blended Online Learning Setting that carries students' activities in a synchronous and asynchronous mode (Power, 2008). Both qualitative data via interviews sessions and observation log, and quantitative data via pre- test and post- test of *Heat and*

Temperature Conceptual Evaluation (HTCE) was used in determining the significant effects of the intervention.

METHODS

Research Design

This study utilized mixed- method research, in particular a *Concurrent Embedded Mixed Design*. This used both qualitative and quantitative data to bring about results and conclusions. The qualitative data set are supporting details to whatever is reflected in the quantitative assessments, for the qualitative assessment contains evaluation of information that can be found in the intervention. This is why, this design is appropriate for this research. Also, a *One-Group Pre- Test- Post- Test Design* was used in this study. This design involved a single group that undergo pre- test measure succeeded by a treatment and a post- test (Creswell, 2009). The pre- test and post- test scores were the quantitative data, driven from a published standardized test for conceptual understanding on heat and temperature (HTCE) which was administered to students synchronously and is timed accordingly.

Research Environment

This research was in a state university in Negros Occidental. The study was participated by BSEd-Science students who come from low to middle class groups. The university uses flexible learning modality where online synchronous and asynchronous meetings are scheduled for students and teachers in carrying out teaching and learning processes. The school has facilities and equipment to support blended- online learning. The university just recently had been converted to becoming a state university with six colleges in the main campus with a number of different undergraduate bachelor courses. The college of education where the participants of this research belong has six programs. Some programs are general education and some with specialization. The subject thermodynamics, particularly on the topic of heat and temperature is in the courses of the first-year students‟ introductory Physics. This is to be implemented on the second half of the second semester of school year 2021- 2022.

Research Participants

The research participants were 29 first year Bachelor of Secondary Education major in science students from a state college in Negros Occidental. And since this study follows pre-experimental, this was accomplished in only one section as sample. And the prospect sample was identified via cluster sampling. The students were selected and were admitted in the state university with high standards due to limited slots to be accommodated relative to free education, so this group of students are in the group of good performing students.

The researcher who plotted and planned the lesson activities and flow found in the lesson sequence developed, trained the teacher implementer. The participating teacher is experienced and an expert in curriculum development. This is apparent in her long-time experience as the coordinator of the BSED internship program and as the subject specialist of the BSED Science major. She is in her mid-50 and had been teaching for 38 years now. Regarding the adaptation that she had been doing with the shift of instruction delivery from face to face to online was not easy. Although two years had passed experiencing the new normal education, it is not a neglected factor in the teacher's reaction with the lesson sequence developed for blended- online modality.

The third and final participants of the research were the three content validators of the instruments in this study, specifically the lesson sequence and the interview questions. Two among the validators are graduate students under CBPSME. The graduate students are second year MAED students in Science Education and are sufficiently familiar with curriculum creation and are subject matter experts. The other one validator was the cooperating subject teacher herself, an experienced expert teacher. All the data gathering procedures were carefully followed by all the participants of the study, in a manner that the data that were collected were conservatively raw and were free from external bias influences that might lead to an altered data gathered. So that the procedure does not result to defective and false results.

Research Instruments

This paper includes aforementioned research instruments in its previous sections. As stated, this research collected qualitative and quantitative data in its progression. This part details the different research instruments used in this study.

Lesson Sequence on Heat and Temperature

This research made use of the Lesson sequence developed using TL in teaching heat and temperature in a thermodynamics course. The lesson sequence was made by the researcher and was subjected to edits based on results of pre- test, and with validation review and recommendation of experts. The lesson sequence encourages self-responsible and collaborative learning as it is the focus in adult education, and of course, parralel to the main component of a TL approach which is critical reflection. The details of the lesson sequence were evaluated based on expectations of an exemplary lesson plan and sequence. For the evaluation on how relevant TL integration in developing conceptual understanding among students, a researcher- made validation tool is available.

Lesson Sequence Validation Matrix

The lesson sequence as one of the main instruments of this research underwent a validation process for its organization and TL adaptation. This was done by the validators adequately described in the research participant's section of this paper. The validation matrix consists of various rubrics for evaluation of the unit plan and individual lesson plans that constitute a lesson sequence can be found in the appendices (Appendix). However, in this portion is the presentation of the interpretation guide for the result of the lesson sequence validation. Table 1 below is the interpretation guide for the lesson sequence, to be followed by Table 2 which is the interpretation guide for the validation of individual lesson plans in the lesson sequence. Table 3 is the interpretation guide for the results of the validation of TL integration in the lesson sequence.

Table 1

Lesson Sequence Validation Scores' Interpretation Guide

Mean Score (Applicable to all Criteria)	**Verbal Interpretation**
5	Exceeds Expectations
4	Meets Expectations
3	Needs Improvement
2-0	Does not meet Expectations.

Table 2

Individual Lesson Plans Validation Scores' Interpretation Guide

Criteria	**Mean Score**	**Verbal Interpretation**
Purpose- Goals	10-9	Exceeds Expectations
	8-6	Meets Expectations
	5-3	Needs Improvement

	2-0	Does not meet Expectations.
Objectives	20-18	Exceeds Expectations
	17-15	Meets Expectations
	14-8	Needs Improvement
	7-0	Does not meet Expectations.
Anticipatory Set	5-4	Exceeds Expectations
	3-2	Meets Expectations
	1	Needs Improvement
	0	Does not meet Expectations.
Procedures	20-18	Exceeds Expectations
	17-15	Meets Expectations
	14-12	Needs Improvement
	11-0	Does not meet Expectations.
Special Accomodations	20-18	Exceeds Expectations
	17-15	Meets Expectations
	14-12	Needs Improvement
	11-0	Does not meet Expectations.
Closure	5-4	Exceeds Expectations
	3-2	Meets Expectations
	1	Needs Improvement
	0	Does not meet Expectations.
Assessment	20-18	Exceeds Expectations
	17-15	Meets Expectations
	14-12	Needs Improvement

	11-0	Does not meet Expectations.

Table 3

TL Integration Validation Scores' Interpretation Guide

Mean Score (Applicable to all Criteria)	Verbal Interpretation
3	Relevant and Essential
2	Relevant but Not Essential
1	Not Relevant

HTCE (Heat and Temperature Conceptual Evaluation)

This research made use of HTCE developed by Ron Thornton and David Sokoloff (2001) (See Appendix B-1). The standardized test for heat and temperature was made accessible to the researcher via a website called Physport. This website provides standardized diagnostic research- based test for physics faculty, in the aim to encourage a research-based modification and improvements of class methods and assessments. As per validity and reliability of the test items, the website categorized HTCE in the Bronze research validation category. Meaning to say that this instrument belongs to the third highest level of research validation, corresponding to at least three validation categories. The three categories are as follows, Based on Research Intro to Student thinking, Studied Using student interviews etc., and Research Conducted at Multiple instiutions etc.

Observation Log

In this study, since this was implemented in a blended online learning environment, observation log can only be done during synchronous sessions. The audio- visual conference of the session was recorded to see small operating manifestations of transformational behaviours and guiding profeciencies towards conceptual understanding of heat and temperature. The recording of every synchronous session was sought for permission form the students, subject teacher and parents and it was assured to be dealt and handled with responsibility in accord with data privacy policies. However, upon implementation and data gathering, the observation log was found to be insufficient to serve as backings to conceptual developments that transpired. So, for triangulation, the journal logs and the student interviews were used.

Interview schedule

For the aim of noting the students' perception of own conceptual understanding development and evaluation of the lesson sequence introduced to them, this qualitative research instrument was required. This is because students' views were one of the vital and critical aspects in the completion of this research. This instrument was concerned with the student's own inspection of his/her way of answering or rationalizing of how their process of answering the questions had been and making them reflect on it. Additional questions were supplied to inspect personal effects of the researcher- made intervention to the students, using questions that bring emphasis on their specific view of their conceptual understanding development. The students were interviewed contextually with questions that are grounded and connected with the research problems and conceptual and theoretical frameworks. The interview questions were validated by three expert validators and was pilot tested to some participants of the class just to make it operational first-hand, and then adjustments for further improvements can be identified. An audio recording was done to secure an account of the students' responses.

Research Procedures

The process of data collection happened in the second half of the second semester for Academic year 2021- 2022. Data collection comprise three main stages: *Development of lesson sequence and materials, implementation of the lesson sequence intervention and evaluation.* To stick with ethical measures the researcher sent out a letter of request for approval from the College president, Dean of the college of Education, teacher, and students that are involved in the prospective research. Below are the following data gathering processes that are defined in particular.

Stage I: Creation of the Instructional Unit and materials

An instructional Material (IM) was conformed to by the teacher who will implement the lesson sequence in her conduct of classes (Appendix E). The IM contains detailed daily lesson plans that has 5 lessons on heat and temperature. The approach that the IM was patterned is transformative learning approach. It followed a 5E design for Instructional materials development. The developed lesson sequence was subjected to revision based on the results of the pre-test that was given to students a week prior to the implementation of the lesson sequence, and from the validation and analysis review of the three expert teacher validators. They used a rubric that is made to evaluate the lesson sequence as a whole and each of the lesson plans. With the instrument at hand, the LP went on an evaluation which includes levels and areas for essential entries for an exemplary lesson plan and sequence. (See Appendix – B) Regarding the interview schedule instrument, it served as a supplementary instrument for not much data were collected in the observation logs, it was validated by the same expert validators. It was then pilot tested to another group of students that were introduced with the intervention but are non- participants of the research. (See Appendix- B3).

Stage II: Implementation of the Lesson Sequence

The HTCE as the primary tool of this research was handed out as a pre- test a week prior to implementation of the lesson sequence and post-test in the conclusion of the lesson sequence. According to the curriculum outline as provided by the thermodynamics teacher at the researcher's prospect school, the total amount of time that this intervention took place was 20 hours. Synchronous meetings were scheduled every Monday and Tuesday- 2hrs/ meeting (equivalent to 4 meetings/ 2 weeks). The rest of the weekdays with two hours allocation for the heat and temperature topics were used for asynchronous learning activities of the students that are based on the lesson sequence. With this schedule being set, a table was presented below to show an organized set- up of topic partitions per synchronous meeting.

Table 4

Total Amount of Synchronous Meetings that the Intervention Took Place.

Lesson	Topic	No. of science periods
1	Mechanisms of Heat Transfer	2hrs
2	Problem solving on Mechanisms of Heat transfer	2hrs
3	First law of Thermodynamics	2hrs

4	Presentation of the students‟ Scientific Journal	2hrs

In this stage of the research procedure, the different research instruments were applied and was brought to actualization. The recording of the synchronous online sessions and the scheduled interviews as the instruments took place in this stage of the research procedure.

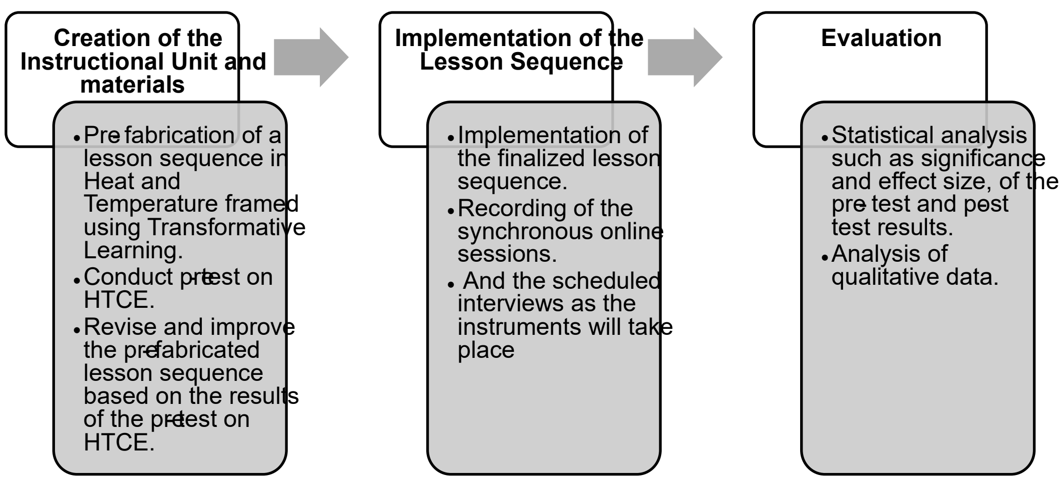
Stage III: Evaluation

This study made use of the standardized Heat and Temperature Conceptual Evaluation

(HTCE). The mean HTCE test scores' percentage in the pre- test was very important to the researcher for it informed him of the conceptual areas where students have high, average and low conceptual understanding. The data that were collected were used as reference in teaching the topics that are within the scope of concepts on misunderstood areas. Post- test was the indicator of a significant effect on the students by the intervention.

Figure 1

Research Procedure Diagram



RESULTS AND DISCUSSIONS

SOP1. The students' misconception and need are on the calculations of amounts and rate of heat transfer, the students' misconception on conductivity and specific heat of materials must be taken into account as well for 2/3 of the items on Thermal Conductivity and ¾ on the category on Specific Heat Capacity was answered wrongly by the students. The students also found it hard to understand the graphical representations in the category, Change of Phase, and the students don't have clear conception that continued boiling of water doesn't mean that its temperature exceeds 100 degrees Celsius, thus agrees with Baser (2006), that it is held constant at its boiling point even when boiled at a lengthened period of time. These diagnostics were sought for incorporation in the lesson sequence in the revision and development of the lesson sequence.

SOP2. The lesson sequence that was made by the researcher to target conceptual problems was validated and was subjected to reliability testing to make sure of its responsiveness to the students' needs and it was scrutinized by validators, and then, revisions were made before it was made ready for implementation.

SOP3. Results showed that after a two-week implementation of the lesson sequence, students did not practically pass the HTCE. However, on a positive individual observation, a significant increase on some students' post- test score performance reflected by $t(28)= 2.32$, $p=.04$ and medium effect size ($d=0.50$) was found. This indicates a medium and statistically significant increase among some students' HTCE post evaluation.

SOP4. The challenges were internet connectivity, zoom platform cost, and teacher's and students' infamiliarity with the approach. For the affordances, data of the research show that TL promotes collaboration, interactivity and flexibility.

CONCLUSIONS AND RECOMMENDATIONS

Transformative Learning is an approach that basically foster and develop learners to become autonomous and independent, this is why it's a theory that is applicable for adult learners. Some research such as of Walvoord (2020) found TL as an effective approach for retention of concepts. TL was found integrable in science classes using its themes especially transformative experiences that is tied with learning goals on conceptual understanding (Pugh et al., 2010; Heddy & Sinatra, 2013). TL themes were incorporated in this research in the Philippine context where TL studies are insufficient. This study is concerned on students' conceptual understanding of heat and temperature.

Based on findings, the following conclusions are drawn:

Transformative Learning Approach is applicable for use in physics teaching in a state university. Despite being state university students, often identified as students who belong to poor families, blended online learning with TL is still effective on developing students' conceptual understanding. Also, the research findings significantly show that TL driven lessons allow independent learning and helps develop in a learner the ability to decide on what best thing is there for him/ her to do for his/ her benefit, especially in learning topics that are abstract like heat and temperature which requires vast awareness of self-thinking in order to understand a concept. With students who are actively aware of their own learning processes, teachers can expect academic outcomes that are satisfactory. With all data available and interpreted, here are the following specific conclusions driven out from the research:

Conceptual development in heat and temperature through Transformative Learning Approach delivered in two weeks is not enough to improve the conception of all the 29 research participants and practically pass the Heat and Temperature Conceptual Evaluation. However, it impacted and improved some students' understanding on a medium scale. Therefore, the researcher is now interested in applying the TL approach longer than two weeks in order to see its effect, since conceptual understanding is a long-term undertaking.

Through proper arrangements, articulation and implementation of activities and assessments in a lesson sequence, the themes such as critical reflection, transformative experience and rational discourse and learning experiences offered by TL support conceptual attainment and thus affect positively students' conceptual understanding.

In the current state of TL literature in the Philippines, this research can be a baseline fact that educators can use as a benchmark if they want to use TL in teaching physics in universities. Since this literature shows satisfactorily a good sign of development for short term interventions, this can open possibilities of integration for attainment and improvement of long-term academic goals.

Blended online learning with TL is benefitial tor students, for it is flexible and helps students in sourcing substantial information from the abundant and wide online resource while being connected with groupmates from different places through internet; and interactive, giving the students a chance to assist the insufficiently knowledgeable among them in a group and it helps them become scaffolded in their learning through peer and it fosters collaboration that promotes to students the value of working together to give a quality work through enhancecd peer monitoring of individual and group progress.

Internet connectivity is the most common problem in the blended online mode of delivery in the school, and it disabled some students to participate and to have the maximum possible benefit of each learning session. So, there should be a closer look on student preparedness and government efforts in securing educational aids for students.

The teacher familiarity of the approach that translates to teacher's adoptive capacity of it, is a very important factor that would determine the effective implementation of TL. So, when a school or research shall be conducted using TL, teacher capacity building and training is a must.

Recommendations

Based on the drawn conclusions, here are the research's recommendations:

1. Make the implementation of TL approach longer than two weeks to see whether the longer Implementation can help the adjustment among students with the approach and foster effectively its aims. In this research's case, the aim was for conceptual development in heat and temperature.

2. For future researchers wanting to employ TL in instruction, it is a must to really give enough emphasis on teacher training and capacity building before implementation of the approach. Especially that in the Philippines TL is not so popular yet, the familiarity of the teacher or implementer should be a focus.

3. When a school or a teacher is planning for a blended online learning with TL, the students' level of readiness in terms of gadgets and internet connectivity should be secured.

4. The students' readiness for a class is not just limited on his/ her personal willingness, a great consideration on materials to support a class with TL in a blended online setup is a need too. Since lack of consistency on the part of the student's internet connectivity was a major affecting factor that can hinder the best quality of education prepared and offered to students.

5. The design and articulation of every given activity that is with TL should be valid and relevant; and adherent to the themes that are found out effective for conceptual understanding, so that the students get the most out of every lesson.

6. Teachers should be creative and regard ultimately that the lesson should not just be clear to the teacher, but to the students as well. Also, it is necessary to make the design of every lesson interactive.

7. For researchers wanting to study TL in a different area of study, it helps when lesson sequences or course syllabus are validated by experts in the field and the purpose of every activity to be given should always be clear for students, since TL primarily is defined to develop autonomous learners.

8. Internet connections should be made better to effectively support Blended online learning. And educational platforms should be made affordable for students, especially that education is not just for the rich, but also for students who are not that well off and are mostly sent out to public schools and universities.

9. Teacher training of the pedagogy should be invested time by the researcher.

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Growing Teacher Professionals in a Post-C19 World: Customized Online Professional Development (PD) on Differentiated Instruction for an International School

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Growing Teacher Professionals in a Post-C19 World: Customized Online Professional Development (PD) on Differentiated Instruction for an International School

Abstract

This paper reports the findings of a customized online Professional Development (PD) course to grow teacher professionals in a post-C19 world using the MCE Teaching and Learning Framework, informed by educational neuroscience research for a new generation of learners.

Entitled “Designing Quality Differentiated Learning Experiences for Every Student”, the customized PD course was conducted online via the Zoom platform. The aim of the course was to challenge science and non-science teachers from an international school with campuses within and beyond Singapore to reflect and refine ways of designing quality differentiated learning experiences for every student in their respective subjects and classroom contexts.

To foster active collaboration among the 62 teacher participants with a focus on the big ideas of Differentiated Instruction (DI) and application of the principles of DI in lesson planning, the course was conducted on a sustained basis from 29 September to 10 November 2023 in three sequential learning segments:

- Learning segment 1: An online Pre-PD session for 8 Team Leaders to equip them as discussion leaders in the Zoom breakout-rooms during the Actual-PD session.
- Learning segment 2: An online Actual-PD session for all 62 teacher participants on the why, what and how of DI for all subjects with a science exemplar based on the adapted 5E Instructional Model.
- Learning segment 3: An online Post-PD session for 8 Team Leaders as a follow-on to the Actual-PD session to share key takeaways and identify common challenges.

Using an online course evaluation, qualitative and quantitative data were collected and analyzed. Results of the analysis showed promising gains by the teacher participants in both affective and cognitive domains after undergoing this customized online PD course.
The sharing by the Team Leaders on common challenges serves as useful inputs to design a future follow-up PD course on Lesson Study as a collaborative action research PLC tool in strengthening the teacher participants’ DI practices for instructional excellence

Keywords: MCE Teaching and Learning Framework; Online Professional Development; Differentiated Instruction, Affective; Cognitive; Lesson Study

Setting the context

After emerging from the world-wide disruption of face-to-face learning by the Covid 19 pandemic, the widespread adoption of blended learning and online professional development (PD) has become the new normal in equipping teachers to deliver joyful and meaningful learning for their students in class (on-site) and/or at home (off-site).

As a global education leader with the vision of "Learning Simplified", Marshall Cavendish Education (MCE) is dedicated to nurturing the joy of learning and preparing students for the future guided by the MCE Teaching and Learning (T&L) Framework shown in Figure 1.

The Framework begins with the end in mind which are the students and teachers because research by New Teacher Centre, USA, has shown that when we focus on teachers, our students succeed (NTC, 2012). So, the two desired outcomes in the Framework are:

- Future-ready students (the App Generation) to thrive in an increasingly VUCA world.
- Future-ready teachers locally and overseas who can ignite the joy of learning in their students.

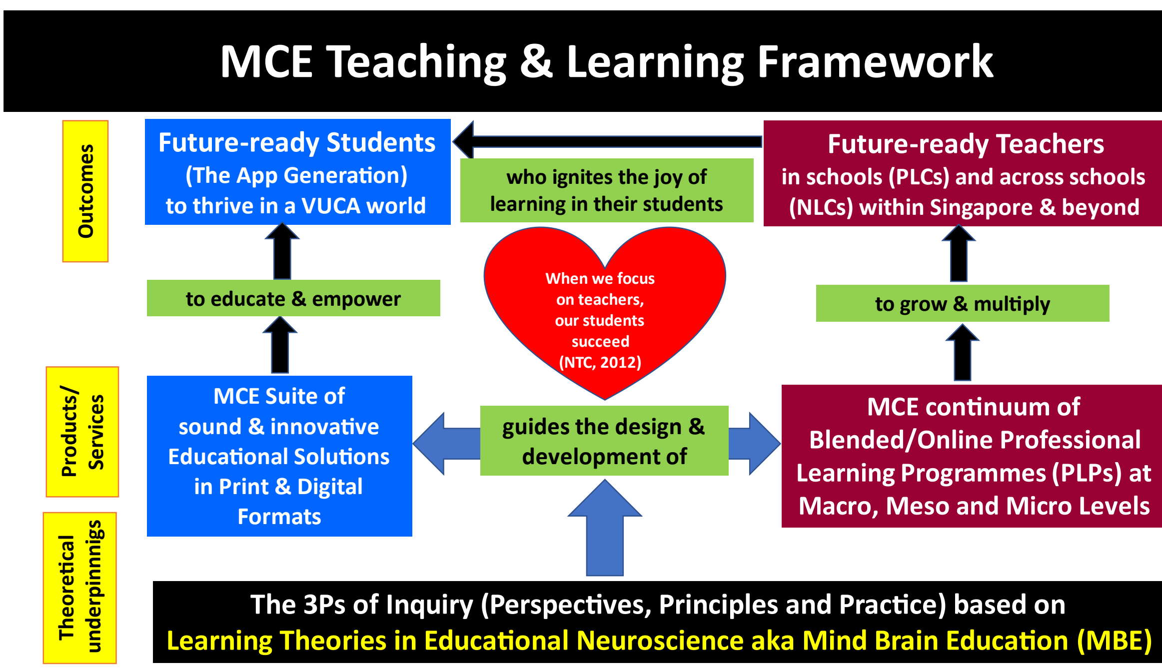


Figure 1. MCE Teaching & Learning Framework

To achieve these 2 desired outcomes, MCE offers the following products and services:

- For the students: Quality T&L resources through MCE's suite of sound and innovative educational solutions in print and non-print formats.

• For the teachers: Quality PD in the form of MCE's continuum of blended/online professional learning programs at the macro, meso and micro levels.

The customized online PD course presented in this paper is one of the Professional Learning Programs offered by MCE that are aimed at helping the teacher participants become future-ready teachers.

A critical aspect of the Framework is that the theoretical underpinnings in the 3Ps of Inquiry (Perspectives, Principles and Practice) in the design and development of these products (educational solutions in print and non-print) and services (blended/online PD programs) are based on Learning theories in Educational Neuroscience aka Mind Brain Education (MBE) or Science of Learning, an interdisciplinary field to translate insights about the brain and mind for enhancing instructional practices in the classroom. An example of a T&L approach based on the neuroscience finding of a strong relationship between physical activity and cognition (Friedman, 2019) is to divide the learning assignment unit into several segments with structured breaks in between these segments. The rationale of this T&L approach is to heighten students' interest, prevent fatigue, and stay within the optimal boundaries of time and information quantity that are most suited for storing information in the short-term (working) memory. The goal of this T&L approach is to allow for repetition of information in separate segments of 10 to 15 min so as to ensure that the new information presented will indeed be stored in the long-term memory. Learning happens when there is a change in long-term memory (Kirschner, Sweller, and Clark 2006, p.75) and 'involves the acquisition of knowledge' (Mayer 2002, p.226).

Design considerations for MCE blended/online PD programs

In the planning of MCE blended/online PD programs, four major considerations are:

- sustained basis of pre-PD, actual-PD and post- PD across time,
- topic of interest (such as Differentiated Instruction) requested by schools,
- harnessing the affordances of ICT tools (such as Zoom) for online delivery,
- 5 key questions that are informed by the Learning theories in Educational Neuroscience aka Mind Brain Education (MBE) or Science of Learning form the design considerations (Table 1).

Table 1. Design considerations for MCE Blended/Online PD Programs

S/No	Key Question	Cognitive Neuroscience underpinning
1	Is the learning environment emotionally safe, open and respectful?	When a person is threatened, the combination of neurotransmitters present in the brain will prevent other chemicals from successfully creating the needed synapses for new learning (Crestani et al., 1999; LeDoux, 1995; LeDoux & Phelps, 2008).
2	Is there something novel to capture the learners' attention with the aim of fostering curiosity and imagination?	Learning is based on the brain's ability to see what is different by comparing recognizable patterns (in numbers, behaviors, landscapes, and so on) with things that stand out as different (Balderston, Schultz, & Helmstetter, 2011).
3	Is there a journey of experimentation & exploration with appropriate scaffolding to construct understanding?	The brain remembers best when facts and skills are embedded in contexts that are authentic for the learner (Frymier & Shulman, 1995; Hollins, 2008).
4	Are the learners able to take ownership of learning through personal meaning making?	Learning is constructivist as 'knowledge arises through a process of active construction' (Mascolo & Fischer, 2005) and 'how we all make sense of our world' (Brooks, 1999).
5	Is there a yearning for further self-directed learning after the lesson?	The search for meaning is innate in human nature so when a person wants to learn something, there are no limits to what he will do, which is why the innate drive to learn is linked to human invention and creativity (Robinson, 2011).

Case study of an MCE customised online PD for an international school

Rationale for the MCE customised online PD course

To provide all students with equitable access to quality education and to nurture an increasingly heterogeneous cohorts of learners of different cognitive readiness, learning preferences and interests in today’s classrooms, there is a PD need to equip teachers with the why, what and how of Differentiated Instruction (DI).

MCE undertook to design a customised online DI course entitled *“Designing Quality Differentiated Learning Experiences for Every Student”* for 62 science and non-science teachers for an international school from various levels and subjects shown in Table 2. The reason for using online PD course via the Zoom platform was because the 62 teacher participants were located in different campus within and beyond Singapore.

Table 2. Distribution of levels and subjects of the 62 science and non-science teachers.

S/No	**Level/Subject**	**Number of Teacher Participants**
1	Early Years	6
2	Primary - Year 1 & 2	8
3	Primary - Year 3 & 4	6
4	Primary - Year 5 & 6	4
5	Science & Math	11
6	English	8
7	Arts, Humanities & PE	11
8	Foreign Languages	8
	Total	62

Aim of MCE customized online PD course

This online PD course seeks to challenge teacher professionals to reflect and refine possible ways of designing lessons based on Differentiated Instruction (DI), with the aim of enabling them to design quality differentiated learning experiences to meet the learning needs of all their students.

By means of an interactive lecture and collaborative discussion, it was intended that the teacher participants would be able to:

- understand the big ideas of Differentiated Instruction (DI)
- apply the principles of DI in lesson planning to design quality differentiated learning experiences for every student in the context of the International School

Implementation of MCE customised online PD course

Drawing reference from the design considerations for MCE Blended/Online PD Programmes in Table 1, the course was conducted on a sustained basis from 29 September to 10 November 2023 in three sequential learning segments for 62 teacher participants.

The appointment of Team Leaders (TLs) by the School Leaders of the international school one month before the Actual-PD session is an important part of this online PD. As instructional leaders in curriculum, pedagogy and assessment, these TLs are catalysts of change before, during and after the PD course.

Learning segment 1 (One month before the Actual-PD session)

The objectives of the on-line Pre-PD session one month before the Actual-PD session for the appointed TLs are:

(1) Provide an overview of the TL role before, during and after the Actual-PD session.

(2) Get the TL to prepare themselves as discussion leaders in the breakout-rooms during the Actual-PD session by doing the following 3 pieces of homework beforehand:
   - choosing a topic of a subject that will be taught in the next semester
   - filling in the Lesson Template for Differentiated Teaching, Learning & Assessment provided by the Chief Facilitator which will be used for discussion during Breakout on the Actual-PD session.
   - reading/viewing the relevant articles/videos for the subject group assigned as background knowledge.

Learning segment 2 (Actual-PD session for all 62 teacher participants)

To promote flipped learning, a course outline with the title, synopsis of the Online PD Session, Programme & Content, Pre-PD Session Readings 1 and Pre-PD Session Poll Questions and Post-PD Questions were given to all the 62 teacher participants (inclusive of the Team Leaders) 2 weeks before the Actual-PD session.

By means of an interactive lecture and collaborative discussion, the online Actual-PD session via Zoom seeks to equip all participants to:

(1) understand the big ideas of Differentiated Instruction (DI)

(2) apply the principles of DI in lesson planning to design quality differentiated learning experiences for every student in the context of the International School

Learning segment 3: (Post-PD session for the 8 Team Leaders)

To consolidate learning and to plan for next steps, an online Post-PD session as a follow-on to the Actual-PD session was conducted for the TLs three weeks after the Actual-PD session with the following two objectives:

(1) Encouraging one another through the sharing of the key takeaways in their journey of leading their group members

(2) Categorizing the common challenges/concerns for potential further professional development/collaboration with MCE facilitators in strengthening their DI practices in (subject) for (level).

Key Findings of the online PD course

Quantitative Findings

Of the total number of course participants N= 62, Table 3 show the quantitative findings of the 29 respondents to the online evaluation survey. The quantitative findings are based the Service Quality (SQ) Indicator which has a maximum value of 4.00 based on the Likert Scale of Strongly Agree (4.00), Agree (3.00), Disagree (2.00) and Strongly Disagree (1.00).

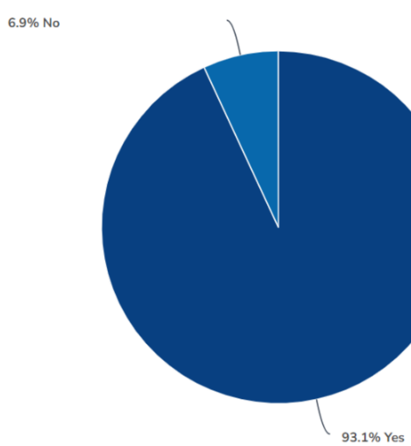
Table 3. Summary of Feedback of the Customised online PD course on DI

Category	**Item**	Mean SQ
Course Design	The content was well-organised.	3.55
	The materials/handouts were relevant.	3.21
	The activities were appropriate.	3.24
	The assignment(s) were relevant.	3.31
	The duration of the workshop was just right.	2.76
	Mean Rating	***3.21***
Course Facilitators	The presentation was clear.	3.59
	The pace of the presentation was right.	3.14
	Mean Rating	***3.37***
Course Goals	The objectives were achieved.	3.41
	The course met my learning needs	3.24
	The activities encouraged reflective thinking in relation to my professional practice.	3.45
	I can apply the ideas/skills learnt.	3.34

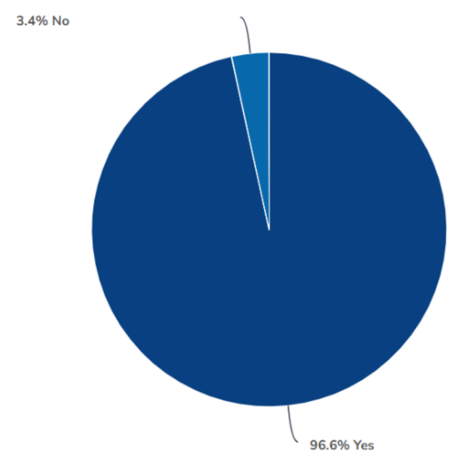
	I am satisfied with the course.	3.38
	Mean Rating	***3.36***
Course Administration	The course coordination (e.g. registration, handling of participants' enquiries and dissemination of workshop information prior to session) is good.	3.41
	The facilities in the classroom were conducive and appropriate for learning.	3.38
	Mean Rating	***3.34***
Course Overall Mean Rating		***3.32***

Two other quantitative findings in terms of percentage from the online survey are:

I will recommend this workshop to my colleagues: 93.1%



I will attend such courses in the future: 96.6%



From the four categories of Course Design, Course Facilitators, Course Goals and Course Administration in Table 3, it is encouraging that the participants have benefited significantly from the course as the mean ratings based on SQ are all above 3.00 out of a maximum 4.00.

While the overall course mean rating based on the average of the mean SQ from the 4 categories is 3.32 out of 4.00, one of the areas that warrant examination is the duration of the workshop with a mean SQ of 2.76. This examination will inform whether any refinements to timeframe between the 3 learning segments of Pre-, Actual and Post-PD session should be made for the next online PD course.

Qualitative Findings

With regard to the qualitative findings, the approach taken was to gather feedback from the Team Leaders at the Post-PD session on two areas, namely, key takeaways and common challenges faced by the teams.

Some typical comments on key takeaways include:

1. DI is able to address student differences in readiness and learning preferences by implementing differentiation in content, process, and product, using the 5E (Engage, Explore, Explain, Elaborate, and Evaluate) Model to engage students through hands-on activities, animations/videos, and projects.
2. DI ensures that everyone in the group understands and is aligned with goals and objectives is essential for coordinated efforts and encourage collaboration, creativity and enables the pooling of diverse skills and expertise.
3. Overall, DI has the potential to transform Primary School classrooms into a dynamic and inclusive learning environment, where each student's unique needs and potential are recognized and supported through:

- personalized learning (varied instructional approaches),
- increased engagement,
- recognizing and addressing learning gaps,
- catering to learning preferences and
- valuing diversity.

Some typical common challenges include:

1. Resources for creating varied materials and assessments.
2. Balance between individualized learning and covering the curriculum and maintaining fairness in the assessments
3. Management of time with the content, resources for lesson preparations, classroom behavior and engagement when students are working on different tasks for big classes.

Conclusion

Teacher professionals are designers of learning experiences before lesson. However, designing learning experiences without knowledge of the differences in the learning needs of every student is like designing shoes without knowledge of the differences in the shapes and sizes of the human feet. It is, therefore, imperative for all teachers as professionals to be skilful and adaptive in providing differentiated teaching, learning and assessment to meet the diverse needs of students.

While the results of the analysis from the MCE customized online PD course on DI showed promising gains by the 62 teacher participants in both affective and cognitive domains, the sharing by the Team Leaders on common challenges serves as useful inputs to design a future follow-up PD course on Lesson Study as a collaborative action research PLC tool in strengthening the teacher participants' DI practices for instructional excellence.

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Vaccination information sources and decision-making among higher-secondary students in India during the COVID-19 pandemic: a qualitative study

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Vaccination information sources and decision-making among higher-secondary students in India during the COVID-19 pandemic: a qualitative study

Abstract

India's comprehensive Universal Immunization Programme has largely focused on early childhood vaccinations. Studies investigating adolescents' perceptions about vaccination and vaccine-preventable diseases (VPDs) are limited. This study attempts to fill this significant knowledge gap in post-COVID India. 16 students from different socio-economic strata (SES) in grades 9–12 were interviewed to ascertain their knowledge and attitudes regarding vaccinations and VPDs. We particularly focused on understanding vaccination information sources and decision-making among higher-secondary students during the COVID-19 pandemic. The study was carried out just after vaccinations were introduced stage-wise in India for children aged 12–18.

Most students had taken the COVID-19 vaccine, however, vaccine awareness varied significantly. Though students have high trust in their science teachers, they preferred the media over school for vaccination information, since they felt school textbooks provided minimal education on vaccination. They used the criteria of "trust" and "authority" (of the information provider) to assess various media sources. Many students perceived themselves as less-informed and less capable decision-makers than their parents, and allowed parents to make decisions on their behalf. Our observations provide insights into the COVID-19 experiences and concerns of adolescent students and are timely given recent Indian government recommendations on introducing Human Papillomavirus (HPV) vaccines to teenagers. The study highlights the role of science education in connecting students with the relevant scientific background about vaccines and shaping their understanding of public health. This is especially important in the post-truth era where students are susceptible to mis/dis-information associated with vaccines.

Keywords: vaccination, decision-making, information-sources, higher-secondary students

Introduction

Public health (PH) is integral for the growth and prosperity of any nation. Public knowledge and perception about health is directly related to how this topic, interdisciplinary in nature, is presented to students in any education system. This was dramatically tested during the COVID-19 pandemic. In India, the pandemic-enforced lockdowns, consequent disruptions and the rollout of vaccines were heavily discussed and debated during the COVID-19 period. India has the world's highest (21%) adolescent population (~250 million). Yet adolescent immunization has been a rather neglected component of India's Universal Immunization Programme (Verma et al., 2014), with COVID-19 providing a wake-up call. A stagewise rollout of vaccines for adolescents 15-18 years old (Dec. 2021), and subsequently for 12-14 year olds (Mar. 2022) raised several concerns. While it is usually assumed that vaccines are desirable, in spite of the government promoting free vaccines, some people outrightly refused vaccines, others had doubts and some took vaccines reluctantly.

This paper is based on a study of students in high school and senior secondary/junior college (aged ~15-18 years), who were interviewed (Nov. 2022–Mar. 2023) about their knowledge and views on COVID-19 vaccination and decision-making. Students had already decided and acted upon their decision about vaccination before these interviews. This study elucidates how students made decisions based on vaccination information sources accessible/available to them. The pandemic provided a context to understand student assessment of various vaccine information sources and their decision-making processes, and highlights the importance of vaccine education for future generations.

Literature review

Very little has been investigated about high-school students' perceptions and decision-making processes around vaccination, with most studies focused on parental perceptions about vaccination. A study with US teenagers aged 12–15 (Willis et al., 2021) found that only 42% were "not at all hesitant" about getting the COVID-19 vaccination, 22% reported being "little hesitant", 21% were "somewhat hesitant," and 15% were very hesitant. A similar COVID-19 study with school students in England aged 9–18 (Fazel et al., 2021) reported that 50% of students would opt-in for vaccination, 37% were undecided, and 13% would opt out. Students who opted out / were undecided had greater levels of social deprivation and felt less socially connected with their school community compared to those who opted in. A qualitative study (Lundström et al., 2012) on Swedish students' (aged 17-19) justifications for their decision about the then new influenza vaccination showed that students used the categories of “risk, solidarity, family and friends and media”, and not their science education experience. A UK study conducted when HPV vaccination was introduced for adolescents (Hilton et al., 2011) examined knowledge of HPV, its association with cervical cancer, and experiences of HPV vaccination among adolescent schoolgirls. Focus group interviews showed that girls knew very little about HPV, how they could protect themselves from HPV infection, and how long the vaccine would provide protection. The girls’ perception of the importance of HPV vaccination was influenced by recommendations made by trusted people – parents and immunization experts.

Research examining students' evaluation shows that they find assessing information difficult. Students have trouble distinguishing information from evidence, often equating the two (Driver et al.,1996). They tend to accommodate evidence that fits into their prior beliefs (Zeidler et al., 2002). Students’ evaluation of information is also influenced by their personal epistemologies (Hofer et al., 1997). As students move from high school to college, their epistemological thinking shifts from seeing knowledge as absolute and certain to critically evaluating information based on evidence. However, most students fail to reach the state where they can critically engage with the information. Another important factor of students' engagement with evidence is trust (Kolstø, 2001). In a study with high schoolers Kolstø found that students’ evaluation of evidence was based on the credibility of researchers who advanced those claims rather than the claims themselves. Connecting Kolstø’s idea of trust to recent work on vaccine hesitancy (Reiss, 2022), it seems that for most, it is natural to trust people and institutions when discerning vaccine information or for decision-making. However, for some individuals and communities, trust is based on the past association between the trustor and the trustee. In such cases, vaccine hesitancy is not just due to people being ill-informed about vaccines.

Research Questions

The review of literature shows gaps in students' understanding of vaccine information sources and decision-making. Hardly any studies in India have examined vaccine hesitancy in the adolescent high-school age group. This study aims to evaluate how higher-secondary school students make sense of various vaccination information sources and see themselves in the decision-making process.The larger goal is to develop an understanding of the vaccine information needs of students and how these are best addressed through science education. This study explores:

1. Whom did students describe as sources of vaccine information and why?

2. How did it influence their decision-making about vaccination?

Methodology

We interviewed 16 students of grades IX–XII (8 boys, 8 girls, from 3 schools in the state education system, and 2 central board schools). The participants were from the Mumbai M(East) ward, spanning a diverse range of socio-economic groups. Ethics approval was obtained from the Institutional Human Ethics Committee (IHEC) of the Tata Institute of Fundamental Research (TIFR). The students were approached after obtaining permissions from school principals, and subsequently interview dates/times decided in consultation with a coordinating teacher appointed by the school. Parental consent and student assent were also obtained for the study. .

Students were interviewed one-on-one to gain insights into various aspects of vaccination – vaccine knowledge, personal histories of vaccines and VPDs, their experiences, attitudes, and decision-making towards the COVID-19 and other vaccines. This paper focuses on students' vaccination information sources and decision-making during the COVID-19 pandemic. All interviews were conducted within the school premises and were 30–60 minutes long. They were audio-recorded, transcribed and safely secured for data analysis.

At the beginning, students were briefed about the consent process and study aims. Before getting to the main questions, an informal introduction discussing hobbies, likes/dislikes etc. created a relaxing environment and built trust during the interview. The interview questions were semi-structured, followed by open-ended questions as required for clarification. The students' identities are anonymized, with pseudonyms used wherever students' quotes are reported.

Results

After transcribing the interviews (translating into English if required) and coding the transcribed data through several rounds of transcript reading, reoccurring, similar, or related codes were grouped into larger categories with supporting extracts for further analysis (Cresswell, 2012; Cohen et al., 2007; Saldaña, 2016). The data analysis (using MAXQDA24) classifies parents, school, media, healthcare providers, and peers as the most commonly reported vaccine information sources in the students' interviews.

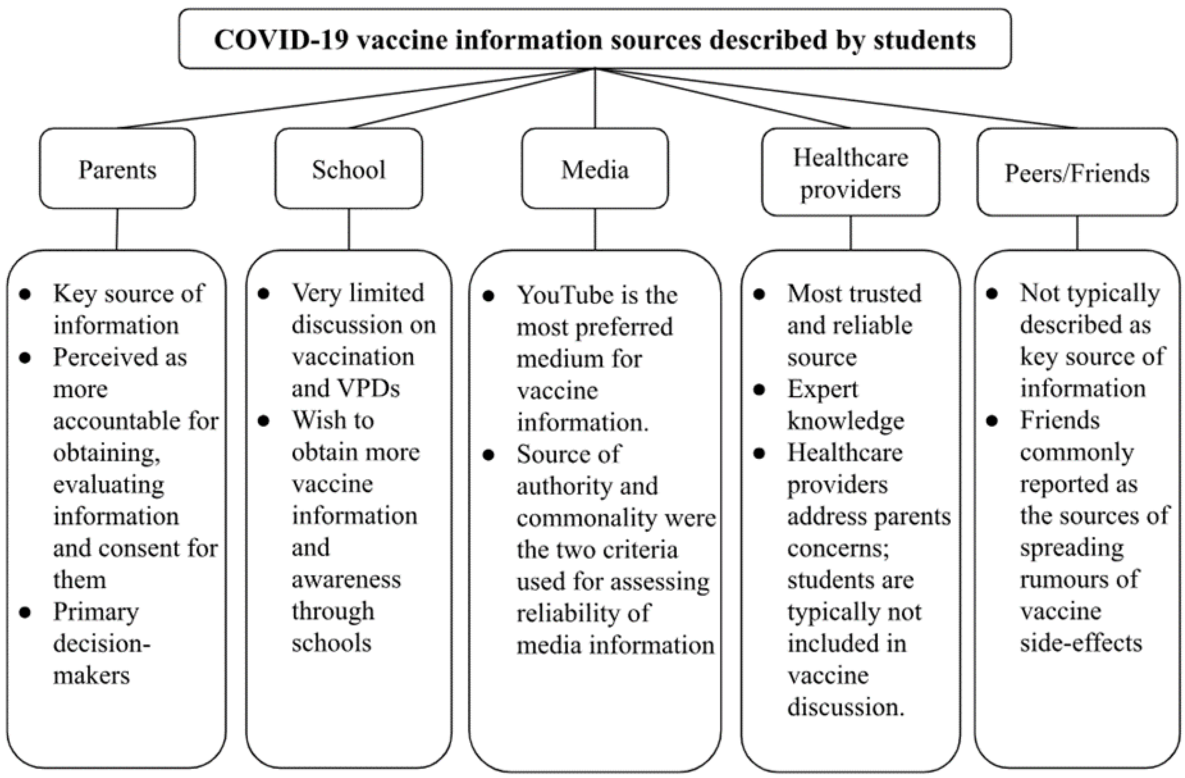

Fig. 1: High-school students' description of vaccine information sources

How are parents viewed?

Most students described their parents as being key informants about vaccine information and decision-making, depending mainly on parents for evaluating vaccine-related information and doing the decision-making for them. Most students felt that vaccine information was directed towards parents and not them. Students viewed their parents to be "more knowledgeable, experienced and accurate" with regards to vaccine information and decision-making. Parents' diverse social circles with different age-groups and varied occupations was thought to be important for gaining and assessing vaccine information.

Excerpt

> *I only heard about babies getting these kinds of vaccines (routine vaccines). So they're very important to the parents… I don't think I'm that intelligent about myself (question on self-consent). And I think my parents are more accountable for what vaccines and shots I get (Trisha: XI)*

Excerpt

> *Like they're more experienced than me plus they are the ones who go around most, like most of the people and I'm just with people my age. So I think their views are more experienced and better than mine. Because my view is between my age group only. Their (parents) friends might be doctors or like more experienced people, old age people... .So their views will be more, much more accurate… (Neha: XII).*

Before the COVID-19 vaccination was made available to adolescents, some students looked up to their parents and other family members as role models who had already taken the vaccines. The students were reassured that since their parents are safe after taking vaccines, they too will likely be safe.

Excerpt

> *I wasn't too scared.... because my father is a frontline worker (police) so he got the vaccine before me.. And they (father's colleague) too were not harmed by the vaccine. Only hand was a little sore. (Prakash: X)*

However, a few students from lower socio-economic groups whose parents were ill informed about vaccines due to low literacy levels or unfamiliar with healthcare language did not rely completely on parents and actively sought information on vaccination.

Excerpt

> *It's not that what our parents say is set in stone, it is not so. We are also 12th class students, even though we do not have that much knowledge about the vaccine, but still we know as much as we can. We ask some things to the biology teacher, common things that they know or would ask doctors (Salim: XII)*

Another student studying in a large public school, says that she motivated and convinced her hesitant parents and her sibling to get vaccinated, showing full charge of her vaccination decision.

Excerpt

> *At first my entire family was reluctant to take the vaccine because there was news on the TVs that it was shortening the lifespan, it is doing many harm like that. I don't remember exactly…, at first my family was reluctant but then I told them it's not like that, vaccines help us against the disease. So then we took the vaccine. (Archana: XII)*

How is the media viewed?

All over the world, print and online media simultaneously kept readers/viewers informed about developments related to the pandemic, but also contributed to the spread of misinformation and fake news. Students assessed the truthfulness of COVID-19 information based on the authority of the presenter of the information. Some students considered official websites and apps as the most reliable sources for finding information while others considered vaccine information provided by medical experts (doctors, scientists etc) on YouTube and news channels as trustworthy.

Excerpt

> *Mmm.. I don't trust that much, but like some websites might be true and news can be true, but also you cannot trust all of them. Some are just... like the one which is reasonable, for example,... like for COVAXIN* (Note: she actually means India's COWIN app) *you have to register in this app. Yes, I trust that website. Yes. I trusted that because it also had information. It was just not for registration. It also had information and the social distance, how to prevent it and all that (Anuradha: IX).*

Excerpt

> *So, I don't believe everything which comes in the newspaper because they're also not sure if they are just assumptions and theories of different people. So I don't believe in that. Well, if something is officially made. I follow a channel and it's a tamil channel and in that they give information which is verified properly with doctors and government (Mohini: XI).*

Excerpt

> *I watched some YouTube videos where they explained about the vaccines and how safe it is…YouTube channels, especially the channels run by doctors (Archana: XII).*

Some students felt that the media did more harm than good. Frequently linking COVID-19 vaccinations to health fatalities like blood clots, cancer, and death only created panic and vaccine scare among them. For some, the media was influential only when it supported a government initiative, such as the promotion of free vaccines for all. Some students were skeptical of some media channels propagating myths and disseminating false information about COVID-19 vaccines.

Excerpt

The media probably did a lot of damage back then. Because I was watching, my parents also used to sit in front of the TV for a long time. Maybe some people died but seeing it repeatedly in the media was having a bad effect on the family members. People were thinking negatively and fear arose in their hearts….they must have suffered a lot due to fear. (Prakash: X)

Excerpt

No, News channels were the ones who encouraged people not to take vaccines. First they showed some random things on the news like someone is dying, someone is getting something, something cancer and all (Archana: XII).

Excerpt

The Internet didn't play a great role; rather they were mostly myths coming from the internet, that it is causing clots and the vaccine is not good for children..(Abhay: XII)

Excerpt

Um, there was a good amount of influence. Yeah, they did influence me, in a negative way I can say at the first time because they were questions like, why are people still getting covid even after getting vaccinated? Although we still know that vaccines do not work right away, we need to give some time and that too COVID was a new disease for everyone, but, showing it like this made me think (Akansha: XI).

However, for some students, social media was the best resource for learning about a specific subject and cross-verifying information. Confirming information provided by doctors with the internet and parents was a method of assessing vaccine information. Others mentioned that the media played a key role in raising awareness about vaccination during the pandemic. A few students eagerly followed the media channels and looked forward to the development of new COVID-19 vaccines.

Excerpt

…we'll go for the proof and the social media because social media is one of the greatest platforms for any knowledge and awareness right now. So we can, for example, a doctor gave me some information about it. So I will go and check it on social media because it is the 21st century and we have a lot of sources. So why not go for more than one

source? We can go for more than one source and then you know, we will be sure about what we are going to do. And of course our family and friends are also aware about stuff, so we must consult everyone (Sabiha: XII).

Excerpt

…I don't have a TV at home, so mostly what I see is in the newspaper. During Covid we didn't have newspapers. So mostly Google news. And I remember,…, I was excited to see when the vaccine is getting discovered…. And about how vaccines work and all, so that was the first time when I came to know how a vaccine is made. I searched YouTube and all..So Covid has raised a certain amount of awareness… (Parikshit: XI)

What students think about school

Most students felt that their schools provided very little education on vaccination, particularly to the younger children and for non-science majors, especially non-biology students (since vaccines were discussed in the 12th-grade biology textbook). Some students said that the school textbooks did not discuss vaccine side-effects. Many students felt that whatever little information on vaccines they had was insufficient to make informed decisions about vaccination. A few students mentioned that even if vaccines were discussed or when vaccination camps were held in school, the healthcare providers mostly addressed parents' concerns, with children not usually included in those discussions.

Excerpt

Vaccine information is not provided so well in schools. It's very little, a lot needs to be provided. Half the people do not pay attention or are not able to (provide) proper information to small children. (Vansh: XI).

Excerpt

I think the school textbook must be modified a bit because it promotes only rote learning in us. So if it's modified… then students will also be able to use this knowledge in daily life applications.. (Archana: XII).

Excerpt

The only education about vaccines is that it is important and without this it can be fatal …In 11th there is no chapter based on vaccines. In 12 there is a small section on vaccines..In ninth and tenth the vaccine topic is not there, but it is said that microbes *help in preparation of vaccines, pathogens and the dead microbes are injected like "vaccine definition" is there but not actually what vaccine is?...and in 12 vaccine is a very small part, it is given that it's memory based, a small part on immunity, (Abhay: XII).*

Excerpt

…if I talk about the NCERT, I don't think they have mentioned anywhere about the working of vaccines till now. I don't know about 12 std…So working of vaccines, mostly we have learned because of COVID. I mean, I've watched videos and youtube and all (Parikshit: XI).

Excerpt

Vaccines are taught only after school, that is college life.…children just do what parents tell me to do. Students' do's and don'ts are decided by parents' instructions whether to do this or not. Children just accept what parents say. And even if there is a meeting regarding all these things, children are not called. Whatever it is, it is discussed with parents (Salim, XII).

Some students also pointed out the vital role of their school teachers in getting vaccinated. A student mentioned the limitations of teachers' knowledge about vaccination as well as time constraints of the teacher not permitting lengthy discussions and the teacher being mindful of not conveying any false information.

Excerpt

Actually schools are not providing that much information…. When we are saying that even the doctors might not provide a certain amount of information, how much will a teacher provide? They already have a lot of things to teach the child and even the children might not pay attention and interest. So it is quite difficult for them to tell every single thing to the kid. And also at that time during Corona, everything was online, the delivery of the knowledge was hard, even the doctors and healthcare were not aware about every single thing, so it is quite difficult for a teacher to know every single thing. And as it's the case with kids, teachers can't pass any news that they're getting because it is quite unsafe, right?(Sabiha, XI)

In a biology classroom, a student recounted an incident where the teacher asked the class about the number of students who had taken COVID-19 vaccines. Only one student raised his hand, and said that he didn't need the vaccine, leading to mockery and hooting in class. The teacher's handling of this incident was not investigated. In retrospect, the incident could have been used to initiate a discussion about vaccination. However, many teachers lack the training and expertise to engage students in a scientific discourse on vaccination. It is crucial for teachers to enable discussions, even when there is dissent, and create an empathetic environment for students to express their views while respecting others in the classroom. Such incidents underscore the importance of teacher training on vaccination education, which could prepare the next generation of parents, teachers, and decision-makers.

Extract

> *Actually at that time, yeah, of course we were talking but not about, vaccines was not a very, very common topic. But yeah, we all knew about vaccines. So in school No. 2 for example, I'm sure most of the people must have gotten the vaccines here also. In the B section, I was in biology class. So ma'am asked during the start… how many of you have gotten the vaccine? So mostly I'll say, around 99% of the class had gotten the vaccine. Only one person, I wouldn't take his name again. He only had not gotten the vaccine, so ma'am asked why, so he said, mujhe zaroorat nahi hai (I don't need it). So, the full class started hooting and all that ooohhh, like that (Pariskhit: XI). .*

How are healthcare workers viewed?

Students considered doctors as the most trustworthy source of information because of their long years of education and training in the field. A few who compared modern doctor's knowledge with practitioners of traditional medicine (Ayurveda) stated that the tools and parameters used by modern doctors are far more rigorous and tested .

Excerpt

> *They are quite influential because they are not someone who just became a doctor within a month or a year. They study so much and they're quite aware about everything that is happening in the surrounding. They know how the thing is working or like to what extent the thing is going to work (Sabiha: XI).*

Excerpt

> *My first priority will be a doctor's prescription because doctors mostly believe in synthetically made tablets, right? So my first priority will be them, like their suggestions because they know more about science. It's my personal opinion, not to offend anyone, but I do think doctors and scientists have more knowledge than ayurvedic doctors*

because they have seen many things in detail like in a microscope, like bacteria under a microscope. They've seen what happens, they know everything in very detail. So, I think we should, we should also believe in ayurveda but we should believe more in doctors and science (Mohini: XI).

However, some students were skeptical and found them indecisive, with some doctors actively discouraging people from taking the COVID-19 test and some believed to be having vested interests. A student noted that, in comparison to doctors, healthcare workers and paramedical health workers such as nurses were more supportive and caring, while doctors' negative attitude towards COVID-19 patients during the pandemic was disturbing. Another crucial factor in vaccine decision-making, is having a doctor as a family member..

Excerpt

Yes, I do trust them (doctors) because they're much more educated than us about these things. Yes, I do trust them…But some doctors that I think are not trustworthy (Anuradha: X).

Excerpt

I have no idea. They (doctors) are kind of not decisive. Some doctors say yes and we are not sure whom to trust. So my mom went and took the test. They said since you have a cold, it'll turn up positive. My father had covid. So we also wanted to get checked if we have that. So we tested but the doctor said No, not to test because it'll turn out positive (Trisha: XI).

Excerpt

So I wouldn't say doctors influenced me, but healthcare workers (did)*, as during COVID, a lot of negative news was heard about doctors…. But the healthcare workers …* (They said) .. *we will help you… when we tested positive, the nurse who was there said, Don't worry, you will get fine in a few days time… like they kept our hopes high. (Jay: XII)*

It was interesting to mention here how two students, with different socioeconomic status and experiences, assessed public and private physicians differently. For instance, Parikshit, a grade XI student in a large public school system catering to children of government employees, feels that unlike public hospitals, private doctors are usually driven by for-profit motives and hence cannot be trusted fully. However, Salim, a XII grade student of a low SES semi-English-Urdu medium school, recalling his previous experience of vaccination campaigns in school, said that in his community, typically government mass initiatives are viewed as unsafe, and they prefer visiting private clinics.

Excerpt

> *…If you go to a private hospital, I will definitely have doubts about whether I should have. If the doctor's recommending this, should I really get that thing done or not? But in government hospitals, mostly, I don't think they'll work for profit. So yeah, that's mostly okay. And I mean, I don't have the exposure of going to hospitals very often because if anything happens, mostly my father only advises (father is a doctor) which thing to take. So mostly dispensary and all (Parikshit: XI).*

Extract

> *Yes, maybe it was the same disease, but I cannot say for sure, there were three types of disease* (referring to MMR-vaccine camp at school). (Doctors) *…had come to provide vaccines for those diseases, and forms were distributed to everyone. Everyone was told to go home, ask their parents, show them the form, give information and all and get it signed. And if there is any doubt then you should come and meet the teacher. At that time, many people refused because there is this belief in us that there is a risk in taking municipality things. Such beliefs are there in our..because of this, the parents of many people refused to take it. If there is really something serious, like if the disease is spreading too much, then we will take it from a private dispensary. (Salim:XII)*

How student view their peers

Friends, or the peer group in or outside school, were not described as key sources of vaccination information. Some said that friends were mostly the source of spreading rumours and fears about vaccine side-effects such as needle pain, fever and fatigue.

Extract

> *My mom was basically calming me down because I thought that if I get the vaccine my hand will go numb and all that because so many of my friends told me that we get fever, we were very ill…we were feeling very weak…my hands were hurting a lot. They were literally scaring me if I say…But then I took it, it was just a pain in my hand. I didn't get any fever and all that (Anuradha: X).*

Extract

Many girls were afraid that after taking the vaccine, we would fall down due to dizziness ….we will get sick by taking the vaccine....(Kritika, IX grade)

Students felt that the pandemic-related lockdowns resulted in minimal interaction with friends as some were away, classes were online and some newly joined the school and didn't have many friends to interact with.

Extract

No, they all had gotten vaccines. but I don't know. But they did not influence me. I was not in contact with them like during the Corona time. (Trisha: XI).

Extract

Not very influential because in Covid period we did not meet and this is the new school for me, so I didn't have many friends either (Archana: XII).

While most reported that many of their peers were vaccinated by the time they returned to the school, some did not get it as their parents were unsure of the vaccine's safety and effectiveness.

Extract

My friends also were not at all skeptical about getting vaccines. They also, almost all of them got vaccines…(Parikshit: XI)

Extract

Even my friends took the vaccination. Some did not take the vaccination due to hesitation…. because they were not assured about it for giving the vaccination to their child (Sabiha: XI).

Extract

Most of them (friends) wanted to take it, but their parents didn't go for vaccination. Because they belong to the old generation, most of them are not educated, so among them there is no good opinion about the vaccine…(Parikshit: X)

Discussion

We seek to understand the different vaccine information sources used by students and how it influenced their vaccination decision-making during the COVID-19 pandemic. Understanding this is crucial in informing future adolescent vaccination campaigns as well as fostering scientific literacy in the high-school population, especially as new vaccines are being introduced for this age group.

The findings suggest that students considered parents and doctors to be the most trustworthy source of vaccine information. Lower SES students demonstrated more agency both in seeking vaccine information and in decision-making, echoing some previous studies (Garcia, et, al., 2021; Zeraiq, et. al., 2015). Most students wanted to know the science behind vaccines and VPDs. Students wished to obtain detailed vaccine information through schools and would like healthcare providers to address their concerns as well. This is particularly true for vaccines like HPV, where most children were clueless about the nature of the disease and the associated risks. Students, particularly those having parents with lower literacy and in families with limited access to medical facilities, viewed school and science/biology teachers and healthcare providers as more credible sources of information. These findings mirror earlier research with South-African teens who relied more on school teachers and doctors to get vaccine information (Zipursky, et al., 2010). Some students felt that even if they were part of the vaccination discussion, they could not meaningfully participate as the information was mostly directed towards parents, highlighting the need to provide adolescent-friendly vaccine information.

Due to the lack of vaccination education in schools, students frequently relied on the media to obtain vaccine information. YouTube was the most preferred source, with videos having doctors as resource persons thought to be most reliable. Students judged media channels based on credibility, with official channels and those featuring doctors and scientists seen as trustworthy, while private channels often propagated myths about COVID-19 vaccines. Students referred to multiple sources of vaccine information but did not elaborate on how they triangulated media information with other sources. Students typically used corroboration as a criteria for assessing the vaccine information where they looked for claims that all the sources agree upon. A study with Irish teens had also noted that students were unaware of specific websites for trustworthy vaccine information (Marshall, et al., 2019).

Finally, friends were surprisingly described as the least reliable source of vaccine information. Most students viewed their friends as inexperienced and less informed, just like them. Friends were rarely viewed as motivators for vaccine uptake; rather most were described as scaremongers. Previous studies have also reported that students felt that peers frequently exaggerate stories of vaccination pain and needles (Hilton, et al., 2013). However, a few studies have reported positive influence of friends in vaccine uptake (Marshall, et al., 2019; Lundström, et al., 2012).

Conclusion

The students' interviews reveal that their assessment of various media information sources was largely based on the criteria of “trust” and “authority" presenting the vaccine information. Students’ perceptions of themselves as less-informed and less capable decision-makers is concerning as they will become the next generation of adult citizens. Students struggled to actively gather vaccine information and participate in decision-making due to limited engagement with vaccination topics in school science textbooks. Though they believe school to be the appropriate place to learn about vaccines, they are compelled to obtain vaccine information from the media. Creating adolescent-friendly content and addressing students' concerns could make decision-making more participatory, enabling students' smooth transition from passive to active decision-makers.

The vaccination scares during the pandemic show just how important vaccine education in schools is. Especially since students have high trust in their science teachers, teacher training in these areas is essential for preparing the next generation of decision-makers. While there is no dearth of vaccine information available outside school, laying its foundation in the school curriculum, connecting students with the relevant scientific background would create safe learning spaces even for those who refuse or have doubts about vaccines. High-quality vaccination education is a must in the post-COVID era, where students are more susceptible to misinformation and disinformation associated with vaccines.

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Is Science Really for All? Investigating Learner Engagement and Equity in a Design Thinking Task

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Abstract

Despite the emphasis on using a multidisciplinary STEAM (Science, Technology, Engineering, Agri-Fisheries, and Mathematics) approach in teaching science in various countries, the Department of Education (DepEd) does not explicitly include engineering in Philippine basic education. This is even though there is an emerging argument in the community of science education researchers that emphasizes the need to engage learners in the engineering process. This study investigates non-STEM learners' engagement in science and engineering practice (SEPs) and power relations in a design thinking-based instructional unit in physics. Engaging in design thinking collaboratively allows learners to participate in engineering practices within their sociocultural contexts, facilitated by interactions with peers. This research employed ethnography vis-à-vis discourse analysis to know how the learners engaged in the eight practices and how power is socially constructed inside the classroom through the multimodal interaction analysis (MIA). The research findings suggest that non-STEM did not manifest SEPs as expected in the stipulations in the Next Generation Science Standards (NGSS). Interestingly, they used their sociocultural backgrounds as leverage to do their design solutions. The role of gender and academic status were seen as the main factors affecting the social interaction and power relations between the two groups.

Keywords: design thinking; engagement; power relations; equity; non-STEM learners

Although there are moves to reinforce the Philippine STEAM education (Anito & Morales, 2019; Sarmiento et al., 2020), efforts are more evident in higher education institutions (HEIs) in comparison with DepEd. Aside from including STEM, with the exclusion of “A,” as a senior high school (SHS) track, DepEd does not provide explicit recommendations to implement STEM-based approaches at the classroom level. The design of the curriculum mainly deals with STEAM as fragments and separate entities without requiring learners to develop cross-cutting concepts and sensemaking skills in these disciplines. Hence, there are calls to deliver STEM education as a holistic and interdisciplinary approach that will provide more opportunities for learners to create and innovate (NRC, 2012; Lesseig et al., 2017). Current research provides varying models on how we should go about this approach, but among these, an emerging consensus highlights the infusion of the engineering design in the basic education curriculum (Berland et al., 2014; Chabalengula et al., 2016; Han & Shim, 2019; Katehi et al., 2009; Mesutoglu & Baran, 2020; Peterman et al., 2017).

Unfortunately, in the Philippines, most science education studies focus on developing inquiry-based learning (Abaniel, 2021; Lubiano & Magpantay, 2021; Tecson et al., 2021), leaving engineering practices (EP) behind, notwithstanding the argument of NRC (2012), “engagement in the practices of engineering design is as much a part of learning science as engagement in the practices of science” (p. 12). Aside from this, in the 2022 Global Innovation Index (GII), the Philippines ranked 59th out of 132 countries in innovation performance, lagging behind its Southeast Asian counterparts like Singapore (7th), Thailand (43rd), and Viet Nam (48th) (World Intellectual Property Organization, 2022). A factor for these two problems might be the lack of explicit inclusion of engineering design and innovation, an essential skill for innovation and product development, in basic education.

In this paper, we provide a brief overview of engagement and equity in science learning, and design thinking (DT) as a pedagogical tool in teaching physics, using the sociocultural perspective of learning. We examined learner engagement in SEPs and equity through their intragroup power dynamics in a DT-based teaching unit on two-dimensional (2D) motion, employing multimodal interaction analysis (MIL). Two groups, namely the yellow group (YG) and the pink group (PG), emerged as the focal points of this study. The findings are presented with transcripts showing the interaction among the learners as they engage in the activity. Finally, we provide discussions and implications for the new K-10 MATATAG science curriculum, teacher training, and professional development.

Equity and Social Justice in STEM Education

Central to the goals of STEM education is to create equitable learning opportunities that can increase the engagement of learners from non-STEM-inclined (those who do not identify themselves with the STEM disciplines) population (Matuk et al., 2021) regardless of their ethnic, cultural, linguistic, socioeconomic, and gender backgrounds (NRC, 2012). Understanding them and using their ideas, which are co-constructed through their embodied experiences, in designing and implementing instructional moves follows the principled reasoning about the problems in the teaching practice (Mikeska et al., 2009).

In the microlevel understanding of equity, it is important to emphasize that the classroom must always uphold social justice. This provides that educational equity is both a goal and a process that stakeholders must facilitate (Patterson, 2019). Collaborative work facilitates cognition nested in a group activity where each member participates and contributes through discourse (Matusov, 1996) but their thinking is considered as just one entity rather than separate (individual) entities (Talaue et al., 2015). Unfortunately, inequity can arise during collaborative work. Some learners experience difficulty in constructing better arguments because of two reasons: (a) they accept ideas without careful and critical evaluation, and (b) they are reluctant to critique the presentation of other groups (Patterson, 2019).

Local research on enhancing skills and competencies in science often focuses on learners who have already chosen to specialize in STEM (either in basic or tertiary education) (e.g., Abaniel, 2021; Absin-Pagara et al., 2017; Carvajal & Lagunzad, 2021; Dacumos, 2021) if not regular basic education students. This undermines a social justice tension in the Philippine science education landscape --- is science exclusive for the people of science? This can be deemed as a form of academic discrimination. Science is not being made available to all but to an elite few (STEM students and/or specialists). As stated, if we want to make ***science for all***, we must be intentional in making it accessible and available to everyone, including non-STEM students.

Learner Engagement as seen in a Sociocultural Perspective

To do this, we need to engage learners in SEPs. Engagement refers to “learners’ identification and participation in disciplinary practices” (Matuk et al., 2021, p. 3). However, in research, engagement is a complex and multifaceted concept that must be operationalized. Wang et al. (2020) identified four characteristics that demarcate engagement from other educational constructs. These are: (a) engagement is multidimensional, (b) engagement and disengagement are not in the same continuum, (c) engagement is multilevel, and (d) engagement is malleable.

Engagement must be seen as the result of the ongoing interaction between learners and their context. Christenson et al. (2012) posit that learner engagement is heavily influenced by sociocultural factors, making it context-dependent and identity-responsive. It is also shaped by classroom processes, especially when tasks are challenging, relatable (or something they can identify themselves with), and authentic (Marks, 2000). As engagement is seen as a proximal process based on ecological models (Bronfenbrenner, 1996). Wang et al. (2020) emphasize that “a child’s characteristics (e.g., sociodemographic, self-efficacy) can determine whether adaptive or maladaptive proximal processes occur and how a child experiences their contexts” (p. 118). A more comprehensive study can be done when the multidimensionality, nature, levels, and malleability of engagement are considered, most especially when these are analyzed through a lens that investigates the social, historical, and cultural context that the learners are dealing with.

As this paper is grounded on sociocultural perspectives of learning and doing, learning science must be seen as an embodied, collective, and situated practice (Wilmes & Siry, 2021) that arises from interactions of learners utilizing an array of semiotic resources (e.g., prior experiences and cultural practices) (Jaipal, 2010). As these resources are permeated by meanings co-constructed and reshaped in the past, new meanings might emerge, which can be reshaped over a period of time (Bakhurst, 2018).

Design Thinking in STEM Learning

As this research project embarked on a journey with the tagline “science for all”, ultimately, there is a need to look at the beneficiaries of science and engineering. Brenner and colleagues (2016) argue that DT “starts with human needs and uses suitable technologies with the aim of creating entrepreneurial value through customer value” (p. 6). If the end includes all humans reaping the benefits of science, the means must also necessitate the “human” factor. As stated, DT must be founded on the needs of humans to create creative innovations and feasible solutions. A rigorous examination of the rationale underlying the cultivation of a culture of design thinking within STEM education is essential, as it directly correlates with enhanced problem-solving skills, innovation capacity, interdisciplinary collaboration, and adaptability to emerging technological challenges and opportunities within the STEM disciplines. Grots and Creuznacher (2016) distinguish five characteristics of a DT culture.

The Hasso Plattner Institute of Design (or d.school) at Stanford University (2020) developed a design process model that consists of five iterative, non-linear stages (empathize, define, ideate, prototype, and test) represented by hexagons to emphasize that each stage is seen as a mode of thinking rather than just being linear steps (Dam & Siang, 2020).

Research Questions

This study aims to use a design thinking approach in task design in the teaching of science, especially in Physics, in local science classrooms. Specifically, the study aims to address the following research questions:

1. How does a design thinking-based task engage twelfth-grade non-STEM learners in science and engineering practices in a design thinking-based challenge in mechanics?
2. How does a design thinking-based lesson mediate power relations among twelfth-grade non-STEM learners?

Research Design

This ethnographic research project was conducted in a public high school in Valenzuela, Philippines. It is an urbanized city in the National Capital Region, Philippines. There are thirty (30) Grade 12 students under the General Academic Strand (GAS) under General Physics 1 (Science Elective for GAS) who served as the participants of the study.

This is the first time they have experienced face-to-face classes (F2F) after two years of distance learning during the height of the pandemic. On average, these learners came from low-income families who suffered financially more so due to the pandemic. There was also a spike in the rate of teenage pregnancy during this time, so there are learners who had to earn their keep to provide for their new family. Some are irregular learners with failed subjects during their previous years, but most of them are regular students.

The DT lesson was observed as a learning activity for the unit on 2D motion. This activity was a part of their regular session where a unit lasted for a week --- three sessions with an hour and forty-five minutes each.

A ten-minute YouTube video (AHA! Meet the Tipas Baseball Kids) was shown at the beginning of the lesson for the empathize phase. The video depicts the "Tipas Baseball Kids," a group of passionate but underprivileged children who want to play baseball despite the lack of equipment and training facilities. They watched, listened to, and observed the context of the children to develop an appropriate product that will be able to help them in practicing baseball. They were only allowed to use recycled materials for their project to lessen the cost, considering the socioeconomic situation of most of the learners. They used post-its and their boards to define what is really needed as a solution. Then, they were able to edit, comment, and reflect on their initial solutions through collaborative work and brainstorming. After that, they developed a prototype based on their chosen solution and tested it. Here, they were able to go back to the prototype phase or even the ideate phase when they fail to achieve their goal.

Data Analysis

Discourse analysis was utilized vis-à-vis ethnography. Discourse provides the contextualized interaction in sociocultural practices among the social actors (Kelly, 2021). This allows the researchers to see how these events were generated through the actions of the learners and their interaction with their peers. This study employed the multimodal interaction analysis (MIA). This technique allows the researchers to use a resource-rich lens in understanding the complexities of social interactions in science in analyzing social interaction (Wilmes & Siry, 2021). Yeo and Nielsen (2020) assert that learning in a science classroom is multimodal as ideas are presented in different modes of representations such as mathematical and scientific models, drawings, language, and pictures.

At each episode of the implementation of the lesson, the following were encoded: time, embodied engagement (actions), video offprints (pictures), and utterances (language). The four steps taken by Wilmes and Siry (2021) in using MIA was followed in this research project: (a) detailing the instructional context; (b) video viewing without the sound; (c) selection of the focus of analysis; and (d) considering verbal information.

The transcription key (see Table 1) adapted from Wieselmann and colleagues (2021) was used in this study. For the purposes of this research and better reporting, all transcriptions were translated in English.

Table 1. The Transcription Key adapted from Wieselmann and colleagues (2021)

Symbol	Meaning	Example
[	Open brackets mean overlapping speech	It's cheap. [I think [It's just fifteen pesos.
()	Parentheses mean silence; timed in tenths of seconds as indicated by a period inside the parentheses	millimeter (.) centimeter (.) decimeter (.) meter. How many inches is that?
↑	An arrow going up mean rising intonation	I agree↑
?	Question mark indicates a rising intonation corresponding to a question	What do I need to learn to do the task?
.	A period indicate a falling intonation	Stop bothering him.
°	Degree signs mean lower volume	°Yeah! Just write it there.°
ALL CAPITAL LETTERS	All capital letters mean higher volume	Angela, REACH! Write reach.
:	Colons mean sound stretch	key concerns:::
______	Underlining word(s) means emphasis	IT'S 42!
(( ))	Double parentheses indicate description of speech	That's wrong ((pertaining to the worksheet)).
( )	Single parentheses with words inside indicate doubtful transcription	(inaudible)
(cuss)	Foul languages	It's basic (cuss).

Findings

To illustrate how learners' dynamics work in a design-thinking task, we focused on two groups (their group names were based on the color they chose) which are YG and PG. These groups were chosen as the focal cases for three reasons. First, their composition is different, with the YG being more diverse than the other in terms of gender and sociocultural background. Second, PG did not achieve the goal with their solution while YG succeeded. Third, they vary in terms of preparation and idea development.

Learner Engagement in a Design Thinking Task

In this section, we provide evidence of how these practices manifested (or not) as aligned with the eight SEPs and how the learners engaged in the task through their epistemological understanding and resources. The summary of observed SEPs in both groups is presented in Table 2. However, in this paper, we opted to highlight the evidence for SEP 1 and 3 because of two reasons: (1) the sociocultural context of the learners engendered their intragroup interactions, and (2) the learners exhibited the ways how they were able to course through a DT-based activity despite their non-STEM background.

Table 2. Observed SEPs in YG and Table 2. PG in a Design Thinking Challenge in Mechanics

SEPs		YG	PG
1	Asking Questions and Defining Problems	They were able to identify the overarching goal and ask relevant questions regarding the design (surface level).	The practice was not evident.
2	Developing and Using Models	They were able to develop a scientific model involving projectile motion but was lacking in a sophisticated engineering model.	They were able to specify rudimentary measurements but did not have a scientific model that can explain how their design will work.

SEPs		YG	PG
3	Planning and Carrying Out Investigations	Both groups conducted “informal” tests which they use as a basis for any of the two remarks: success or failure.	
4	Analyzing and Interpreting Data	There was no evidence of the learners participating in the analysis and interpretation of data.	
5	Using Mathematics and Computational Thinking	Their engagement in this practice was limited to estimation, unit conversion, and basic geometry concepts.	They measured the materials to find the best point in connecting the wooden plank and pole.
6	Constructing Explanations and Designing Solutions	They were able satisfy the first success criteria and apply scientific concepts.	They were able to modify their work but were unsuccessful in achieving the goal.
7	Engaging in Argument from Evidence	Their arguments were based on their experiences interacting with the materials rather than quantified data and measurements.	
8	Obtaining, Evaluating and Communicating Information	There was not enough evidence of learners interacting with scientific and technical text in any form.	

SEP 1: Asking Questions and Defining Problems

After doing WS1, the entire class convened for a whole-class discussion. The teacher asked about the needs of the end-user in this scenario. As the Tipas Baseball Kids have already received baseball bats and gloves from the program, the groups must articulate what else they can use in their training. YG was describe the task's required equipment – the pitching machine, however, they were not familiar with its proper name. Roger described the machine as something "which fires the ball." YG was able to identify the overarching goal of the design task which is to make a pitching machine that will help the kids refine their skills in playing baseball. This indicates the beginning of defining a design problem that would lead to developing a system with criteria and constraints.

Table 3. Excerpt 1 from the discourse of YG while doing WS3

Line	Speaker	Statement
1	Pat	(Cuss) We always play with this when I was a child (…) The tube must be big enough for the ball to pass through.
2	Mark	How about the angle?
3	Pat	Angle? It's just straight.
4	Mark	I mean where will the batter stand?
5	Pat	Like this ((drawing the batter)) and here's his bat.

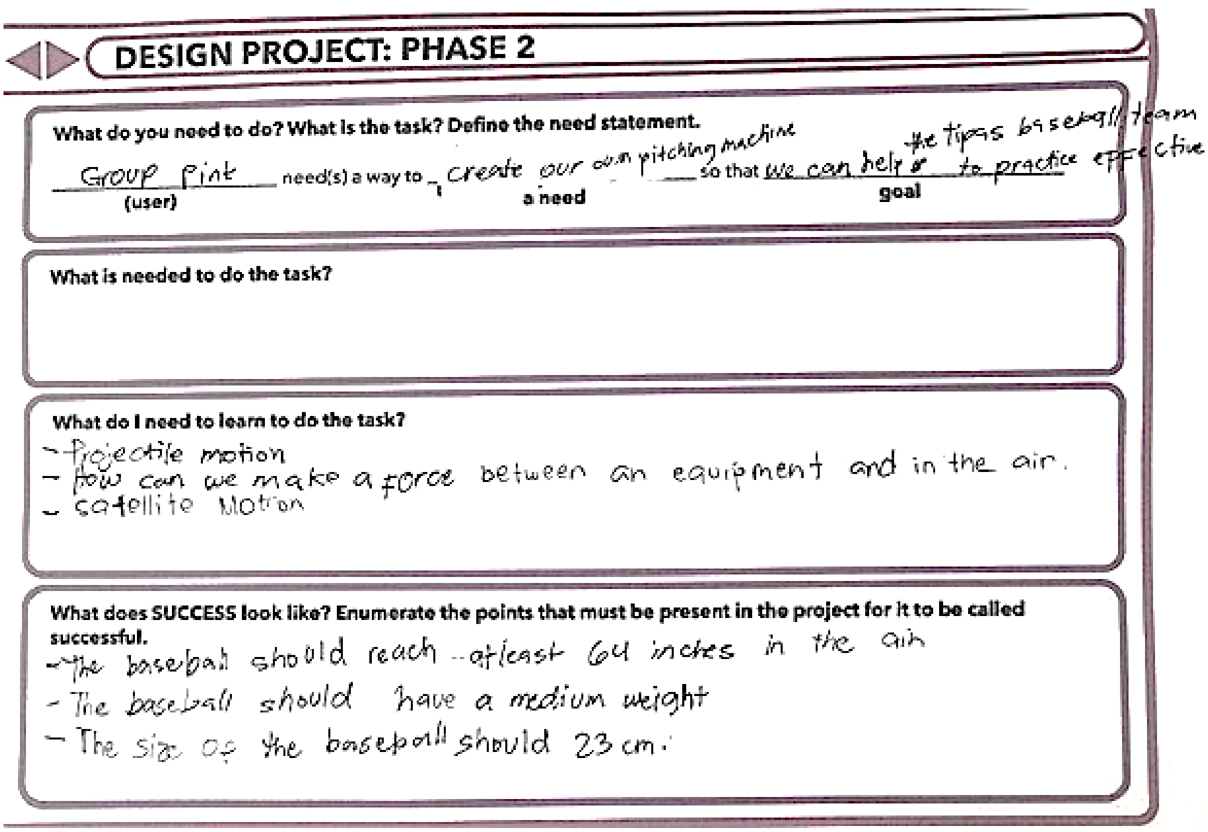
In Excerpt 1, they were asked relevant questions to determine the relationship between quantities. In line 2, Mark asked about the angle at which the pitching machine would fire. As angles are important in finding the maximum height in projectile motion, they thought this must be defined for a proper solution. However, Pat could not understand the term "angle" in this context. He thought Mark pertained to the path or trajectory of the projectile.

Mark asked where the batter would stand with respect to the machine. In this case, they exhibited the first practice again by asking specific questions relevant to the design. Essentially, they asked about the distance between the batter and the pitching machine. However, no quantities were uttered or estimated. This can be due to the non-STEM nature of the learners. The immediate response was to visualize rather than to quantify. However, in the sketch, they estimated a distance of 5 meters between the machine and the batter. This is, again, based on Pat's idea.

The first NGSS practice focuses on asking questions about natural phenomena, texts, and relevant information. This also involves defining the problem to be solved and eliciting ideas to identify the parameters and specifications for the design solution (NGSS Lead States, 2013) as evident in Excerpt 1.

There was limited evidence for PG that they could articulate the problem by asking questions. WS1 was accomplished with Joshua writing everything on his own and other members just looking at him do the work. His group mates did not contribute except when Andrei had to write his ideas.

Figure 1. PG's responses to WS2 (Define Phase)


DESIGN PROJECT: PHASE 2

What do you need to do? What is the task? Define the need statement.

Group Pink need(s) a way to create our own pitching machine so that we can help the tipas baseball team to practice effective
(user) a need goal

What is needed to do the task?

What do I need to learn to do the task?
- Projectile motion
- how can we make a force between an equipment and in the air.
- satellite Motion

What does SUCCESS look like? Enumerate the points that must be present in the project for it to be called successful.
- The baseball should reach atleast 64 inches in the air
- The baseball should have a medium weight
- The size of the baseball should 23 cm.

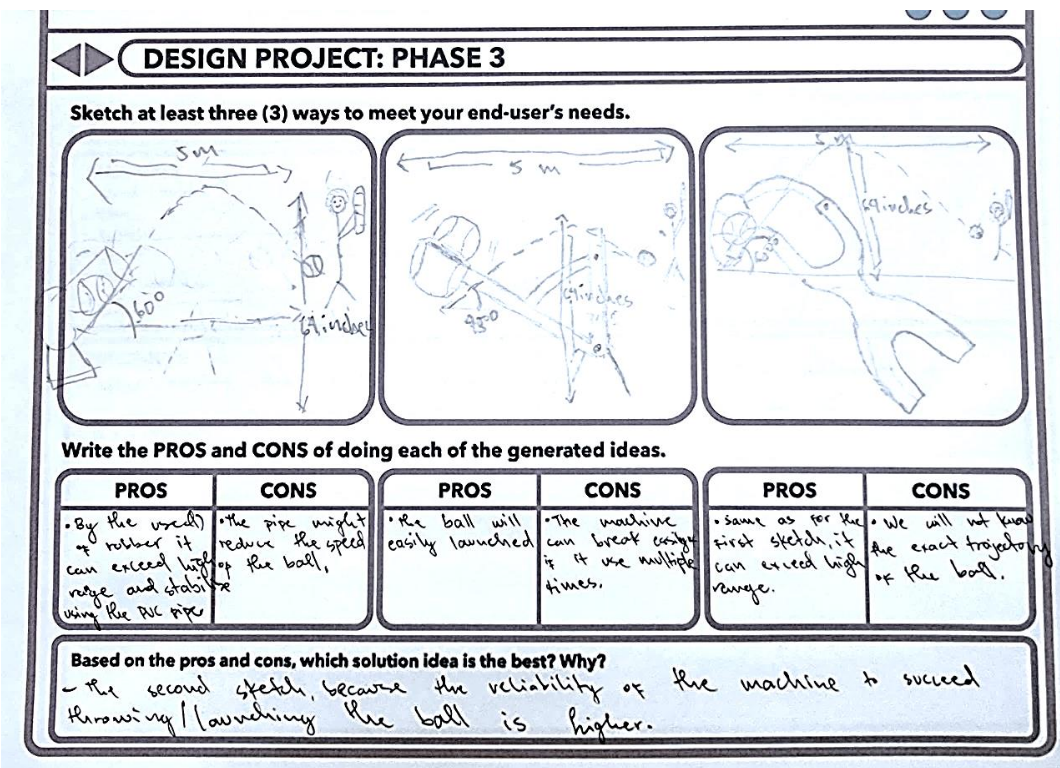
Joshua thought that he just needed to write something down for the size and weight of the pitching machine. By guessing the size and vaguely estimating the weight of the design solution, they could not identify constraints as informed by various considerations (e.g., technical and environmental).

Essentially, neither group could identify definite and testable success criteria that are bounded by different considerations except for the one required in the task, which is to make the ball reach 64 inches midair.

SEP 2: Planning and Carrying Out Investigations

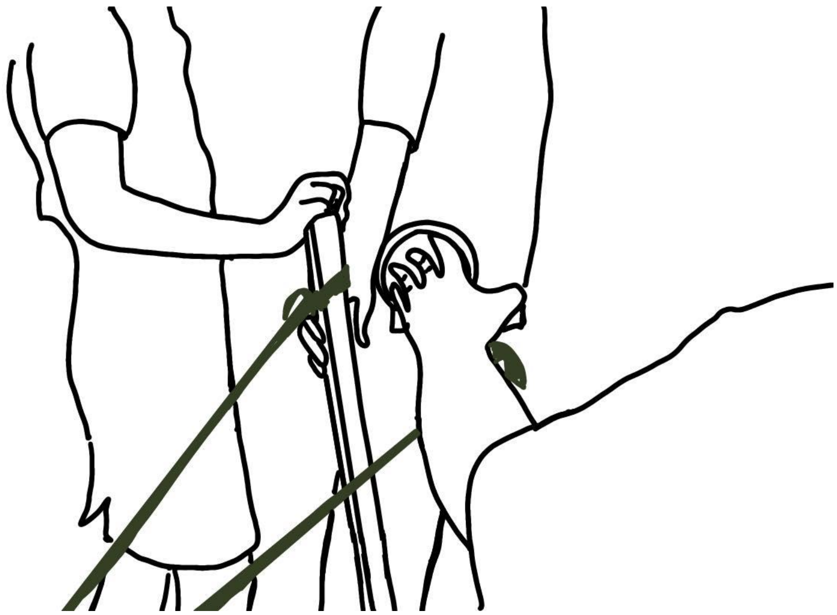
The YG was able to choose and carry out the best solution based on their own perspective after analyzing the pros and cons of each possible solution. In excerpt 4, they were planning how to carry out the catapult design (design number 2; see Figure 3). They were thinking about how to actualize their sketch using various materials. While doing so, Shaina kept on asking (Practice 1) about the parts that Pat and Roger visualize without having to discuss.

Figure 2. YG's responses to WS3 (Ideate Phase)



They thought of using cup noodles as the ball holder. There was an instance where they had been specific on which brand of cup noodles to use. They thought of using a plastic one (Lucky Me) instead of a carton (Nissin) for structural integrity. Shaina activated an epistemological resource as she described the Lucky Me cup as the one that is being used in households as a drinking cup.

Figure 3. Janine, Regine, and Dino hold the wooden pole as they test their initial prototype.



For PG, they tested their initial design three times. When they were testing it, Janine, Regine, and Dino had to hold the wooden poles because those were not sturdy enough to withstand the force brought by the stretching of the rubber (see Figure 8). In their trials, only one trial got a successful result. They decided on changing the design for two reasons: unreliability and instability. Each test, in most cases, led to (a) design changes or enforcement or (b) social interaction which then led to immediate design changes.

Power Relations and Dynamics in a DT Task

As there is an issue of inequity for diverse groups in science classrooms, we investigated how their social interactions, affected by various factors, establish equity and social justice in their intragroup activity. In turn, this can provide us with suggestions on how their successes or failures may be attributed to their positions in the group. YG and PG exhibited polar dynamics in terms of engagement in a design thinking task. Having discussed the success of the YG in comparison with PG in the previous section, we find it interesting to discuss the power dynamics between the two groups.

Gender Roles in YG

YG is a mixed-gender group where there was an obvious power gain for the male learners towards the end of the activity. When working on WS1 and 2, the power lies with Shaina, Angela, and Mark. In these instances, Shaina led the discussion in answering the worksheets and initially took the responsibility of writing the answers. She listens to her peers' responses but was quite stern in following her own thoughts.

In Excerpt 2, they were arguing on what to write as an answer to the question: "What are the key concerns?"

Table 3. Excerpt 2 from the discourse of YG while doing WS3

Line	Speaker	Statement
1	Shaina	What's the concern?
2	Roger	Ah. The concern:::
3	Shaina	Children's wish?
4	Roger	[The safety::: player safety:::
5	Shaina	To have:::
6	Angela	((imitating))To have:::
7	Shaina	No↑ Safety was not mentioned in the video! The concern was for their dream to happen.
8	Mark	I agree↑
9	Roger	[(cuss)! The reason why they were given proper equipment and…
10	Mark	[Yeah, I agree. He has a point.
11	Shaina	The children's wish to be… uh… to be granted… which is to have proper equipment in playing baseball for their safety.
12	Roger	°Yeah! Just write it there.°

In this excerpt, Shaina was facilitating the group to construct an answer to the question. As Shaina uses paralanguage to assert her position of validating her classmates' responses and Angela continuously supporting Shaina's statements through reiteration, they were able to hold a higher authority in the conversation compared to their classmates. However, it took turn when Roger suggested adding the idea of "players' safety" in the answer. Initially, Shaina, in Line 7, refuted this suggestion but Roger, in Line 9, answered back. Note that in many instances of this study, learners uttered many insults (e.g., stupid) and swear words, but no one seems to take offense at these words. In the sociocultural context of these learners, they deem those kinds of words as an expression without an intention to offend. Mark supported Roger's assertion about the inclusion of "players' safety" in the answer. That's when Shaina accepted the answer.

Table 3. Excerpt 2 from the discourse of YG in Phase 3 where Pat and Roger were seen as an authority in constructing and designing the prototype

Line	Speaker	Statement
1	Pat	It can fit! The cup noodle is bigger [than this ball].
2	Shaina	So we'll use the plastic noodle cup?
3	Pat	Yeah.
4	Carlo	[The Nissin cup is the big one::
5	Shaina	[How are we going to put that here?
6	Pat	It's basic (cuss). We worked as a carpenter before ((pointing to Roger)). It will fit.

During the ideate phase where they need to develop the three possible design solutions for the activity, the authority now shifted to the male peers, especially to Pat and Roger. Mark and Shaina asked them how the design would look like. They were seen as authority as they activate their sociocultural resources to add into the discussion. It was further established by the utterance in Line 6. Since they were planning to construct something, Pat said that Roger and he worked as carpenters before (implicitly stating their estimation skills). This premise served as a support to his claim that the ball will fit inside the cup.

During the prototyping and testing phase, the males were in full control of the flow of the group since it involves construction. These results are in agreement with Wieselmann (2019). She found out that girls were more active in the initial phase where boys demonstrated off-task behavior more frequently. Then, during the construction phase, the boys became more engaged in using the physical materials. In this study, the power naturally shifted to the male members as they had experience of working with the materials they used.

Centering the Power on the "Achiever" in PG

As introduced, Joshua was known in the class as a student achiever. It was apparent that he withheld the power in the group for all the phases of the activity. In Figure 11, it can be seen that Joshua was in-charge of answering the worksheet whereas his peers were just looking at him and his answers and agreeing without any refutations except for Andrei who was using his cellphone for an off-task activity.

When asked about who contributed the most to the group work, Joshua answered:

> **JOSHUA:** Me, because I always remind them of what we are going to do and tell them what the plans and preparations are that we are going to make for us to be successful in our task. Moreover, most of the ideas and effort are from me, including the preparation of materials, answers to our questions, and the design itself.

Figure 4. PG answering WS1 (L-R: Andrei, Regine, Dino, Marie, Janine, and Joshua)

As he withheld the power within the group, he was seen as an apparent leader without any official appointment. He was responsible for dividing tasks according to his classmates' skills and availability. However, what's interesting in Joshua's perspective is that he felt like the female members were unfair because they were not given tasks enough fitting for their "gender." He identified the construction of the prototype as "men's work." This mindset might have kept him hold the power as he saw that he needed to be responsible because he is a man, and the job is masculine in nature. This mindset was aligned with the thinking of his classmates. The male members thought that they contributed more than their women counterparts.

Essentially, in PG, the power dynamics were affected by academic status and gender profile. These results were in line with Cohen's (1994) assertion that "academic status is the most powerful of the status characteristics in the classroom because of its obvious relevance to classroom activities" (p. 23). Furthermore, she discussed that differences in social status, such as gender, affects social interaction between learners.

Discussion

This study contributes to the scarce literature in integrating EDP in the Philippine basic education curriculum. This research proves to be more relevant and significant especially in the current state of the K-to-10 where a new curriculum will be implemented. In the new science curriculum, aligned with the DepEd MATATAG agenda, one of the salient features that differs from previous ones is the focus on technology and engineering literacy that aims to allow learners to make meaningful connections between the content and the technological and engineering applications in real-world contexts.

One of the problems that was encountered is the multidisciplinary nature of EDP. While the target is to apply science concepts into real-world problems, EDP is still inseparable from mathematical and technological applications. Hence, learners must be equipped with skills and tools from STEM subjects to produce innovative solutions. Such can be done through focus group discussions (FGDs) and learning action cells (LACs) sessions. For pre-service teachers, HEIs might refocus their degree programs towards the teaching of STEM rather than just having separate specializations in science.

The fragmented view of STEM in basic education manifested in the results of this study. As seen, the learners, even though they are non-STEM, did not exhibit scientific and engineering practice as provided in the NGSS. Unfortunately, evidence from this study suggests that their engagement in the activity is founded almost entirely by their sociocultural background rather than their conceptual and procedural epistemologies in science. These problems, if not cured immediately, may cause bigger problems in macroscale such as scientific misinformation. An example of this would be how many internet users gave their own opinions online on how to fight COVID-19 without any support or evidence from legitimate scientific sources.

In doing so, we must break the barrier brought by several factors such as gender and academic status, as seen in this study. These factors polarize our learners into being powerful and powerless inside the classroom. Those who were deemed powerless will be marginalized and void of opportunities while those who are powerful will gain more. This is the reason why we should start looking at equitable science teaching that will provide learners with opportunities based on their necessity. Addressing inequity and social injustice inside the classroom will allow the learners to feel safe, which in turn facilitates learning.

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Science Education and Economic Growth from the late 1940s to the early 1970s:

A Case Study of Japan

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Science Education and Economic Growth from the late 1940s to the early 1970s: A Case Study of Japan

Abstract

Between the late 1950s and the early 1970s, Japan went from a devastating defeat in World War II to achieving rapid economic growth; this is known as the “Japanese miracle.” This study investigates the relationship between science education and economic growth in Japan by exploring the following research questions: (1) how is science education connected to economic growth and (2) who took the initiative to develop the country’s science education framework? Japanese students have achieved high scores in international comparisons since the 1960s. Although the recommendations of the United States Education Mission to Japan held a major influence, domestic factors also played a role. Japan’s government regarded education, especially science and technology education, as a vehicle for promoting industry and building a cultured nation. Based on demands from the business community and a recommendation by the Central Council for Education, the Ministry of Education published a white paper on Japan’s growth and education, which stated that education had contributed to achieving the modernization and economic growth in Japan that began in the mid-19th century, emphasizing the importance of investing in education to address social needs. Starting in the 1950s, the business community also issued several policy statements on education. During this decade and the first half of the 1960s, a focus on human resource development in the fields of science and technology appeared, represented by the expansion of vocational secondary schools and higher institutes. Although Japan’s government organized the Liberal and Democratic Party to take the obvious initiative to develop education, there were also strong demands from the business community. The ideas of the government and the business community were based on the theory of human capital, viewing education as something that benefited the nation, rather than the individual well-being. Understanding the history of science education can provide insight into the post-truth era. Consequently, we can conclude that, if we aim to improve scientific literacy for all Japanese, there is a need to emphasize the benefits of science education on individual well-being.

Keywords: science education (*rika*); economic growth; politics

Introduction–background and research questions

During World War II (WWII), which was also a war of science and technology, Japan was completely defeated, being reduced to scorched earth. After occupation by the Allied Powers, led by the United States (US), Japan became an independent country in 1952 under the San Francisco Peace Treaty. Thereafter, under the political situation called the “1955 system” (Masumi, 1988), Japan achieved remarkable economic growth that is called the “Japanese miracle” (Johnson, 1982). In 1968, Japan’s nominal gross domestic product (GDP, and gross national product at that time) was the second highest in the world, surpassed only West Germany; however, its GDP was surpassed by China in 2010 and Germany in 2023; this GDP is therefore the fourth highest in the world.

Reischauer (1977), the US Ambassador to Japan (1961–1966), pointed to high literacy and excellent educational standards as the keys to Japan’s technological and economic success. Morishima (1982) also observed the relationship between economic growth and education to be the cause of the Japan’s success. Japanese students have traditionally obtained higher scores in international comparisons, such as Trends in International Mathematics and Science Study, and the Performance of International Student Assessment.

How did Japan rise from the ashes in such a short time to become one of the world’s most advanced high-tech nations and an economic success story? What is the relationship between economic activity and education, especially science education? What impact do politics and economics have on education? To consider these questions, this study investigates the relationship between science education–called *rika* (e.g., Isozaki, 2014) in Japanese–and economic growth in Japan, exploring the following research questions: (1) how is science education connected to economic growth and (2) who took the initiative to develop the country’s science education framework?

Literature review and theoretical framework

Economic theories and political analyses are employed to answer these questions. According to Rostow (1960), “the age of high mass consumption” started around 1955 in Japan (around 1935 in the United Kingdom (UK)), and 1920 in the US). The year 1955 was thus important for the Japan’s economics and politics. An economist, Ito (1992) defined the post-WWII period as: “reform and the beginning of strong growth (1945–1950)” and “rapid growth” (1950–1973) (pp. 43–76). Judging from Japan’s economic situation in the world, the 1956 Annual Economic Report declared that the country was no longer “postwar” (Economic Planning Agency, 1956). Another economist, Ishii (2015) defined the economic high growth period as follows: 1) initiation phase (1955–1959), 2) development phase (1960–1969) and 3) convergence phase (1970–1974) (pp. 227–228). Then, Ishii (2015) asserted that, from 1955 to 1985, Japan dramatically transformed itself from a backward capitalism at the level of developing countries to a mass consumer society as an advanced capitalism (p. 227). Using the economics perspective of the "convergence/catch-up effect," Abramovitz (1986) emphasized the need for the social capability, which "depends on more than the content of education and the organization of firms" (p. 389) to catching up in economic growth. This means that education played at least some role, if not directly, joining the rank of the developed countries.

In 1955, two major conservative parties merged to form the Liberal Democratic Party (LDP) was established, along with the 1955 system, which is "a confrontational system" (Masumi, 1988, p. 287). The LDP gained the upper hand in the Diet, and the relationship between the bureaucracy, such as the Ministry of Education (MoE), and the business community grew stronger. Consequently, the 1955 system had a strong influence on educational policies involving science education. Ohta (1978) argued that a system of collusion between the business community and the state/nation was established, and that the demands of the business community were carried out through the medium of state power in education policy in the 1950s and the 1960s.

Postwar reconstruction (1945–1954) and science education

Social conditions

If the prewar education policy was to develop human resources capable of contributing to the nation's prosperity by enriching the country, strengthening its military, and promoting industry, the postwar education policy focused on human resource development for the purposes of building a peaceful and cultured nation, and achieving economic growth. Just after the atomic bombing of Hiroshima and Nagasaki in August 1945, the newly appointed minster of education, Maeda, stated the promotion of science is a future challenge for Japan (*Asashishimbun,* 1945, p. 2). The MoE proposed the "Educational Policy for the Construction of a New Japan" in September 1945; it included 11 main points, one of which refers to the promotion of science (MoE, 1980). This was the main policy for becoming a science-based nation; further, the defeat in the scientific war made Japan build a peaceful nation through science. In contrast to Japan's policy, the General Headquarters (GHQ), the Supreme Commander of the Allied Powers, which was centered in the US, which aimed to build a democratic society in Japan, had a slightly different view of school education.

The GHQ required to the US government to make recommendations regarding education to Japan. The GHQ published two reports, one in 1946 and another in 1950 (MoE, 2000). Although the first report made no special reference to science education, the second asserted the importance of skilled hands and educated minds for building an industrial nation. It is noteworthy that the second report was published at the beginning of the Korean War (1950–1953), which triggered Japan's economic recovery, as it became a logistic base for the United Nations. In 1951, the Promotion of Industrial Education Law was passed by the Diet, which aimed to develop knowledge, skills, and attitudes through vocational education involving technology. The Promotion of Science Education Law was enacted in 1953. As science facilities were almost completely destroyed due to the war, this law stated that Japan, a country with few natural resources and a small land area, needed to improve its science education to upgrade industry and build a cultured/civilized nation. Owing to these promotion laws, *all* schools wanted to improve their scientific facilities to meet the criteria that would allow them to apply for national subsidies.

Science education

Based on the recommendations of the GHQ, Japan's education system, which was strongly influenced by the US, was reorganized into 6 years of elementary, 3 years of lower secondary, 3 years of upper secondary, and 4 years of university education. Elementary and lower secondary schools are compulsory for all students. Science, *rika* in Japanese, continued to be a subject studied by all students, as it was before the war, and it was introduced in elementary schools through upper secondary schools' curricula. Science at upper secondary schools was one subject, newly reorganized into four sub-subjects: physics, chemistry, biology, and earth science.

What was the objective of science in this period and what content was being taught? For example, Edmiston (1947), who was a member of the Civil Information and Education (CIE) at GHQ, stated that "whether science education in Japan moves toward so that science becomes a part of daily living, depends on what teachers do about it" (p. 3), and Wickware (n.d.), who was a science education consultant from the US, stated that the challenge to science education in Japan is having enough information to combat disease and to produce food and energy resources.

The Course of Study (which was introduced from the US) (National Institute for Educational Policy Research (NIER), n.d.), as the National Curriculum Standards, is revised approximately every 10 years through recommendations from the Central Council for Education under the MoE, based on discussions about changes in society, international trends in education, periodic review, and the actual situation of students and other factors related to education. During this period, science was compulsory from grades 1 through 12. The Course of Study for Elementary and Lower Secondary School Science (tentative/draft) stated that the objective of science teaching is to enable everyone to lead a rational and better life. The concept of science education in Japan meant “science in the daily life,” thus, showing a child-centered approach. The contents of Science G1 through G9 consisted of units such as G7: How important is water?; G8: What is a *kimono* (traditional Japanese clothing) made from?; and G9: How should we change our lives? Therefore, during this period, science was called *seikatsu-tangen gakushū* in Japanese, which means life-unit curriculum/learning, aiming to solve problems in real life and using the student’s experience and needs, while being rooted in the life experientialism/empiricism from the US. Although it is understandable that the scientification of life, or the living of science, was important due to the unprecedented circumstances of the defeat in WWII, the influence of the US through GHQ/CIE is visible. It is noteworthy that this idea, based on the progressive education in the US, was not novel at that time; instead, it was practiced in Japan within a limited number of schools during the Taisho era (1912–1926). However, *seikatsu-tangen gakushū* was severely criticized for lacking scientific systematicity and causing a decline in academic performance.

Further, science education in upper secondary schools, which were the former middle schools for boys and girls’ high schools, consisted of four elective compulsory subjects (physics, chemistry, biology, and earth science) for all students; their content was more academic because of the lower enrollment, just like before WWII. The Course of Study for upper secondary school science has been flexibly revised in response to the diversification of students’ interests, career paths and aptitudes, social changes, and global trends that accompanied the increase in the percentage of students entering upper secondary schools.

Economic high growth period (1955–1985) and science education

Social conditions

After 1955, economic and political conditions drastically changed compared with the previous period. In the postwar period, Japan’s industrial structure underwent significant changes due to technological progress and the changes in consumption expenditures associated with economic growth. During this period, the real GDP trend from 1956 to 1975 as follows: 1955–1960, 8.6%; 1960–1965, 10.6%; 1965–1970, 11.2%; 1970–1975, 4.6%; and 1975–1980, 5.1% (Ito, 1992, p. 45). The Japanese lifestyle has gradually changed during this period as well. Consequently, in the 1970s, a symbolic word was created to reflect this: *ichioku sō-chūryū* (the consciousness that almost all people of hundred million belong to middle class). Two baby booms occurred over this period: during 1947–1949 and 1971–1974. These factors have increased the number of students entering upper secondary schools. The rate of advancement to the upper secondary schools, which were not compulsory, rose sharply from 42.5% (1950), to 57.5% (1960), 82.1% (1970), and 91.9% (1975) (MoE, 1980). While the share of primary industries (agriculture, forestry, and fishing) continuously declined from 21.0% in 1955 to 1.6% in 2008, the share of secondary industries (mining, construction, and manufacturing) increased from 36.8% in 1955 to 46.4% in 1970 (Ministry of Health, Labour and Welfare, 2010).

As we will discuss later, the increase in population, higher enrollment rates in upper secondary schools, and changes in industrial structure have led to stronger demands from the business community for the government involving LDP to reform science and vocational education in secondary education and engineering education in higher education.

Since its founding, the LDP had advanced policies promoting education aimed at forming well-rounded individuals and the development of science and technology to meet the needs of the new era (LDP, 1962, p. 51).

Determination of a science education policy

The business community had frequently expressed its opinions and demands on education since the 1950s. Essentially, their consistent argument was for “diversification” and “meritocracy” (Hirose, 1985; Nishikawa & Kobayashi, 1985; Ohta, 1978; Schoppa, 1991) in education. The industrial society and the business community needed mid-level technical specialists, engineers, and scientists to promote the industry. Behind these demands of the business community was the idea of creating a high-quality skilled labor force for economic growth. The business community demanded that the MoE develops human resources to improve industry. Japan Federation of Employers’ Association (*Nikkeiren* (1963)), a business community, published in 1956 their “*Opinions on technical education that meets the demands of the new era*,” which required the government to build a system for developing scientists, engineers, and middle-level technical specialists in 1956. *Sputnik I* was launched by the Union of Soviet Socialist Republics in October 1957. The Central Council for Education, which had been created through the demands of the business community, proposed the "*Strategies on promotion of science and technology education*" in November 1957. Then, *Nikkeiren* published "*Opinions on the promotion of science and technology education*" in December 1957. Economic magazines, such as *Weekly Toyo Kezai Shimpo* (1957a, 1957b, 1958) repeatedly the importance of science and technology education for economic growth.

Shotoku Baizō Keikaku (Income Double Plan), which was a long-term economic growth plan, was launched by the cabinet in 1960. The LDP (1962) argued that the Income Double Plan by the cabinet was a specific economic policy based on LDP commitments, and stated that, as Japan is natural resource- and capital-poor, human resources are the most valuable resources and their advanced utilization is the greatest road to the development of the nation and its people (pp. 136–137). Consequently, the expenses under the jurisdiction of the MoE accounted for 12.4% of the budget for fiscal year 1961 budget (in FY2023, it was 4.7%), which represented a 24% increase from the previous year (*Monbukōhō*, 1961). Notable were the budgets related to equal opportunity, human resource development, and the promotion of science and technology education, which were designated as priority items for improving the Income Double Plan. In 1962, the MoE (1963) published *Japan's Growth and Education*. This white paper regarded education as "investment" based on the human capital theory which was one of economic research trends in the US, such as Schultz (1960). Unquestionably, MoE's white paper strongly reflected the ideas of the business community and the LDP cabinet. Specifically, they indicated that education, primarily science and technology education, is connected to economic growth and has reached the level of advanced countries in science and technology. However, the conclusion of Aso and Amano (1972), that the economic theory on education, especially in the 1960s, did "not furnish adequate suggestions in regard to ideal form and contents" (p. 91), is worth considering as a historical insight.

The Six Subject Survey (1970–1971), known as the First International Science Study (FISS), was conducted by the International Association for the Evaluation of Educational Achievement (IEA) (Comber & Keeves, 1973), and the Second International Science Study (SISS) (1983–1984) by the IEA (Keeves, 1992). Japanese students in both elementary and lower secondary schools scored highest among the participating countries. Such international comparisons are very important for government policymaking. Additionally, in 1976, the MoE has started a system called *kenkyū-kaihatsu gakkō-seido*, which means designated schools to experimentally research and development curriculum to offer data that could be used when revising the next Course of Study. Indeed, while Japanese students scored high in international comparisons, their attitudes toward science declined. As Table 1 shows, although the attitudes toward science in the FISS were good for both elementary and lower secondary school students, those in the SISS intended to decline for both elementary and lower secondary school students, especially lower secondary school students.

In the 1970s, environmental issues became social issues in Japan and the authoritarian nature of science began to be questioned. Considering these conditions, Kida (1991) expressed regarding the declining attitudes toward science of students and argued that science education "make[s] clear the multilateral relationship between science and social development" (p. 195). This means that lower secondary school science was too be abstract and less focused on the concept "science in the daily life context."

Table 1 Scores for attitudes toward science

Table 1-1 Standard scores in 1970

	Age	England	Japan	US	Thailand	SD*
Science interests and	10	-0.2	0.38	0.27	-0.48	4.16
activities	14	-0.1	0.07	0.14	-0.25	4.31

Table 1-2 Means scale scoreds in 1984

	Age	England	Japan	US	Thailand	Mean
Interest in science	10	39	52	31	**	47
	14	25	-9	12	43	18
Ease of learning science	10	8	52	19	**	25
	14	0	-18	2	-24	-5
Importance of science	10	42	26	50	**	41
Career interest in science	14	28	-3	30	63	28

Note: * only developed counties; ** no data

(Source: Table 1-1; Comber and Keeves, 1973; Table 1-2; Keeves, 1992)

Science education

In 1958, each Course of Study for elementary to upper secondary school was revised and has been legally bound by the removal of the letter of the draft/tentative since this revision. The concept of elementary to upper secondary schools' science was "the systematization of science," which refers to the systematic teaching and learning based on emphasizing the systematic teaching content for science, along with a process of science focusing on experiments and observation. The shift from a child-centered approach to a discipline-centered one is one response to the criticism of previous science concepts in the Course of Study, which led to a decline in academic abilities in science.

The Courses of Study for elementary, lower secondary, and upper secondary schools were revised in 1968, 1969, and 1970, respectively. This revision reflected two primary factors: Western science curricula, some of which has its theoretical basis in Bruner (1960), and the national economic policy for developing highly talented human resources by the Council on Economic and Fiscal Policy (1963). There are some differences between primary and secondary sciences. The concept of elementary school science was "problem solving," and that of secondary school, especially upper secondary school, was "inquiry," which enhanced both structuring scientific concepts and the process of scientific inquiry. Recently, inquiry and problem solving have been used as similar technical words in science education. However, at that time, while the term "inquiry," which Schwab and Brandwein (1962) proposed, was introduced as a key word from the Western curricula in Japan in the 1960s, the term "problem solving" was based on the traditional idea of "learning from nature directly," which was what had been done before WWII in elementary school science. Consequently, secondary school science reflected strong Western influence.

To respond to the diverse aptitudes, interests, and career paths of students, due to the significant increase in the percentage of students entering upper secondary schools, a balanced science, such as integrated, combined, and general science, has been introduced as elective compulsory or compulsory since this revision of the Course of Study. Basically, in Japan, a balanced science (its concept is "science in the daily life context") has been regarded as not pure academic science compared with separated sciences. It is unlikely to be a university entrance examination subject. Due to the wide range of teaching content, upper secondary science teachers with an academic science background lacked awareness of teaching balanced science. Consequently, this can be considered a failure to reflect on the various problems that arose in general science during the 1930s.

The Course of Study for elementary and lower secondary school was revised in 1977 and for upper secondary schools in 1978, based on the following policies: emphasis on basic and fundamental knowledge and skills, and a reduction of 10% in lesson times and 20–30% in teaching content. In this revision at upper secondary schools, regarding several science subjects were offered, and all students were required to take the balanced science, called *rika I*, and also electives from other sciences (*rika II*, physics, chemistry, biology, and earth science). Similar to the previous version, the concept of science was “problem solving” for elementary school science and “inquiry” for secondary school science.

Discussion

The relationship between politics, economics, and science education

Under the 1955 system during this period, two axes of conflict emerged regarding educational policies from 1955 to the 1980s. This political conflict also affected the creation of educational policies, presenting as the conflict between the MoE on the side of the LDP and the business community, and the teachers’ union on the progressive political parties and the labor union. In the case of science education, there was less conflict between the two axes regarding other educational issues, such as moral education and academic achievement tests. However, van Wolferen (1989) observed that there are three discernible ruling classes in Japan: bureaucrats (ministries), businessmen (business community), and one section of the LDP (government), called administrators as “a symbiotic” term (p. 114). Schoppa (1991) described these three classes as “actors.” During this period, the prime ministers and the minsters of education were usually members of the LDP. Schoppa (1991) also noted that, during this period, “the demands [on education] almost always originated from the business community and while the policies were usually developed and implemented by the Ministry of Education, the LDP acted as the middle man in ensuring that business demands were put into effect” (p. 64). Ohta (1978) criticized the education policy as being subordinated to economic policy. Consequently, some statements were reflected in the policy decision-making process and in the results of the power relations between these three actors, as shown in Figure 1.

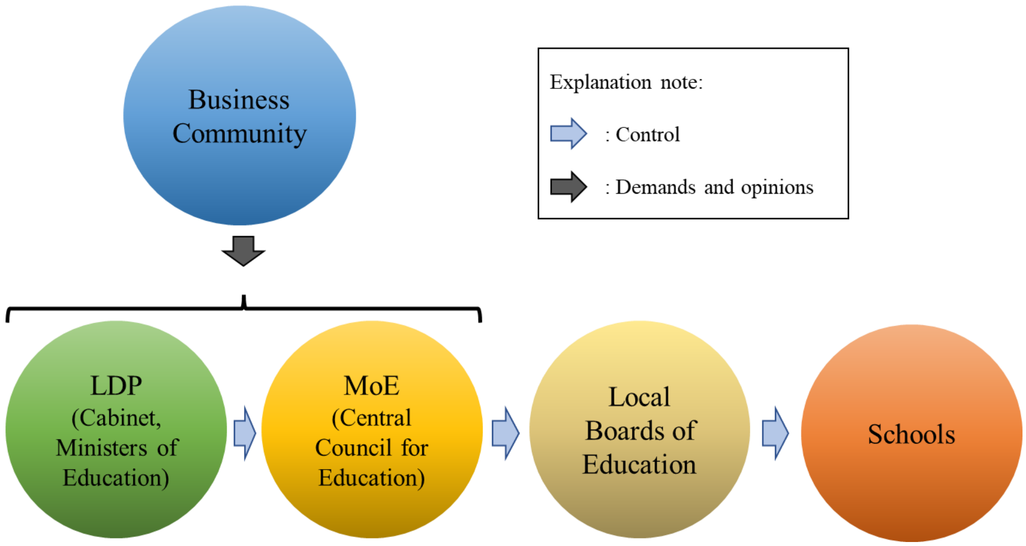

Figure 1: The relationship between three actors, local board of education, and schools

The diversification and meritocracy of upper secondary schools and science education

Under the subsequent rapid economic growth, education was linked to the qualitative improvement of the labor force with knowledge and skills and was positioned as a means to achieve economic growth. The promotion of science and technology (involving engineering) education has become a national policy, implemented by the government in response to the demands of the business community. Science and technology education during this period primarily focused on the expansion of technology education into upper secondary and higher education. Why was technology education given priority over science education? Morishima (1982) argued that the policy of “overemphasis on engineering and neglect of natural science” (p. 177) can be traced back to the Meiji era (1868-1912), and it was rooted in the Meiji government policy: *wakon-yōsai*, which means Japanese spirit and Western techniques. Compared to the UK and US, technology education in upper secondary/post-secondary schools (e.g., specialized schools), and engineering education in higher education, has been valued in Japan since the Meiji era.

The newly organized upper secondary school (G10 to G12) has offered two courses: general and specialized. Specialized courses include industrial (technical), science and mathematics, and other vocational courses. Upper secondary schools which have offered industrial course are called *Kōgyō-kōkō* (Technical High Schools); some of them were vocational school before WWII. Sasaki (2000) found that an increase in technical high schools played a supporting role in promoting Japan's economic growth during this period. Despite these specialized courses, students must study science as a compulsory part of their basic education. In 1961, the *Kōtō senmon-gakkō*: *Kōsen* (College of Technology) was incorporated into a system of five-year higher educational institutes to meet the demand from the business community, and the first 12 national *kōsen* were established in 1962. Although the education system consists of five years of consistent engineering education, starting at 15 years of age, students study science as part of general education.

In response to diversification and meritocracy, an elective compulsory system was introduced in science education, and then, balanced science was introduced in the 1960s. The combination of science subjects differed according to each revision of the Course of Study. Additionally, in response to the business community's emphasis on meritocracy, the science and mathematics course in upper secondary schools was established as one of the specialized courses.

Conclusion and implications

Who took the initiative to develop the country's science education framework? During the analyzed period, the changes in science and technology education in Japan were primarily determined by the relationship between three actors: LDP, MoE, and the business community, as Figure 1 shows. Their interest, especially that of the business community, was primarily on vocational education involving technology in upper secondary schools, and engineering and science education in higher education, to develop a skilled and knowledgeable labor force from middle-level technical specialists to engineers and scientists rather than science education from elementary to secondary schools. During this period, the environment surrounding science education, from elementary to specialized schools and universities, such as enacting laws, increasing the budget for science education, and establishing science education centers for in-service teacher education, was successfully improved. In addition, an academic research system in science education was gradually institutionalized through actions such as establishing PhD courses at two national universities (Tsukuba and Hiroshima) and organizing research associations (e.g., the Society of Japan Science Teaching in 1952).

Science education policies are viewed as a benefit for the nation rather than for individual well-being. Apart from the three main actors, science teachers who were practicing in the classroom every day were not clearly visible in the policymaking process. However, it is noteworthy that, under the control of the MoE and local boards of education, teachers formally and informally engaged in "lesson study" (e.g., Isozaki & Isozaki, 2011) to improve their teaching competencies and students' learning through continuing professional development. Consequently, this led Japanese students to score high in international comparisons. However, despite the efforts of teachers, students have shown lower levels of interest in learning science and lower intentions to work in science-related careers in the future than the international average.

Japan, a county with poor natural resources, has utilized its limited human resources through education since modernization. In its observations, during analyzed period, the MoE's white paper (1963) evaluated that "Japan has become one of the countries which have attained the highest educational standard at the most rapid rate of expansion" (p. 2). Indeed, education, especially science and technology education, benefited the nation both before WWII and during the period of rapid economic growth; it also built a cultured nation. The business community, LDP, and conservative government regarded education, especially science and technology education, as a vehicle for economic growth in the mid-1950s. Then, owing to the Course of Study revision in 1958, the principle of science curriculum organization shifted from a child-centered to a discipline approach, aiming to develop students' academic abilities. Consequently, while Japanese students have achieved high scores in mathematics and science in international comparisons since the 1960s, their attitudes toward science have been more negative compared to those of students in other countries since the 1980s (e.g., Keeves, 1992). This offers historical insights into the nature of science education.

The Organisation for Economic Co-operation and Development (2001) extended this definition of well-being "[*t*]*he knowledge, skills, competencies and attitudes embodied in individual that facilitate the creation of personal, social and economic well-being*" (p. 18. Italics in original.) Therefore, if we aim to improve scientific literacy for all Japanese, science education needs to emphasize its benefits to individual well-being.

Typical traditional research on the history of science education employs an internal approach (e.g., Kuhn, 1977), which focuses on science education itself. By employing an external approach (e.g., Bernal, 1939; Kuhn, 1977) that investigates the relationships between society (e.g., economic growth, and the process of policymaking) and science education, as in this study, we can observe science education within boarder contexts, such as social, economic, and national policy contexts, and reveal novel aspects. Understanding the history of science education from multiple perspectives is important way to broaden and deepen one's perspective for scholars, policymakers, and teachers. Furthermore, it can provide insights into the post-truth era to appreciate the complex nature of policymaking in science education. The approach adopted in this study strongly supports the historical and social construction of science education by stakeholders and teachers.

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Enhancing Flipped Classroom Learning in Higher Education in Singapore Through the Socratic Methodology: A Synergistic Approach

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Enhancing Flipped Classroom Learning in Higher Education in Singapore Through the Socratic Methodology: A Synergistic Approach

Abstract

Higher institutions in Singapore such as the Polytechnics are using the flipped classroom model, commonly attributed to Bergmann and Sams (2012). The underlying assumption in flipped is that the students are able to effectively self-learn through watching a series of videos. It would greatly benefit instructors if they were able to determine whether the self-learning was done well before transitioning to deeper discussions. To this end, we experimented with the integration of the Socratic Method into the flipped classroom model and evaluated the process. In addition, our study investigates the synergistic potential of combining the flipped classroom and Socratic Method to enrich student engagement. The Socratic questioning played a function in eliciting and challenging students' pre-lesson self-learning, and in extending students' understanding. It served to extract knowledge and information from within the students. Features of the Socratic method were categorized in accordance with Chin (2007) as pumping, reflective toss, and constructive challenge. This exploratory study was piloted in five classes (sample size = 109) over a semester. Students were briefed on the study, and both student feedback and a focus group were conducted at the end of the semester. Both quantitative and qualitative analysis were performed on the data collected. The findings strongly suggest that the use of Socratic Method helped affirm students of their self-learning, increase classroom engagement, and strengthen the student thought process. The implications of these findings include contributions to the ongoing discourse on methods to enhance the flipped classroom, offering educators a nuanced understanding of how the Socratic Method can complement and enhance the flipped classroom learning model, fostering a more inclusive and intellectually stimulating educational experience.

Keywords: flipped; self-learn; Socratic Method

Introduction

In recent years, higher education institutions in Singapore adopted the flipped classroom model. Popularized by Bergmann and Sams (2007), the flipped classroom approach flips the traditional instructional model by having students engage with instructional content independently before class, thus allowing in-person class time to be dedicated to interactive discussions and activities.

Numerous successes have been attributed to the flipped classroom model, and it clearly offers “a potentially exciting model” that is “pedagogically sound” (Johnson & Marsh 2016). But, for all its potential, it is not ‘entirely unproblematic’ (Lo & Hew, 2017) and teachers and institutions frequently report a number of challenges (Turan & Akdag-Cimen, 2019). One of the problematic underlying assumptions is that students, through self-directed learning, can gain a foundational understanding of the subject matter, paving the way for deeper exploration during classroom interactions.

Kim, Kim, Khera, and Getman (2014) have pointed out a dearth of research on effective design of flipped classrooms; they argued that educators using flipped learning should assess comprehension and link at-home work with in-class activities.

To address this concern, we embarked on an experiment, integrating the renowned Socratic Methodology into the flipped classroom framework. The Socratic Method, known for its rigorous questioning and emphasis on dialogue, provides a means to assess the depth of students' understanding and the quality of their pre-lesson self-learning.

This paper explores the synergistic potential of combining the flipped classroom and Socratic Method to not just assess student comprehension, but also to enrich student engagement. By both challenging students' pre-lesson self-learning and extending their understanding through Socratic questioning, we aim to contribute to the ongoing discourse on innovative pedagogical approaches in higher education.

Method

A total of five classes, with a combined 109 students, took place in the study. While the majority of the students are Singaporeans, there were some foreign students and permanent residents in these classes. There is a wide range of learning readiness of the students from high readiness to middle readiness to low readiness as there were students who studied Physics at GCE O-level and others with no background in upper secondary physics.

The students were briefed at the beginning of the semester that the Socratic questioning method would be used in their classroom delivery. To ensure consistency, these classes were taught by the same tutor, who is also the first author.

The Socratic questioning process incorporated elements categorized according to Chin's (2007) framework, including pumping (eliciting foundational knowledge), reflective toss (encouraging thoughtful reflection), and constructive challenge (prompting critical analysis).

Pumping

Hogan & Pressley (1997) used this terminology to refer to the teacher pumping the students for more information. Essentially, it is a series of questioning techniques. In our classroom discourse, pumping was used right at the beginning of the class. Student names were called after the question was asked, so that each student would have to remain alert and attentive. The process of starting and staying with the same student for a series of questions before moving on to the next student to repeat the process is known as the pumping. The practice to call student names also allowed the tutor to find out about each student's pre-learning, instead of just having a few students dominating the answering of the questions. Pumping was used to solicit short answers, such as yes or no, or a terminology. The purpose of seeking short answers was to build up the learning momentum of the entire class, engaging to students to listen, think and participate. The pace of the questioning was also rather rapid because short answer questions were used. This ensured that all students did not have to wait too long before they got called upon again.

An example of the technique of pumping used in our class discourse on the topic of wave properties is reproduced in the classroom talk below. In the classroom talks that follow, "T" denotes the tutor, "S" followed by a number denotes different students, and [student name] represents an actual student name. Irrelevant conversations were omitted.

T: There are two types of wave motion. The medium particles of one of these waves vibrate perpendicularly to the motion of the waves. Is this a transverse wave or longitudinal wave, [student name]?

S1: Transverse wave.

T: That's correct. Can you give me an example of a transverse wave?

S1: Light.

T: Good. Light is a special type of transverse wave. Does light require a medium for propagation? Yes or No?

S1: No.

T: That's right! Light does not require a medium for propagation. Can someone name another transverse wave that requires a medium? [Student name]?

S2: Rope wave

T: In a rope wave, does the rope particle propagate in the direction of the wave motion? Yes or no, [student name]?

S2: No. Rope particle does not propagate in the direction of the wave motion.

T: That's right. The rope particle does not propagate in the direction of the wave motion. What is being propagated in a transverse wave, [student name]?

S3: Energy.

T: What do you call a wave that propagates energy? Progressive wave or stationary wave, [student name]?

S3: Progressive wave.

T: Correct. Energy is propagated by progressive wave. We are interested in describing the motion of a progressive wave. Name me a property that describes wave motion, [student name].

S4: Period.

T: Yes, Period is one important property. There are four other properties – frequency, amplitude, velocity, and wavelength. How is the period related to frequency, [student name]?

S4: Period is the reciprocal of frequency.

T: That's right! Period is the reciprocal of frequency. There are two types of graphs that describe wave motions. One is a displacement of the particle versus time graph. The other is a displacement versus distance graph. Would you be able to obtain information of the period from a displacement versus distance graph? Yes or no, [student name]?

S4: No.

In each lesson, pumping questions are used to cover the entire learning outcomes with the teacher staying with the same student for a series of questions before moving on to the next student to repeat the process. Pumping was the main technique used in evaluating the proficiency of the students' pre-lesson self-learning. As far as possible, every student was called during pumping to ensure that each and every student was "evaluated".

Reflective Toss

Van Zee & Minstrell (1997) described reflective toss as a question or questions posed by a teacher to the class in response to a prior question or comment made by one of the students. The teacher does so to throw the responsibility of thinking back to the students, and to guide the students to the correct answer. It shifts the class towards a more reflective discourse. Reflective toss was less frequently used, because it is dependent on what type of questions were being raised in class by the students. Sometimes, it might be triggered when a teacher asks students if they had any questions in their pre-class reading. Other times, it was used in the deeper discussions sessions of the flipped classroom.

An example of a reflective toss used in our class discourse is as follows.

S1: Why does sound undergo refraction when it leaves through the window?

T: Good question. Before I answer the question, can someone tell me how refraction occur? How about [student name]?

S2: When there is a change in speed.

T: That's correct. When there is a change in speed. When does a change in speed take place, [student name]?

S2: When there is a change in medium.

T: Yes, when there is a change in medium. Are there two different media as sound leaves a room into the outdoor, [student name]?

S3: Could it be difference in temperature?

T: Indeed. Hot and cool air are two different media. How does air temperature affect the speed of sound, [student name]?

S3: Sound travels faster in hot air.

T: Yes. Sound travels faster in hot air. So, we established that as sound leaves a room through a window into the open, there is a change in the speed of sound because of a difference in air temperature. The cooler air in a room and the hotter air in the open represent two different mediums. As sound travels through two different media, refraction occurs due to a change in speed. [S1], does that answer your question.

S1: Yes.

T: Is refraction the only phenomenon that sound experiences as it leaves the window? [Student name], yes or no?

S4: No.

T: what is the phenomenon that sound also experience as it leaves the window, [student name]?

S5: Diffraction.

In the example given, reflective toss is used together with pumping to elicit further answers from the class. Instead of answering the question directly, the tutor provided scaffolding by asking a series of questions, leading the class to the answer. He then summarized the information for the students and check the understand of the student who triggered the question.

Constructive Challenge

Constructive challenge is used when a teacher wants a student to reconsider his answers or to demonstrate that an alternative method can be used to solve a question (Chin, 2007). The teacher posed a question that challenged students' thinking and prompt the students to reconsider their answers.

In our classroom setting, constructive challenge was used, more often than not, after the evaluation of pre-lesson self-learning has been completed and the class was ready to move on to deeper discussions. Tutorial questions were often used for such deeper discussion. An example of constructive challenge being applied is as follows.

A student was asked to solve a question related to refraction. In the question, it was given that a monochromatic light with wavelength of 750 nm passed through a glass prism with a reflective index of 1.68. The student was asked to calculate the wavelength of the monochromatic light in the glass prism.

In working out the answer, student S1 calculated the speed of light in the glass prism through the use $v_g = \eta_g c$, where η_g is the reflective index and c is the speed of light. He then calculated the frequency of monochromatic light using $c = f\lambda$, where f is the frequency and λ is the wavelength. Finally, having found v_g and f, he calculated the wavelength of monochromatic light in the glass prism, λ_g, using $v_g = f\lambda_g$.

While there was nothing incorrect about his approach, the tutor wished to show the class the relationship between the two wavelengths. That relationship would be obvious if the student had worked with algebra instead of applying the numeric values into a formula right away. The tutor then defined the variables in their algebraic terms $v_g, \eta_g, c, f, \lambda,$ and λ_g and then asked the classroom *"Could the answer be obtained without calculating the frequency?"*, *"Is there a direct relationship between the two wavelengths?"* and then called upon the class to find the algebraic relationship between the two wavelengths.

Eventually, a student S2 managed to find the algebraic relationship using these steps $v_g = \eta_g c \Rightarrow f\lambda_g = \eta_g f\lambda$, which gives a direct relationship between the two wavelengths as $\lambda_g = \eta_g\lambda$.

By challenging the students to evaluate their own alternatives, the tutor guided them to understand that applying algebra can reveal further relationships of physical quantities.

Data Collection, Results and Discussions

Both quantitative and qualitative data were collected to assess the impact of this integrated approach.

The quantitative data were collected through the use of anonymous surveys that were distributed to students. The data of interest was the students' perceptions of the Socratic Method's effectiveness in enhancing student engagement. Since student engagement is positively correlated to academic performance. We defined student engagement as a meta-construct that includes behavioral, emotional, and cognitive engagement (Fredricks et al., 2004). Its impact could be measured through three dimensions: motivational, emotional, and cognitive engagement (Singh et al, 2022).

The questions used in the survey are shown in Table 1. These questions collective addresses the emotional, cognitive, and motivational aspects of the students. Questions 1 to 4 were used to elicit their emotional responses; questions 5 to 8 their cognitive responses; and questions 9 to 11 their motivational responses.

Some questions are an interplay of two aspects. For example, question 2 may also be interpreted as questions to draw out the motivational dimensions of students. Question 3 may be interpreted as a measure for the student's cognitive development.

Table 1. Survey Questions

	No.	**Survey Questions**	**Score**			
			4	**3**	**2**	**1**
emotional	1	I feel more attentive and alert during lessons when the teacher ask questions throughout the lesson than when the teacher does not.	Strongly agree	Agree	Disagree	Strongly Disagree

	2	I feel the need to prepare myself for class when the teacher ask questions throughout the lesson than when the teacher does not.	Strongly agree	Agree	Disagree	Strongly Disagree
	3	I feel that I am more a curious learner now than I was at the beginning of the semester.	Strongly agree	Agree	Disagree	Strongly Disagree
	4	I feel more confident about my concepts after the lessons when the teacher ask questions throughout the lesson than when the teacher does not.	Strongly agree	Agree	Disagree	Strongly Disagree
cognitive	5	Answering questions or attempting to answer questions helps me to think about the topic.	Strongly agree	Agree	Disagree	Strongly Disagree
	6	When the teacher asks questions, it guides my thinking progress.	Strongly agree	Agree	Disagree	Strongly Disagree
	7	I chip in to answer questions that my classmates are unable to answer.	Often	Some-times	Seldom	Rarely
	8	The teacher's questioning cause me to examine my own thinking about the topic. (Situation is not restricted to lesson time only.)	Often	Some-times	Seldom	Rarely
motivation	9	When the teacher ask another classmate a question I was unable to answer earlier, I still feel motivated to learn instead of switching off and disengaging myself from the class.	Most like me	Like me	Unlike me	Most unlike me
	10	I am interested to hear my classmate's answers and find out how similar or different the answers are compared to mine.	Most like me	Like me	Unlike me	Most unlike me
	11	I spent more and more time with my pre-lesson preparation because I wanted to be able to answer the teacher's questions in class.	Most like me	Like me	Unlike me	Most unlike me

	12	Overall, I benefitted from this method of teaching.	Strongly agree	Agree	Disagree	Strongly Disagree

Table 2. Means and standard deviations of collected responses by question type

Survey Questions	**Mean**	**SD**
I feel more attentive and alert during lessons when the teacher ask questions throughout the lesson than when the teacher does not.	3.093	0.561
I feel the need to prepare myself for class when the teacher ask questions throughout the lesson than when the teacher does not.	3.000	0.677
I feel that I am more a curious learner now than I was at the beginning of the semester.	2.680	0.785
I feel more confident about my concepts after the lessons when the teacher ask questions throughout the lesson than when the teacher does not.	2.866	0.589
Answering questions or attempting to answer questions helps me to think about the topic.	3.144	0.612
When the teacher asks questions, it guides my thinking progress.	3.021	0.612
I chip in to answer questions that my classmates are unable to answer.	2.402	0.874
The teacher's questioning cause me to examine my own thinking about the topic. (Situation is not restricted to lesson time only.)	2.948	0.635
When the teacher ask another classmate a question I was unable to answer earlier, I still feel motivated to learn instead of switching off and disengaging myself from the class.	2.876	0.617
I am interested to hear my classmate's answers and find out how similar or different the answers are compared to mine.	2.845	0.635

I spent more and more time with my pre-lesson preparation because I wanted to be able to answer the teacher's questions in class.	2.474	0.561
Overall, I benefitted from this method of teaching.	2.907	0.678

Table 3. Means and standard deviations of collected responses by category

Category	**Mean**	**SD**
Emotional Dimension	2.910	0.674
Cognitive Dimension	2.879	0.746
Motivational Dimension	2.732	0.677

A total of 97 completed and usable survey outcomes were collected. The responses were converted into a 4-point system. The mean scores and standard deviations of each question were calculated and summarized in Table 2.

The means and standard deviations emotional, motivational, and cognitive responses are summarized in Table 3.

We could see from Tables 2 and 3 that the means were above 2, which demonstrated that the students tend to agree, as a whole, that Socratic questioning had positive effects on their emotional, motivational and cognitive well-being in class. This result suggests that the Socratic method does lead to higher student engagement.

Question 5, which asked “Answering questions or attempting to answer questions helps me to think about the topic.”, garnered the highest mean score of 3.114 among the twelve questions.

Question 7, which asked “I chip in to answer questions that my classmates are unable to answer.”, garnered the lowest mean score of 2.402 among the twelve questions. This does not come as a surprise to most Singapore educators. Singapore students at this level tend not to participate actively in class discussions.

Questions 8 pointed out that some students continue to think about a particular topic, even after the lesson.

If Questions 2, which may also interpreted as a motivational dimension, and Question 3, which may be interpreted as a measure for the student's cognitive development, are then included the calculations in these categories, the mean scores on the cognitive and motivational dimensions would become 2.799 and 2.932 respectively. Their respective standard deviations would be 0.686 and 0.728. These values are slightly higher than those in Table 3, and are inline with our earlier conclusions about the positive effect brought about by the Socratic Method on student engagement.

To gain further qualitative insights into the lowest mean values in each category, a focus group was conducted at the end of the semester. For example, in the emotional dimension category, question 3 had the lowest score. To understand how to encourage students who feel less "curious" than before, we asked in the focus group how we can emotionally encourage the students to be more inquisitive.

In the cognitive dimension category, question 7 was the lowest score and a question on how to encourage other students to chip in into the classroom discussions was asked in the focus group. In the motivational dimension, question 11 was the lowest score and a question on how to keep student motivated in their pre-lesson self-learning was asked.

The questions are summarized in Table 4. These focus group questions serve to gather inputs to address the questions with the lowest mean scores so as to improve the classroom discourse. In addition, they do not directly address the Socratic questioning method used, but instead, it focuses on how to achieve higher levels of student engagement whilst using Socratic questioning. A group of seven students were randomly selected for the focus group interview.

The responses of the students were clarified and noted down on the spot. The responses are then coded. Based on the codes, we were able to identify themes on how to improve Socratic questioning method of delivery to increase the level of student engagement. These codes, themes and their analysis are also listed in Table 4.

In the emotional dimension, to emotionally encourage students to be more inquisitive, the themes uncovered were to "promote curiosity" and "foster a safe and supportive environment". Such an environment creates a culture that values curiosity and encourages students to ask questions, take risks, and explore new ideas without the fear of judgment or criticism.

In the cognitive dimension, to encourage students to actively participate in Socratic discourse at time when the called upon student was unable to answer, the themes uncovered were to "use positive reinforcement" and "promote a growth mindset". Positive reinforcement would signal to the students the active participation is a positive behaviour and chipping in to answer provides opportunities for learning and improvement.

In the motivational dimension, to encourage students to keep up with their pre-lesson learning, the themes uncovered were to "offer incentives" and "monitor progress and provide regular reminders". Some participants felt that tangible rewards would motivate them while others asked for some ways to monitor their progress and remind them if necessary.

Table 4. Questions, Codes, Themes and Analysis of focus group discussion

Category	**Question asked**	**Codes**	**Themes and Analysis**
emotional	Some students felt less intellectually engage. What are some ways to emotionally encourage students to be more inquisitive?	Remind others not to judge. Stress the importance of asking questions.	*Foster a safe and supportive environment.* Emphasize that it's okay to ask questions, take risks, and explore new ideas without fear of judgment or criticism. *Promote curiosity*. Create a classroom culture where curiosity is valued and encouraged.
Cognitive	What can teachers do to encourage students to chip in in a question-and-answer session when their classmates are unable to answer?	Give more encouragement. Show excitement or give praise when student answer correctly.	*Promote a growth mindset*. Encourage students to adopt a growth mindset, where they see chipping in to answer as opportunities for learning and improvement. Remind students that chipping in is valuable to the learning process. *Use positive reinforcement*. Provide positive feedback and reinforcement for

			students who are willing to take risks and participate, especially when their contributions help move the discussion forward or provide new insights.
Motivational	Pre-lesson self-learning tend to falter over time. What should the polytechnic do to ensure that students keep up with their pre-lesson self-learning?	Give sweets or rewards. Give reminders.	*Offer incentives*. Provide incentives or rewards for students who consistently engage with pre-lesson self-learning activities. This could include bonus points, recognition, or other tangible rewards. *Monitor progress and provide regular reminders*. Implement systems to monitor students' engagement with pre-lesson self-learning activities and provide regular reminders.

Feedback from tutor

In using Socratic questioning during lesson delivery, I was able to determine how well students had prepared themselves for lesson as a whole and what specific learning objectives needed to be address before going to deeper discussion.

I am also able to, over time, determine which are the students that have been more thorough and consistent in their pre-lesson preparation.

Conclusions

The use of the Socratic Method in flipped classroom was investigated. It was found that the Socratic Method was able to determine the pre-lesson knowledge proficiency of students. This proves to be useful and allows the tutor to address specific learning objectives that students need more help in, rather than jumping into deeper discussions right away. The emotional, cognitive and motivation dimensions of the students measured using a survey showed positive results. These dimensions are often used to indicators of student engagement. Hence, it is reasonable to conclude that the use of the Socratic Method enriches student engagements, which had been shown to improve academic performance. Furthermore, it was found that by promoting a growth mindset, using positive reinforcement, fostering a safe and supportive learning environment, promoting curiosity, offering incentives, and monitoring progress would enhance the use of the Socratic method and improve students' emotional, cognitive and motivational dimensions for a joyful and meaningful learning experience.

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Enhancing Learning in Engineering Physics: Integrating Misconception Discussions with the 5E Instructional Model

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Enhancing Learning in Engineering Physics: Integrating Misconception Discussions with the 5E Instructional Model

Abstract

The effective learning cycle proposed by educators J. Myron Atkin and Robert Karplus (1962) has long been a cornerstone of technical education, encompassing exploration, term introduction, and concept application. While this model has proven valuable, our study identifies a crucial omission—the discussion of misconceptions. Research has indicated that misconceptions can significantly hinder new knowledge acquisition, as they are often deeply ingrained and resistant to conventional instructional correction. In response, we propose the integration of a discussion on misconceptions within the learning cycle, and employing an inquiry-based approach such as the revised 5E Instruction Model (Bybee 2009) in our classroom discourse. This approach actively engages students, fosters cooperative learning, and reduces reliance on rote memorization. The purpose of our study is to investigate whether the deliberate incorporation of a discussion of misconceptions into the instruction material and applying the 5E instructional model in a lesson delivery would produce better learning outcomes. The subject in our study is Engineering Physics. Learning of Engineering Physics has been a challenge for students because they come into physics classes with pre-conceived ideas about the subject matter that do not align with the scientific conceptions they are expected to master. Misconception-related problems were constructed using concept cartoons, video or media clips, and structured questions. The sample group consists of forty-eight students (Control Group=25; Experiment Group=23). An assessment quiz designed using two-tier questions, a student survey and a focus group discussion were used as data. Both qualitative and quantitative analyses were employed to interpret the findings. Our results suggest that integrating a discussion on misconceptions with the 5E instructional model positively impacts learning outcomes. While some misconceptions were remediated, complete elimination proved challenging. This study provides valuable insights into enhancing the effectiveness of instructional strategies in Engineering Physics education.

Keywords: revised 5E instructional model; misconceptions; learning cycle

Introduction

The teaching of science has been largely influenced by educators J. Myron Atkin and Robert Karplus (1962). They proposed a way to structure the teaching of science through the use of a learning cycle, which involved three key elements: exploration, term introduction, and concept application.

A learning cycle moves students through a scientific endeavour by having them first explore materials, then construct a concept through the introductions of terms, and finally apply or extend the concept to other situations.

Abraham and Renner (1986) investigated and found that these three stages of the learning cycle are in their optimal sequence. They found that when concept introduction followed exploration, students learned better. The introduction of terms after investigations helps students connect new concepts with prior experiences. This is consistent with constructionism and experiential learning, which state that learning is construed through action.

However, the learning cycle as proposed does not explicitly tackle the challenge of misconceptions. In our case, we found teaching Engineering Physics a significant challenge. This is because educators must not only impart new knowledge but also address and rectify the deeply ingrained misconceptions held by students. Misconceptions can be described as pre-conceived ideas based on non-scientific beliefs, mixed conceptions or plain conceptual misunderstandings.

These misconceptions, often established from an early age, arise from non-scientific beliefs, partial understandings, or outright conceptual errors. They may stem from various sources, including well-intentioned but misinformed responses from adults, misleading information from cartoons, or even educational authorities themselves. For example, when adults are confronted with questions from young children, rather that admitting to not knowing the answer, it is common for them to give an incorrect one. Misconceptions are also built into our languages, such as “the sun always rises from the east”.

To address this issue, we propose the integration of misconception discussion into the instructional material itself. In addition, we propose the use of the BSCS 5E Instruction Model, as popularized (Bybee & Landes, 1990) and then later revised Bybee (2009), as the mode of delivering this set of instructional components. The BSCS 5E Instruction Model is an inquiry-based teaching that is highly effective in supporting the learning cycle (Duran and Duran, 2004). This model, known for promoting active student engagement, cooperative learning, and reducing reliance on memorization, provides an ideal framework for incorporating our discussions of misconceptions.

This paper focuses on assessing the impact of intentionally incorporating misconception discussions on student learning and academic achievement. We will outline the methodology employed, our measurement criteria, and the outcomes of our investigation, aiming to demonstrate the value of addressing misconceptions directly within the educational process.

Method and Materials

The BSCS 5E model consists of these cognitive stages of learning: engage, explore, explain, elaborate and evaluate (Figure 1).

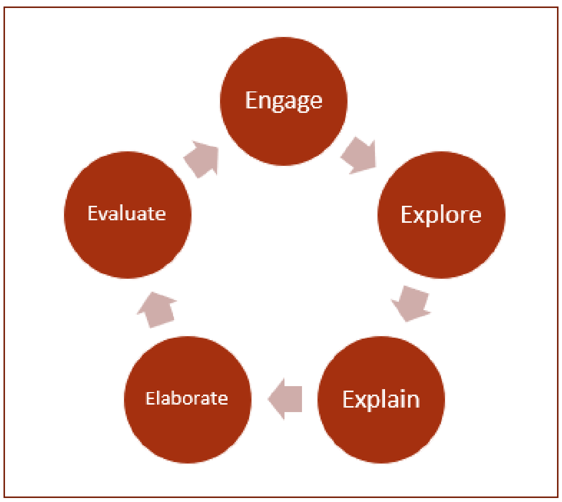

Figure 1. BSCS 5E model

In the preparation of materials and delivery design, we picked a misconception to work on for each topic. For instance, in kinematics, the relationship between velocity and acceleration is often misunderstood, and in dynamics, the identification of action and reaction pairs, and so on. For each topic, we delegated one lesson to the discussion of misconceptions. In the following sections, we would be describing our course of actions taken in each of the 5E stages.

Engage

In this first phase of the cycle, our goal was to provide a context that would pique the students' interests by relating the content being taught to something relevant and relatable. As much as possible, that "something" was taken from experience in daily life. Different "hooks" were used for different topics. The task of the tutor in introducing the hooks was to leave unanswered questions and to build a sense of curiosity and challenge. The tutor would also need to invoke the students' prior knowledge so that knowledge could be constructed from what students already knew. Students were then encouraged to apply process skills, such as investigating, hypothesizing, and debating to find the answers.

An example of a hook that we designed is shown in Figure 2. In this example, we wanted to address the misconceptions pertaining to the relationship between velocity and acceleration. Acceleration is commonly mistaken to be always in the same direction as the velocity. We made use of the tossing of a ball to set the scene for students to examine the relationship between velocity and acceleration. The tossing of a ball vertically upwards is a common experience in daily life.

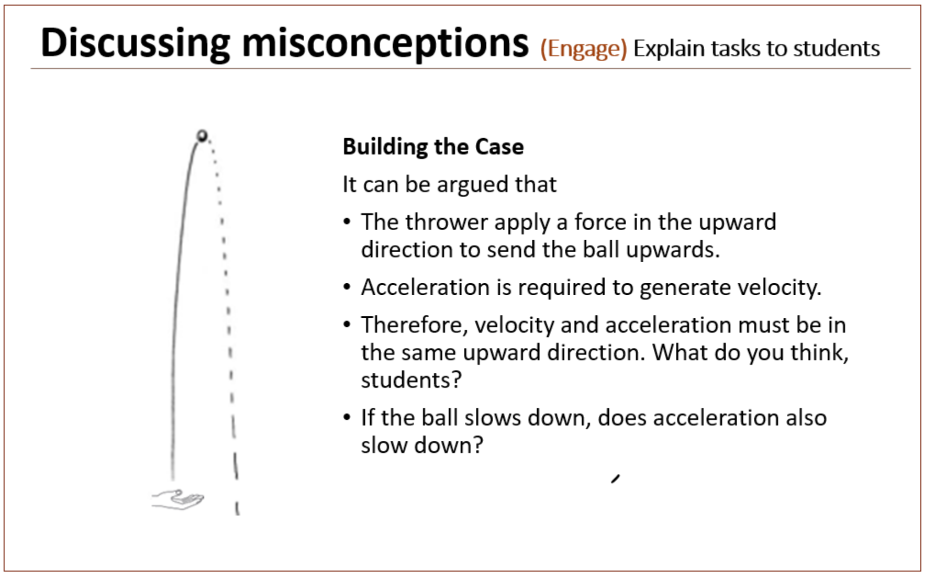

Figure 2. Sample of teaching material used in engaging

In the preparation of materials, we also made use of cartoons, YouTube videos, or even structured questions as our hook. Figure 3 shows an example of a YouTube video being used as a hook.

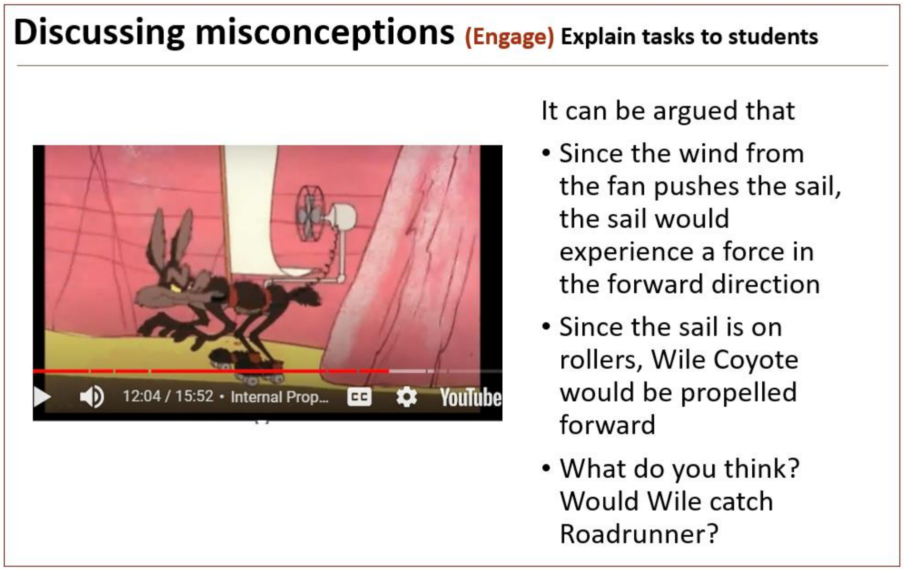

Figure 3 Example of a hook using YouTube videos

Explore

In this second phase of the cycle, the students formed groups to investigate the hook or misconception that was assigned to them. This phase is the main inquiry-based activity, and it incorporates active learning and collaboration. Students were encouraged to work in a cooperative learning environment without direct instructions from the teacher. In some instances, students could design a simple experiment to investigate their hypotheses. Students may also make use of the internet or AI tools such as chatGPT to assist them as they work among themselves to suss out the misconceptions.

In our example of the investigation into the relationship between velocity and acceleration, a total of four hooks, one for each student group, were introduced.

In some lessons, due to lesson time constraints, we delivered the engage phase only and asked students to go through the explore phase as a homework. This deployment can be viewed together as a problem-based learning (PBL) approach, especially if students make use of the FILA chart approach in their explore phase. For the uninitiated, FILA is an acronym for Facts, Ideas, Learning issues and Action plan. This methodology is now a PBL approach because students are presented with a problem to trigger learning as opposed to direct presentation of facts and concepts. Lo (2017) described such an implementation as a flipped classroom technique. When engagement takes place as a pre-assigned task, and students take the exploration of the topic on their own before the start of the next lesson, it reverses the traditional practice of introducing new content at school before assigning homework.

Explain

In this third phase of the cycle, students were asked to explain their understanding of the misconceptions. It is likely that new questions will be generated. The explanation phase is essential because students have to internalise their understanding and articulate their thoughts. In trying to explain their understanding to their classmates, students must address the other misconceptions that their classmates have. Explaining is a mind-on process that crystallizes one's thinking and reinforces one's understanding of the underlying concepts.
After the students had shared their own explanations, the tutor introduced scientific terms and technical information in a direct manner. This phase includes the clarification of any student misconceptions that may have emerged during the engagement or exploration phases and are not satisfactorily dealt with. Formal definitions and notes were also provided at this stage.

Elaborate

In this fourth phase of the cycle, students were required to link their newly acquired concepts and apply them to other applications. That is, they would need to seek out applications and day-to-day phenomena that can be explained using these concepts. The goal was to help students develop a broader and deeper sense of their newly learned concepts. For some topics, students might be asked to do further research on the internet and write a short report of applications that apply those concepts. For other topics, students might only need to attempt some structured questions that were related to applications.

Evaluate

In this fifth phase of the cycle, students were evaluated to assess their understandings and abilities, as well as their progress towards meeting the desired learning outcomes.
Evaluation is an on-going process in all stages and not just at the last stage of the learning cycle, even though in Figure 1, it appears diagrammatically that evaluation is only carried out only at the very end.

In the engagement stages, the tutor evaluates if the students' curiosity has been stirred. In the exploration stage, where the main inquiry-based activity is, the tutor evaluates the students by observing if they have applied the process skills to look for evidence or to test their hypotheses. In the explanation stage, the tutor evaluates the students' thought process and system of thinking. In the elaboration stage, the tutor looks out for the students' ability to apply their new knowledge to different situations through their written reports or answers to the structured questions. Finally, a summative assessment in the form of a quiz would be given to evaluate the students' learning.

Mode of research

The sample in our study comprised of forty-eight students from two classes. The experiment group consisted of twenty-three students from one class and the control group consisted of twenty-five from another class. Students in both classes had similar abilities and scores in their previous summative assessments prior to the introduction of the teaching of misconceptions to the experiment group. This was confirmed through a quantitative analysis of the two groups.

To evaluate the effectiveness our study, we made use of both quantitative and qualitative methods.

Our quantitative evaluation was based on the summative quiz mentioned in the *Evaluate* section. This quiz consisted of two-tier multiple-choice questions. The first tier was a fact-based question, and the second tier was a reasoning-based question. The use of two-tier multiple-choice question permitted higher order thinking skills to be evaluated. An example of a two-tier question that we designed is shown in Figure 4.

1. Mr. Pasan tossed a ball vertically into the air and it landed on the grass patch just in front of him. Which of the following statement is true about the ball's acceleration?

A. Its acceleration at the highest point of motion is zero.
B. Its acceleration at the highest and lowest point of motion is zero.
C. Its acceleration on the upward path is -10 m/s and downward path is +10 m/s.
D. Its acceleration on the upward and downward paths is -10 m/s.

(a)

2. Mr. Pasan tossed a ball vertically into the air and it landed on the grass patch just in front of him. Taking the starting point as the point where the ball leaves Mr. Pasan's hand, which of the following statement is true about the ball?

A. Its displacement and acceleration are always in the opposite direction throughout the entire motion.

B. Its displacement, velocity and acceleration are all in the same direction when the ball has fallen past the starting point.

C. Its velocity and acceleration are always in the opposite directions.

D. Its velocity and displacement are always in the opposite direction when the ball is falling.

(b)

Figure 4. Sample of two-tier question used (a) tier 1 (b) tier 2

In addition, further data were collected through a survey and a focus group. The sample investigated was only on the experiment group of 23 students. The survey comprised a list of dichotomous questions and open-ended questions. These questions aimed to collect the students' perspectives of these lessons on misconceptions.

A group of seven students were selected for the focus group interview. The purpose of the focus group was to clarify some of the responses to the forementioned survey to get a better insight into the dynamics that took place during the lessons.

Results and Discussion

Prior to the introduction of misconceptions, the two selected groups were analysed in terms of their mean scores of a summative assessment to ascertain that they had comparable abilities in Engineering Physics. We conducted a two-sample F-test to ascertain that the variances of score were not significant. This is followed by a two-sample t-test to ascertain that the means of score were not significant. The idea was to increase the likelihood that when misconceptions were introduced into the class, any significant improvement in the student outcome was due to the introduction of the misconception itself.

The null hypothesis for the F-test was that the variances of the two groups were the same and the alternative hypothesis was that the variances were not equal at the 5% level of significance. The analysis was performed using Microsoft Excel, as shown in Table 1. The p-value needed to be doubled, since Excel only performs a one-tailed test, and that yielded a p-value of 0.42, which was greater than the alpha value of 0.05. The test showed that there was no significant difference in the variances of the two groups with a 95% confidence level.

Table 1. F-test on the 2 samples

	Control	*Experiment*
Mean	3.88	3.65
Variance	1.11	0.78
Observations	25.00	23.00
df	24.00	22.00
F	1.42	
P(F<=f) one-tail	0.21	
F Critical one-tail	2.03	

In the case of the two-sample t-test, the null hypothesis was that the mean scores of the two groups were the same and the alternative hypothesis was that the mean scores were not equal, at the 5% level of significance. Again, the analysis was performed using Microsoft Excel and is shown in Table 2. The t statistic of 0.81 was less than the critical value of 2.01. Hence, we did not reject the null hypothesis.

Together, these analyses confirmed that the mean scores of our selected groups were not significantly different and the variability of each group was the same.

Table 2. t-test on the 2 samples

	Control	*Experiment*
Mean	3.88	3.65
Variance	1.11	0.78
Observations	25.00	23.00
Pooled Variance	0.95	
Hypothesized Mean Difference	0.00	
df	46.00	
t Stat	0.81	
P(T<=t) one-tail	0.21	
t Critical one-tail	1.68	
P(T<=t) two-tail	0.42	

t Critical two-tail	2.01

Next, we used the two-sample t-test again to investigate if the deliberate discussion of misconceptions using the BSCS 5E model was effective in clarifying misconceptions. The data was on based on a summative assessment that was carried out after the introduction of such lessons. The null hypothesis was that the mean scores of both the experiment and control groups were the same. The alternate hypothesis was that the mean score of the experiment group was higher than that of the control group. The level of significance was selected at 5%. The data was analysed using Microsoft Excel and our results are shown in Table 3.

Table 3. Result of two-sample t-Test (assuming equal variances)

	Experiment	*Control*
Mean	2.22	1.36
Variance	1.72	0.91
Observations	23.00	25.00
Pooled Variance	1.30	
Hypothesized Mean Difference	0.00	
df	46.00	
t Stat	2.61	
P(T<=t) one-tail	0.01	
t Critical one-tail	1.68	
P(T<=t) two-tail	0.01	
t Critical two-tail	2.01	

The analysis showed that the mean score of the experiment group was greater than that of the control group with 95% confidence level, since the t statistic of 2.61 was greater than the critical value of 1.68. This meant that students in the experimental group had an improvement in scores after receiving lessons discussing misconceptions using the BSCS 5E model.

Furthermore, from our qualitative survey, we found that 84.2% of the students could discover their misconceptions through this mode of instruction and that 89.5% of them agreed that this mode of instruction helped them to understand their concepts.

The outcome of all dichotomous questions of our survey is summarised in Table 4. Active learning took place, as evident in questions 1, 2, 7 and 8. Collaborative learning was demonstrated, based on the outcomes of questions 4, 5 and 6. Relating to real-life situations and getting feedback from the tutor were better ways of reinforcing their concepts, as pointed out in questions 9 and 10.

Table 4. Summary of dichotomous questions in survey

Q.N.	Questions Asked	Agree	Disagree
1	Exploring the solutions with my groups mates helped me to think about the problem from multiple dimensions.	84.21%	15.79%
2	The explore stage helped me to think about the solutions actively.	78.95%	21.05%
3	By exploring the solutions with my group mates, I felt we could learn from one another.	89.47%	10.53%
4	We were able to build on one another's solutions or ideas in our discussion.	89.47%	10.53%
5	I enjoyed the discussion about the problems and solutions with my group mates.	89.47%	10.53%
6	Explaining our solutions to our other classmates help us to think about what our classmates might have misunderstood.	100.00%	0.00%
7	Explaining our solutions to our other classmates made us want to know if they understood us or not	89.47%	10.53%
8	I find trying to explain to our classmate satisfying.	78.95%	21.05%
9	Relating the problem to a real life situation reinforces my understanding of the concept (the Elaborate stage)	89.47%	10.53%
10	Feedback from tutor help me to reinforce my concept.	100.00%	0.00%
11	Overall, I could discover my misconceptions through this method.	84.21%	15.79%
12	Overall, this method helps me to understand the concepts	89.47%	10.53%

We also included open-ended questions in the survey, and found the following:

1. To the question on what the students liked most about the exploration stage, the common responses given were seeking “clarifications” from teammates, “talking and discussing with friends”, and “exploring” different answers on their own. The common response to what they dislike most about exploring was dealing with the “uncertainties”.
2. To the question on what the students like most about the explaining stage, the common responses given were “sharing” and “helping others understand”. What the students dislike most about the explaining stage was giving incorrect answers and not being able to understand the misconceptions of their fellow classmates.
3. To the question on what the students like most about the elaborate stage, the common responses given were that the real-life applications were “interesting”, “useful” and helped “reinforce their understanding”. What the students dislike most about the elaborate stage was answering structured questions based on applications as they found such questions “challenging” despite having learnt about the concepts.
4. To the question on what the students like most about the evaluation stage, the student found the feedback from the tutor useful in their learning. What the students dislike most about the elaborate stage was fear of not doing well in the summative assessment.

The focus group discussion centred on how to improve the delivery of the lesson, the data and results of the focus group discussion is not discussed here because the main focus of this paper was to evaluate if the inclusion of misconception into classroom discussion could improve student outcome. Table 5 shows a sample of the questions asked during the focus group.

Table 5. Focus group questions

1	Provide some suggestions on how to improve the learning material.
2	How do we encourage students to speak up more freely during the explain stage?
3	Do you feel that the environment was safe enough for you to express your thoughts and make mistakes?

4	In what way could the facilitator increase the level of participation in the exploring stage?

Conclusions

A study into the use of the BSCS 5E model mode of instruction for the discussion of misconceptions in the teaching of Engineering Physics was conducted.

Two groups of students with similar mean scores and variances were selected for the study. The experiment group had 23 students and the control group had 25 students.

The introduction of misconceptions in lessons using the BSCS 5E model was effective in improving student's learning outcome. The mean score of students in the experiment group was found to be higher than that of the control group at a confidence level of 95%.

84.2% of the students surveyed agreed that they could discover their misconceptions through this mode of instruction and that 89.5% of them agreed this mode of instruction helped them to understand their concepts.

In general, students benefitted from the BSCS 5E delivery mode. Active learning was achieved, and collaborative learning was demonstrated. Relating to real-life situations and getting feedback from tutor was a better method of reinforcing their concepts.

Feedback from students showed that while they were uncomfortable dealing with uncertainties, they enjoyed exploring and discussing solutions and ideas with their friends. Overall, the introduction of discussion of misconception using the BSCS 5E model was able to improve student learning outcome in Engineering Physics but did not root out misconceptions completely.

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Development and Implementation of a Cognitive Conflict–Based Learning Package: Effects on Grade 10 Students' Conceptual Understanding of Electromagnetism

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Development and Implementation of a Cognitive Conflict–Based Learning Package: Effects on Grade 10 Students' Conceptual Understanding of Electromagnetism

Abstract

This study aimed to investigate the effect of a researcher-developed lesson package using Cognitive Conflict-Based Learning (CCBL) Model on the Grade 10 students' conceptual understanding of Electromagnetism. This study employs Concurrent Embedded Design. One class of Grade 10 students in a secondary public school in Mandaue City, Cebu, Philippines, and a teacher-implementer participated in the implementation of this study. The students answered a pre-test, followed by the implementation of the researcher-developed lesson package in Electromagnetism using CCBL Model. Semi-structured interviews were conducted during the implementation to monitor the change of conception of students during the implementation of the lesson package. A post-test was administered to the students after the implementation phase. Qualitative Content Analysis was employed to obtain the concepts the students have before, during, and after the implementation phase. These concepts were categorized into Sound Understanding, Partial Understanding, Partial Understanding with Alternate Conceptions, Alternate Conceptions, and No Understanding. Paired-sample t-test was used to compare the scores of the students in the pre-test and post-test and Cohen's d-test to measure the effect size. The affordances and challenges were also determined. It was found out that before the implementation phase, a lot of students don't have prior understanding of concepts of Electromagnetism and only few students have sound understanding and partial understanding. It was also found that some students have improved their understanding, and some remained to have difficulty understanding concepts of Electromagnetism. The scores of the students in the post-test (Mean = 12.96, SD = 3.51) are significantly different to their scores in the pre-test (Mean = 9.07,rnSD = 2.31) at t(46) = 6.362, df=45, and p<0.001. This means that the performance of the students based on their scores improved after the implementation of the lesson package in Electromagnetism, with a large effect size (d=0.938). There were affordances and challenges that were encountered during the implementation phase.

Keywords: Conceptual Understanding, Cognitive Conflict-Based Learning Model, Electromagnetism

Introduction

One of the goals of science education is having students achieve a sound conceptual understanding of the topics that are needed to be mastered. As observed in the current K to 12 Curriculum Guide for Science in the Junior High School level, concepts are presented from the basic and simplest ones to an increased complexity as students move from one grade level to another. This way, core concepts are being understood more by the learners. However, the problem is that along the way, they have acquired an understanding of certain concepts and carry that along with their progression onto a higher grade level which is affected by their day-to-day experiences and exposure to different sources of information outside of the classroom. One way to address this one is using cognitive conflict strategy. In this strategy, students are exposed to scenarios that conflict with or depart from their prior knowledge. This helps students replace incorrect concepts with correct ones and rearrange their cognitive structures in such a way that misconceptions will gradually give way to correct ones. Students' initial beliefs will be challenged by the presentation of cognitive conflict, and the cognitive structure will change to rebuild new scientific concepts (Mufit, 2020). This learning can overcome the problem of understanding the concepts experienced by students by integrating deep thinking. Mufit, et al. (2019) used this idea of cognitive conflict strategy to develop the Cognitive Conflict-Based Learning (CCBL) Model. The model was not yet tried on a lesson sequence in Electromagnetism, thus, this study will investigate if the CCBL Model will be effective in addressing the misconception of Grade 10 students in Electromagnetism during and after the implementation of the lesson package anchored on it.

The problem on misconceptions is further highlighted in studying the concepts involving Electromagnetism, which is taught in Grade 10. The alternate conceptions that they have carried from their previous grade levels affects how they understand these concepts. Therefore, the problem of them having the incorrect understanding compounds. One strategy to mitigate this problem is by using simulations. In interactive simulations, the user is often able to change some simulation parameters and see the results of these changes (Dervić, et al., 2018). One simulation program that can be used for this is Physlets®. The outcomes of physics education research were used to generate Physlets, which are little Java applets (Belloni & Christian, 2001) as cited by Dervić, et al (2018). Thus, the integration of Physlets® in the researcher-developed lesson package anchored on the CCBL Model will be another feature of this study.

The use of the CCBL Model in teaching Electromagnetism aligns with the important facets of the recent change in the Philippine educational setting: the implementation of the K to

12 education curriculum. The principle of responding to cognitive conflict-based learning models necessitates student-centered learning, focuses on the learning process, and supports students in developing critical thinking skills. To apply the model, the social system will need cooperation from the students as well as scaffolding from the lecturers to meet the demands of the students. Additionally, there will need to be multidirectional interaction between the students and the lecturers (Mufit, et al., 2019). This supports Constructivism which is the main basis of the K to 12 Curriculum Framework. This also is compatible with one of its features, which is the "spiral progression". The integration across science topics and other disciplines will lead to a meaningful understanding of concepts and their application to real-life situations (DepEd, 2016). This means that learners are expected to have mastery of the basic skills and concepts. CCBL Model will help students master and enhance their conceptual understanding of the concepts in Electromagnetism. Furthermore, the use of Physlets® will answer another important aspect of the recent educational reform in the Philippines, which is ICT Integration in classroom instruction. The onset of the COVID-19 pandemic further highlighted its importance. Teachers are the primary users of ICT in their regular classroom settings, assisting in the process of educating pupils for the contemporary digital era. The topic of ICT integration in schools, specifically in the classroom, is crucial since students are accustomed to technology and would learn better in a technology-based setting (Agatep & Maquio, 2022). In Physics, one way to integrate the use of ICT both by the teacher and the students is by using simulations.

The implementation of a lesson package in Electromagnetism anchored on the CCBL Model will also align with the directive of the DepEd of implementing intervention programs for learners. According to DepEd Order No. 39, series of 2012, that immediate interventions for bridging gaps must be put in place as a matter of urgency. If these learning gaps will continue to compound and accumulate, then it will be a burden for the learners to catch up. This only means that there must be an implementation of an intervention program that can help students have mastery over concepts in Physics, especially in Electromagnetism, which is taught in Grade 10. In the current situation of our educational setting, this has been a problem that has not been properly addressed. This is evident in the results of the Programme for International Student Assessment (PISA) Result from 2018, which was administered to fifteen-year-old learners. As experienced in the field, concepts in Electromagnetism are the least mastered by the students due to its abstract nature and complexity. Experiments are a great help in making the students concretize these abstract concepts, however, the scarcity of materials and the absence of a proper laboratory hinders their implementation by the teachers, thus making them adhere to lecture-based discussions. The use of Physlets® will be a great alternative to these experiments to help the students understand better the concepts in Electromagnetism.

Having discussed these imminent gaps and problems, this study focused on the use of Cognitive Conflict Based Learning (CCBL) Model together with the six-stage conceptual change model (CCM) by Stepans (1999), cited by Surtiana, et al. (2020), in helping improve the conceptual understanding of learners in Grade 10 on the unit of Electromagnetism during and after its implementation. Furthermore, the study employed the use of Physlet® Physics 3E: Interactive Illustrations, Explorations, and Problems for Introductory Physics by Christian, et al. (2013). The results of this study contributed to the literature by checking the evolution of the conceptual understanding of students during, and after the implementation of the lesson package in Electromagnetism. The procedure involved the conduct of a two-tiered pre-conceptual test followed by the development, validation, and implementation of the lesson package in Electromagnetism anchored on the CCBL Model, and then the conduct of the same conceptual test after the implementation of the lesson package.

Statement of the Problem

This study aimed to investigate the effect of a researcher-developed lesson package using Cognitive Conflict – Based Learning (CCBL) Model on the Grade 10 students' conceptual understanding in Electromagnetism. Specifically, it aimed to answer the following questions:

1. What are the students' initial conception in Electromagnetism?
2. What lesson package may be developed to address students' alternate conceptions in Electromagnetism using CCBL Model?
3. How did the students' alternate conceptions change during and after the implementation of the lesson package?
4. What are the affordances and challenges encountered in implementing the lesson package using CCBL Model?

Review of Related Literature

This section presented the theories, models, approaches, and concepts upon which this study was anchored on. First, the theory of constructivism was discussed as the fundamental theory of learning of the researcher-developed lesson package. Next, the conceptual change model was discussed as the model of learning that supports constructivism. In connection with this, the cognitive conflict strategy was discussed as the main model of learning for teacher intervention. The establishment of conceptual change among students using simulations and also why there is a move to use simulation programs in teaching Physics, in particular, Electromagnetism was then discussed. Lastly, the anchor topic and target concepts in Electromagnetism were discussed as stipulated in the K to 12 Science Curriculum for Grade 10 (DepEd, 2016) and some studies that talked about the teaching and learning of Electromagnetism.

Constructivism

Constructivism is a learning theory that claims that the best way to absorb knowledge is through reflection and active mental building. Knowledge, then, is a subjective interpretation. The student must analyze the facts being taught and build an interpretation based on prior experiences, personal beliefs, and cultural background (Brau, 2022). It is a method of teaching and learning that aims to increase student comprehension. It's a way of thinking about how people build their own understanding and knowledge of the world by doing things and reflecting on them. It occurs when a student connects his or her preconceptions to new knowledge that is presented to him or her. This occurs in the classroom when teachers assist students in applying their prior knowledge to better understand a more difficult concept. The pre-existing conceptions act like a scaffold in reaching and mastering a more complex skill or concept.

Jean Piaget's work influenced cognitive constructivism. According to him, humans cannot be handed information that they understand and utilize right away; instead, they must generate their own knowledge. Furthermore, as children progress through Piaget's four stages of development, they establish their schema through assimilation and accommodation. Piaget's (1953) four stages of development are the Sensorimotor stage, which a child goes through from ages zero to two; the preoperational stage (two to seven years old), the concrete operational stage (seven to eleven years old), and the formal operational stage (eleven years old to adulthood). Piaget's theory includes assimilation and accommodation, which are processes children go through in a search for balance or "equilibration" (Wadsworth, 2004). When describing Piaget's theory, "equilibration occurs when children shift from one stage to another and is manifested with a cognitive conflict, a state of mental unbalance or disequilibrium in trying to make sense of the data or information they are receiving. Disequilibrium is a state of being uncomfortable when one must adjust his or her thinking (schema) to resolve conflict and become more comfortable" . According to Piaget (1953), assimilation occurs when children incorporate new information or knowledge into their schémas, whereas accommodation occurs when children must alter their schémas to "accommodate" the new information or knowledge. When learning, this adjustment occurs as new information is processed to fit into what is already in one's memory. In the classroom, teachers must assist this process. Piaget's theories of equilibration, assimilation, and accommodation all deal with children's ability to generate new knowledge cognitively or autonomously within their stages and resolve conflicts (Piaget, 1953). Recognizing that this process occurs at a variable rate in each student aids the teacher in facilitating constructivist learning.

Teachers should not just transfer knowledge to students, according to one of the most essential concepts of educational psychology. Students must create their own information in their heads. The key to the future is education. Tomorrow belongs to those who start preparing today. As a reflection of Piaget's personal constructivist character, the metacognitive constructivist model includes the notions of schemata, cognitive conflict, assimilation, accommodation, and equilibration in learning syntax. As a depiction of the character of metacognitive strategies, students who learn to apply the metacognitive constructivist model will be guided to plan, monitor, and assess the achievement of learning objectives and techniques (Efgivia, et al., 2020).

Vygotsky's social constructivism places a strong emphasis on learning through guided discovery. This implies that children learn through interaction with their social and physical environments. In one's sociocultural setting, learning is easier to discover. The Proximal Development Zone (ZPD) or the Proximal Development Zone and mediation are the core concepts of sociocultural learning theory, which focuses on how a person learns with the assistance of others to understand something and solve the challenges he encounters, within a zone of his own limitations. This idea places a strong emphasis on how society, environment, and culture all influence human intelligence. Additionally, according to this idea, interpersonal (interaction with the social environment) and subsequently intrapersonal learning are the two primary ways that individuals acquire cognitive skills (internalization that occurs within oneself). In this study, the focus on Piaget’s idea of assimilation and accommodation will be highlighted as the core idea of the change of conceptual understanding of students. This leads to the objective of correcting misconceptions of students through conceptual change. In addition to that, the idea that through interactions and influence from the environment affects how students build their conceptual understanding, this study will employ structuring of lesson and learning experiences of students to attain conceptual change.

Conceptual Change

According to a paper by Flaig, et al. (2018) conceptual change, or reorganization, is required. Prior knowledge of the learner is required for the acquisition of new conceptual knowledge. Prior knowledge influences and constrains how new information is interpreted and stored in memory. It frequently arises from observations and explanation attempts made outside of formal training and thus might be incompatible with the scientific principles to be learnt. This helps to explain why grasping academic subjects can be so challenging. Educational, developmental, cognitive, and philosophical scientists have studied conceptual transformation and found it useful in content domains as diverse as physics, chemistry, biology, mathematics, medicine, and the social sciences (Carey, 1985; Posner, et al., 1982; Vosniadou, 2008).

The fragmentation and integration of information are two essential component stages of conceptual change, according to research with school-aged children. Observations, hypotheses, explanations, analog mental models, mental representations, category exemplars, and subjective knowledge can all be found in networks of conceptual knowledge in long-term memory (Flaig, et al., 2018). Another form of knowledge fragmentation is the fact that remembering correct concepts in long-term memory does not always mean forgetting related misunderstandings. In long-term memory, naive errors and scientifically correct concepts or parts of them can coexist and do so regularly, not only in youngsters, but also throughout life (Shtulman & Harrington, 2016, as cited by Flaig, et al. (2018). Learners do not always understand when they have fragments of knowledge in long-term memory that support or contradict one other because fragmented knowledge is triggered based on context. As a result, one of the most essential goals of instruction is to integrate fragments of knowledge into a coherent overarching knowledge framework.

A study by Li, et al. (2021) in science education states that meaningful learning for conceptual change should attempt to assist students in changing their existing beliefs and developing an accurate knowledge of scientific topics. The primary goal of science education is to increase student scientific literacy (NGSS, 2013; NRC, 2012). Students with higher levels of scientific literacy have a better understanding of and capacity to apply scientific principles to construct explanations or predictions about natural phenomena. Because many misconceptions are robust and resistant to educational interventions and teaching approaches, science educators and practitioners have reported that it can be difficult to help students change their existing misconceptions to develop an accurate understanding of scientific concepts (i.e., conceptual change). They cited Chi (2008) who stated that "Conceptual change does not imply the addition of new knowledge or the filling of gaps in existing knowledge; rather, it entails the transformation of misconceptions in existing knowledge systems into an accurate grasp of scientific concepts." To put it another way, conceptual change occurs when students improve their ability to construct and identify a scientifically accurate and complete scientific explanation, requiring a substantial reorganization or revision of their existing knowledge structures that were previously distorted by misconceptions. Many previous studies have found that achieving conceptual change in science education is difficult because some misconceptions are stable, robust, and resistant to traditional tell-and-practice teaching approaches and even innovative instructional interventions. Furthermore, determining how to maintain conceptual change over time is an emerging problem in science education.

A study by Harteis, et al. (2020) states that, "Conceptual change research looks into learning that necessitates a significant revision of existing knowledge and the acquisition of new concepts, usually under the supervision of a teacher." Conceptual change is a cognitive achievement that Piaget (1976) defined as accommodation: when an individual's schemata or mental models fail to adequately represent a phenomenon, he or she creates a new mental model that does. Most of the research on conceptual transformation comes from scientific education, although it is applicable to other areas of learning as well.

The six-stage conceptual change model (CCM) by Stepans (1999) will be the main basis for this study. This model, which is also patterned with the conceptual change model of Posner, et al. (1982) is one of the conceptual change-oriented instruction models that is frequently used for remedial teaching with the method of face-to-face learning in the classroom, as cited by Surtiana, et al. (2020). It consists of the following six stages of the learning process: 1) The phase in which students' conceptions are disclosed, 2) The phase in which students' conceptions of beliefs are disclosed, 3) The phase in which conception beliefs are confronted, 4) The phase in which new conceptions are accommodated, 5) The phase in which conception reinforcement is strengthened, and 6) The phase in which conception is expanded.

The researcher-developed lesson package featured the six-stage conceptual change model (CCM) by Stepans (1999) as its main framework. This built up on the idea of Cognitive and Social Constructivism to help students develop their conception in Electromagnetism.

Cognitive Conflict Strategy

Researchers have looked into the benefits of cognitive conflict strategies, particularly in overcoming misunderstandings or conceptual changes. In a study by (Wartono, 2018), they presented that cognitive conflict strategies helps in achieving conceptual change among students regarding their misconceptions of concepts on Light. Cognitive conflict strategies present students with circumstances in which their prior knowledge is contradictory or diverse. It is hoped that students will be able to replace outdated ideas with accurate ones and rearrange their cognitive structures in such a way that incorrect ideas will gradually give way to accurate ones. The objective of the cognitive conflict technique is to alter the conceptual understanding of physics held by students (Wartono, 2018). Furthermore, Mufit, et al. (2018) created a Cognitive Conflict Based Learning (CCBL) paradigm through the design and implementation of research in an effort to enhance conceptual understanding and correct mistakes. Four types of syntax make up the CCBL model: (1) activation of preconceptions and misconceptions; (2) presentation of cognitive conflict; (3) discovery of concepts and equations; and (4) reflection. The response to cognitive conflict-based learning models premise calls for student-centered learning, is focused on the learning process, and encourages students to engage in deep thought. The social framework for putting the concept into practice calls for student participation, the requirement for scaffolding from lecturers in accordance with students' needs, and multidirectional interaction between students and lecturers.

Cognitive conflict or conceptual conflict strategies are also in line with constructivism theory's guiding principles, which encourage learners to create their own new ideas or body of knowledge. By rushing to deliver the material without taking the time to ask students about their prior knowledge, teachers do not monopolize learning. Students are given the chance to recognize conceptual errors (misconceptions) that could happen when developing new concepts, and this causes cognitive difficulties for students when trying to understand a new concept correctly. Cognitive conflict tactics teach students to think critically, identify and admit faults, discover and test ideas, and create new ideas or concepts (Mufit F., et al., 2018).

The Cognitive Conflict Based Learning Model, together with the Conceptual Change Model by Stepans (2006) was the main basis for the framework of the researcher-developed lesson package for the intervention of student’s misconceptions of Electromagnetism, which was the focus of this study.

ICT-Based Teaching and Simulations

A lot of physics textbooks also call for classroom demonstrations of physics ideas, but due to the limitations of available media for experimentation and demonstration, not all physics phenomena can be explicitly demonstrated by a teacher. Thus, adherence to ICT integration in classroom instruction has become the trend.

Mufit, et al. (2019), used CCBL Model together with real experiments video analysis to address misconceptions on motion concepts. The use of ICT tools such as video cameras and trackers is a proof that ICT integration is possible in classroom instruction. However, there weren't always learning resources available for experimentation and demonstration. Time constraints and following the schedule of competencies limits the capacity of teachers to conduct this kind of ICT integration. Thus, researchers are becoming more interested in exploring the possibility of using simulation as a teaching tool as a result of advancements in computer technology. According to a number of studies, simulation can improve learning by fostering conceptual changes in students and enhancing knowledge of science content and process skills (Eveline, et al., 2019).

In interactive simulations, the user is often able to change some simulation parameters and see the results of these changes (Dervić, et al., 2018). Thus, the problem of misconception can be addressed using simulations. One simulation program that can be used for this is Physlets®. The outcomes of physics education research were used to generate Physlets, which are little Java applets (Belloni & Christian, 2001) as cited by Dervić, et al. (2018). In contrast to the majority of other simulation programs for physics education, Physlets® are available for free use at https://www.compadre.org/physlets and cover almost all of the topics that are generally covered in beginning physics courses at the university level. Another unique aspect of Physlets® is that the package offers simulation-style physics tasks in addition to pictures and explorations for all beginning physics topics (Dervić, et al., 2018).

To help students visualize abstract concepts in Electromagnetism, the researcher-developed lesson package utilized the simulations on Physlets® and integrated them on the lesson plans which helped students build their conception in Electromagnetism and therefore addressed their misconceptions.

Teaching and Learning Electromagnetism

Based on the K to 12 Science Curriculum developed by the Department of Education, the concepts on Electromagnetism are taught in Grade 10. Furthermore, the concepts on Electricity are already taught as early as Grade 7, therefore showing the spiral progression of topics that is the key feature of the curriculum. This shows that the students should have already mastered the prerequisite skills and knowledge on Electromagnetism by the time the reach Grade 10. However, the results of the the Programme for International Student Assessment (PISA) Result from 2018, which was administered to fifteen-year-old learners, has shown that the Philippines scored 357 points, which puts it in the second-to-the-last place.

Furthermore, only 22% of the participants achieved a Level 2 or higher proficiency in the subject area. This only shows that majority of learners upon reaching Grade 10, in which the average age is fifteen years old, still have not mastered skills that have been taught in the lower grade levels. Also, based on the spiral progression of topics, the topics involving Electromagnetism that are taught in Grade 10 are the most complex in the Junior High School level.

According to Gunstone, et al. (2009) as cited by Mbonyiryivuze, et al. (2019), physics and science curricula at the primary, secondary, and tertiary levels of education place a strong emphasis on the study of Electromagnetism. Moreover, Electromagnetism, as one of the fundamental domains and essential topics in physics, have applications embracing a wide range of aspects of our daily lives. However, it has been noted that this field has a number of topics where students form views that differ from those that are held to be true scientifically (Turgut, et al., 2011; Li, 2012). Due to their abstract and complicated nature, topics connected to Electromagnetism are particularly challenging for students to understand (Arnold & Millar, 1987; Mulhall, et al., 2001; Miokovi, et al., 2012).

Numerous researchers have noted pupils' difficulty with Electromagnetism, according to Bagno and Eylon (2022) as cited by Rendon, et al., (2022). Learning concepts, understanding them, and determining how the concepts relate to one another to solve problems are all tough tasks for students. Success in solving quantitative problems is not a reliable indication of conceptual understanding. Research shows that although students are excellent at solving quantitative problems, they have trouble with conceptual ones. Some students succeed academically even when they don't fully understand some basic physics concepts. Additionally, it has been shown that most students do not possess the necessary conceptual understanding when asked to solve problems in a variety of developing nations (Mbonyiryivuze, et al., 2019).

This further showed that there must be an intervention against the misconception of students that they had acquired from the previous grade levels, and that the use of the cognitive conflict-based model (CCBL) was tested in teaching Electromagnetism in Grade 10 students.

Thus, in this study, the researcher-developed lesson package was anchored on the Cognitive Conflict – Based Learning Model, which was supported by the Constructivist Theory and the Conceptual Change Model. Furthermore, to help concretize abstract concepts in Electromagnetism, Physlets® was used as a simulation application and was integrated in the lesson package to demonstrate examples and scenarios for students.

Methodology

Research Design

The purpose of this study was to address the misconceptions that Grade 10 students had in Electromagnetism by developing a lesson package anchored on the Cognitive Conflict-Based Learning (CCBL) Model. This study used Concurrent Embedded Design, which employed both qualitative and quantitative methods to obtain data. In this design, the qualitative and quantitative data were obtained concurrently and simultaneously, but one is given priority than the other (Creswell & Plano Clark, 2007; Almeida, 2018) Obtaining the qualitative data was embedded in the process of obtaining the quantitative data since the quantitative data couldn't sufficiently answer the main problem and thus needed a qualitative approach to accurately discuss the results of the implementation of the study. Following this design, the quantitative data from the pretest and posttest results was obtained together with the qualitative data which came from the explanations of their answer after each item of the pre-test and post-test, but with more emphasis on the latter, with the former serving as a support to help answer the research problems. This also followed a one-group, pre-test-post-test design, in which one (1) intact section of Grade 10 students was chosen through a draw-by-lot system. Also, additional qualitative data was obtained during the implementation of the lesson package, which came from responses to the semi-structured interview questions that was asked to the participants during the implementation of the lesson package, and the observation notes of the researcher on the implementation of the lesson package by the teacher-implementer.

Research Procedures

The process of data gathering occured in the first half of the Second Semester of the academic school year 2022-2023. The data gathering consisted of the following Phases: *Phase I: Conduct of the Pre-test, Phase II: Development, Validation, and Implementation of the Lesson Package Anchored on the Cognitive Conflict-Based Learning (CCBL) Model, and Phase III: Conduct of the Post-test and Evaluation.* In consideration of the ethical standards, the researcher sought approval from the Division Superintendent, Principal, Grade 10 students that were the participants of this study, and their parents and/or guardians. The following sections explain the data gathering in detail.

Phase I: Conduct of the Pre-test.

The researcher administered the concept test comprised of 30-multiple choice items on the topic of Electromagnetism to the students. The number of students per category of understanding was obtained to determine the alternate conceptions. Moreover, the students will be grouped based on their scores: high (top three highest scorers), low (three lowest scorers), and middle (randomly selected near the median score), which was done due to the low scores of the students in the pre-test (highest score was 15 out of 30). The results of the pre-test and the basis of groupings was kept confidential by the researcher.

Phase II: Development, Validation, and Implementation of the Lesson package Anchored on the Cognitive Conflict-Based Learning (CCBL) Model.

Based on the data from the pre-test, a lesson package anchored on the Cognitive Conflict-Based Learning (CCBL) Model was developed and validated by subject-matter experts in Science. After it was validated, it was implemented for a duration of three weeks. This is equivalent to 12 Science meetings. The concepts covered in the Lesson package were based on the Science Curriculum Guide for Grade 10. The progress was checked according to the schedule (see Appendix F). Interviews were also conducted to check the change in conception of students during the implementation of the lesson package.

Phase III: Conduct of the Post-Test and Evaluation.

After the implementation of the lesson package, a post-test was administered. Same with the pre-test, the number of students per category of understanding was obtained to determine the alternate conceptions. The conceptual understanding for both pre- and post-test was determined and compared. The affordances and challenges was determined from the semi-structured interview.

Results And Discussion

Initial Conceptions of Students of Electromagnetism

Forty-six (46) students answered the Conceptual Test in Electromagnetism developed by Caballero (2018), which is a two-tiered, multiple-choice test. The students provided explanations on why they thought their answer is correct. To determine the conception of students before the implementation of the lesson package in Electromagnetism, the answers of the students in the second tier were scored 0-4 based on a rubric used in the study of Kurnaz and Eksi (2015) which they adapted from Abraham, et al. (1994). The conceptions are categorized into Sound Understanding (SU) which are responses from students that scored 4 points and contain all parts of the scientifically accepted concepts, Partial Understanding (PU) which are responses from students that scored 3 points and contain a part of the scientifically accepted concept, Partial Understanding with Alternate Conceptions (PU-AC) which are responses that scored 2 points and show understanding of the concept but have alternate conceptions, Alternate

Conceptions (AC) which are responses that scored 1 point and are scientifically incorrect, and No Understanding (NU) which are responses that scored zero point and that means any of the following: the students did not give any explanation for their answers and left it blank, the response is irrelevant or unclear, or they only repeat the description of the choices for the question (Kurnaz and Eksi, 2015; Abraham, et al., 1994). Qualitative Content Analysis (QCA) was employed on the answers that fall for each category to determine their conceptions. There were four major concepts of Electromagnetism that were targeted in the conceptual test: Magnetism, Magnetic Field Produced by Current, Force of a Current on a Field, and Electromagnetic Induction (see Appendix F).

For the major concept of Magnetism (items 1 – 7 of the Conceptual Test for Electromagnetism), the students' initial conceptions are presented in Table 1, which are categorized into SU, PU, PU-AC, and AC.

Table 1. *Students' Initial Conceptions of Magnetism*

Sound Understanding (SU)	**Partial Understanding (PU)**	**Partial Understanding with Alternate Conceptions (PU-AC)**	**Alternate Conceptions (AC)**
1. Same poles repel, opposite poles attract. 2. A compass can be used to identify the poles of a magnet. The compass needle points to the North Pole of the magnet. 3. The curved lines represent the	1. The end of the bar facing the magnet is the south pole and the other end is the north pole. 2. The diagram shows the magnetic field around the magnet with two poles.	1. Electric charges can attract and repel, while magnetic poles only attract. 2. Electric charges can attract and repel, while magnetic poles only repel. 3. The magnetic board shows magnetic field	1. The magnetic field strength is the same anywhere around the magnet. 2. If two magnets are facing each other, their poles switch. 3. Magnetic field lines are represented by straight lines from

magnetic field of a magnet and run from North Pole to South Pole. 4. Magnetic effect is caused by moving charges, while electric field is present in stationary charges.	3. Magnetic poles do not exist alone, and electric charges can. 4. Magnetic field is stronger at the poles of a magnet. 5. A magnetic board shows the direction of the magnetic of a magnet. 6. A compass can help identify the poles of a magnet.	lines direction from South to North. 4. Electric charges can't exist alone while magnetic poles can. 5. In a magnet, each area have. different strength of magnetic field, including in the North pole and South pole. 6. The south poles are both negative, so they repel. 7. Not only North Pole and South Pole can attract, but it is also same everywhere in the magnet.	the North Pole and South Pole 4. Magnets repel each other, regardless of what poles are facing each other. 5. North pole receives current. 6. South pole is attracted to south pole. 7. We can locate the magnetic field using a string. 8. If one end of the iron bar is facing North Pole of a bar magnet, it will be North Pole, and the other end is also North Pole. 9. The poles of a magnet can attract objects placed ½ inch from it. 10. Magnet absorbed the water, so it's easier to locate the poles in the water.

	11. Magnets with North Pole of one magnet facing the South Pole of another magnet will be easy to separate. 12. Magnetic poles only attract. 13. The iron bar has North poles at both of its ends. 14. North Pole of a magnet is always to the left and South Pole is to the right.

We can see in Table 1 that there are four conceptions that are categorized as sound understanding in which the most common conception was “Same poles repel, opposite poles attract” which constitutes 39.13% of students getting it and the two conceptions “The curved lines represent the magnetic field of a magnet and run from North Pole to South Pole” and “A compass can be used to identify the poles of a magnet. The compass needle points to the North Pole of the magnet” are the least common ones with only 2.17% of students knowing them (See Appendix H). There are six conceptions that are categorized as partial understanding, in which the most common conception was “A magnetic board shows the direction of the magnetic of a magnet” with 17.39% of students getting it and the least common conception was “Magnetic poles do not exist alone, and electric charges can” with only 4.35% of students knowing it. There are seven conceptions that are categorized as partial understanding with alternate conceptions, in which the most common conception was “Electric charges can attract and repel, while magnetic poles only attract” which constitutes 13.04% of students getting it. Also, there are also a few concepts that is unique to one student only or 2.17 % of the total number of respondents. There are fourteen conceptions in total that are categorized as alternate conceptions in which the most common concept was the idea that "The magnetic field strength is the same anywhere around the magnet" which constitutes 10.87% of students getting it. There are also a few concepts that are unique to one student only or 2.17 % of the total number of respondents. We can see that fewer students have a sound understanding and partial understanding compared with those having alternate conceptions.

For the major concept of Magnetic Fields Produced from Currents (items 8 – 14 of the Conceptual Test for Electromagnetism), the students' initial conceptions were presented in Table 2, which are also categorized into SU, PU, PU-AC, and AC.

Table 2. *Students' Initial Conceptions of Magnetic Fields Produced by Currents*

Sound Understanding	**Partial Understanding**	**Partial Understanding with Alternate Conception**	**Alternate Conceptions**
	1. The innermost loop is where the magnetic field is the strongest since it has the least circumference. 2. The same side of the electromagnets are facing each other so they repel. 3. Moving charges create magnetic field.	1. The electromagnets have the same poles facing each other so their forces cancel. 2. Any charged particle produces magnetic field.	1. The three loops show the same pattern of magnetic field so the strength is the same. 2. The magnetic field has the same direction as the current in the wire. 3. Same ends of the electromagnets are facing each other so they move towards each other.

	4. Turning the conductor into a coil with several turns makes the magnetic field stronger.	4. Magnetic field causes radiation that attracts objects. 5. Using thinner wire can make magnetic field stronger. 6. Only permanent magnets produce magnetic fields. 7. Magnetic field will be reduced to half since they are on the same direction with the current. 8. Any charges particle produces magnetic field like when you rub a balloon and it makes your hair stick to it. 9. The direction of the magnetic field is circling to the left. 10. Magnetic field exists as magnets are found in soil. 11. Permanent magnets only

			produce magnetic field.

In Table 2, we can see that there were no conceptions categorized as sound understanding. There are a total of four conceptions that are categorized as partial understanding in which the most common conceptions are “The innermost loop is where the magnetic field is the strongest since it has the least circumference” and “The same side of the electromagnets are facing each other so they repel” which constitutes 8.70% of students getting them and the least common conception was “Turning the conductor into a coil with several turns makes the magnetic field stronger.” with only 4.35% of students knowing it. There are a total of four conceptions categorized as partial understanding with alternate conceptions in which the most common conception was “The electromagnets have the same poles facing each other so their forces cancel” which constitutes 6.52% of students getting them and only 4.35% of students got the idea that any charged particle produces magnetic field”. There were also eleven conceptions categorized as alternate conceptions in which the most common conception was “The three loops show the same pattern of magnetic field, so strength is the same” which constitutes 15.22% of students getting it. There are also a number of concepts that are unique to one student only or 2.17 % of the total number of respondents (see Appendix H). There are also more alternate conceptions compared to conceptions that are categorized as sound understanding and partial understanding.

Presented in Table 3 were the students’ initial conceptions of Force of a Current in a Field (items 15 – 21 of the Conceptual Test for Electromagnetism), which were also categorized into SU, PU, PU-AC, and AC.

Table 3. *Students’ Initial Conceptions of Force of a Current in a Field*

Sound Understanding	**Partial Understanding**	**Partial Understanding with Alternate Conception**	**Alternate Conceptions**
1. Electric motors work by converting electrical energy	1. We need electricity to produce mechanical		1. Magnetic Field and current are in the same direction, that’s

to mechanical energy in order to create motion.	energy to make the toy car move. 2. The wire is placed in a uniform magnetic field, so it experiences magnetic force. 3. The loop's rotation is lessened if magnetic field strength decreased. 4. The rotation of the loop will be faster since the amount of current is doubled. 5. Electrical energy is supplied to the car and it moves. 6. The direction of the magnetic force depends on the direction of the current.		why the loop's rotation will be reduced to half. 2. Current in the wire will stop if placed in a uniform magnetic field. 3. The force has no function in the setup 4. There is no force since it does not show its right direction. 5. Magnetic field direction is either to the left or right of the conductor because its very fast. 6. Electric Motor has mechanical energy

We can see in Table 3 that only one student or 2.17% of the total got the lone conception categorized as sound understanding is "Electric motors work by converting electrical energy to mechanical energy in order to create motion". Six conceptions were categorized as partial understanding in which the most common was "We need electricity to produce mechanical energy to make the toy car move." which constitutes 6.52% of students getting it.

Also, a few concepts are also unique to one student, or 2.17 %. There are no conceptions that are categorized as partial understanding with alternate conceptions. There are a total of six conceptions which are alternate conceptions, in which only one student or 2.17% has answered.

Presented in Table 4 were the students' initial conceptions of Electromagnetic Induction (items 22 – 30 of the Conceptual Test for Electromagnetism), which were also categorized into SU, PU, PU-AC, and AC.

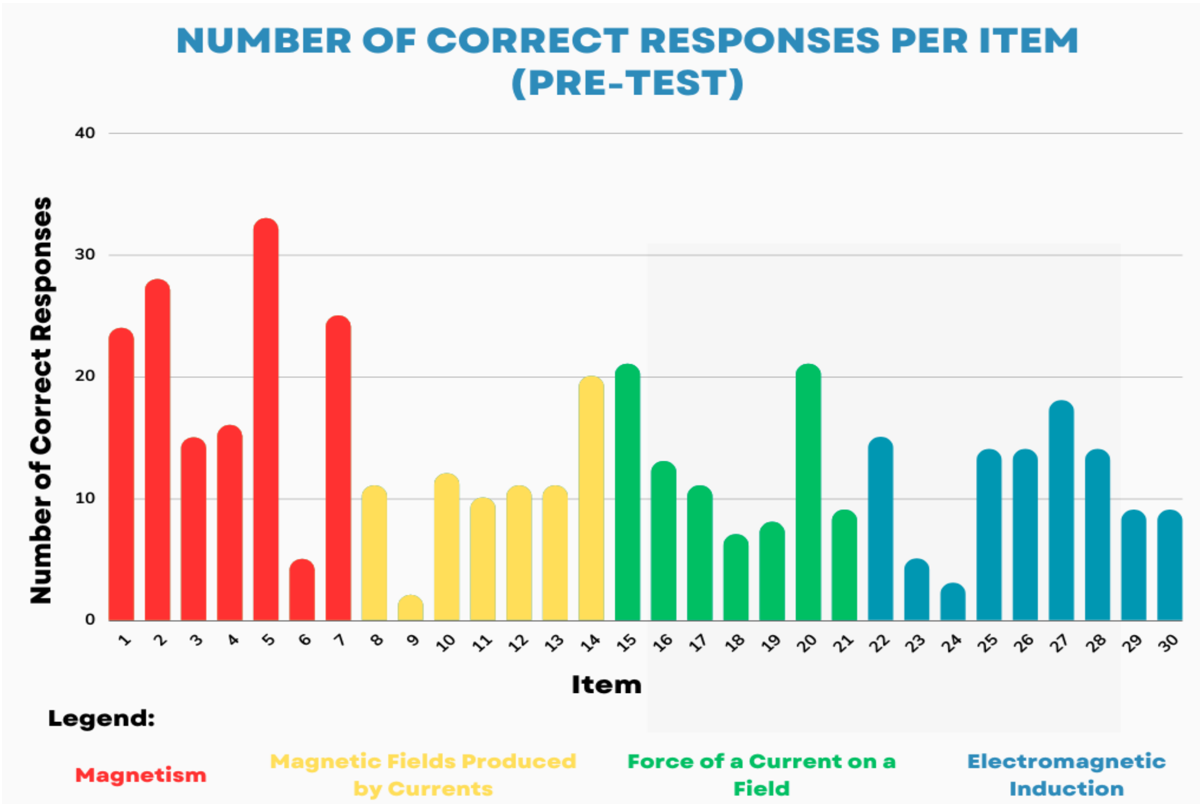
Table 4. *Students' Initial Conceptions of Electromagnetic Induction*

Sound Understanding	**Partial Understanding**	**Partial Understanding with Alternate Conception**	**Alternate Conceptions**
			1. More number of magnets will be easier to move inside the coil

In Table 4, only one alternate conception was derived which was "More number of magnets will be easier to move inside the coil", and 6.52% of students have this conception (See Appendix H).

Figure 1 showed the number of correct responses per item number for the pre-test. The graph was also color-coded to represent the items that fall under each of the major concepts of Electromagnetism.

Figure 1. *Number of Correct Responses per Item for the Pre-test*



We can see from Figure 1 that for the concept of Magnetism, item number 5 has the highest number of correct responses with students having 33 correct answers. This item targets the concept that the magnet has a magnetic field that is directed away from the north pole and towards the south pole, and the item with the least number of students having a correct response is item number 6, which targets the idea that magnetic poles cannot exist alone in contrast with electric charges, with only five students answering it correctly. For the concept of Magnetic Fields Produced by Currents, item number 14, which targets the relationship of the magnetic field strength to the radial distance of the loop of wire, has the highest number of correct responses with 20 students getting correct, and the item with the least number of students having a correct response is item number 9, with only two students having the correct answer. For Force of a Current in a Field, item number 15, which targets the idea of the magnetic force experienced by a current-carrying wire placed on a uniformed magnetic field, and item number 20, which targets the idea of the relationship between the strength of the magnetic field with the rotation of the loop of wire while keeping the current constant, has the highest number of correct responses from students with 21 students having the correct answer, and the item with the least number of students having a correct response is item number 18, which targets the idea of the direction of the magnetic force a rectangular circuit experiences in a uniform magnetic field, with seven students having the correct answer. For Electromagnetic Induction, item number 27, which targets the idea of the amount of induced emf on a moving conductor placed in a uniform magnetic field, has the highest number of correct responses with 18 students getting the correct answer. The item with the least number of students having a correct response is item number 24, which targets the idea of the direction of the induced current in a coil moving away from a uniform magnetic field at constant speed, with five students getting the correct answer. Overall, item number 5 has the greatest number of students getting the correct answer and item number 9 has the least.

Table 5 shows the number of students per category of understanding during the pre-test, which includes now the students having no understanding of the concepts of Electromagnetism.

Table 5. *Categories of Understanding of the Students' Initial Conceptions (N=46)*

Item No.	**SU**	**PU**	**PU-AC**	**AC**	**NU**
1	18		1	10	17
2		7		6	33
3		4		8	34
4	1	1	1	8	35
5	1	16	1	3	25
6	1	3	4	7	31
7	1	5		4	36
8		5	1	5	35
9				8	38
10		1	1	2	42
11		2		9	35
12		1	1	3	41
13		4	1	6	35
14		1		1	44
15		2		1	43
16				4	42

17				5	41
18				2	44
19		1			45
20		2		1	43
21	1	4		2	39
22					46
23					46
24					46
25				3	43
26					46
27					46
28					46
29					46
30					46

For Magnetism, item number 1, which targets the concept of “Like poles repel and unlike poles attract”, has the greatest number of students having a sound understanding, and the least number of students having no understanding. However, it does not have the highest number of correct responses as seen in Figure 1. This means that some students only know a part of the scientifically accepted concept while some have alternate conceptions. Item number 5, which targets the concept that the magnet has a magnetic field that is directed away from the north pole and towards the south pole, has the second least number of students having no understanding and the highest number that has partial understanding, while having the highest number of correct responses. This means that some students know a part of the scientifically accepted concept for this item. Item number 6, which targets the idea that magnetic poles cannot exist alone in contrast with electric charges, has only the third highest number of no understanding despite having the lowest number of correct responses. Item number 7, which targets the idea of how to identify magnetic poles of a magnet, has the highest number of no understanding but has the third highest number of correct responses. This could mean that the students got the correct answer by chance or at random. For Magnetic Fields Produced by Currents, item number 8 has one of the three items with the least number of students having no understanding. It also has one of the highest number of students with partial understanding. However, it does not have the highest number of correct responses as seen in Figure 1. This means that some students only know a part of the scientifically accepted concept while some have alternate conceptions. Item number 9, which targets the direction of the magnetic field in a straight current-carrying wire, has the least number of correct responses, and this corresponds with the students only having alternate conceptions or no understanding of this item. Item number 14, which targets the relationship of the magnetic field strength to the radial distance of the loop of wire, has the highest number of correct responses as seen in Figure 1 but it also has the highest number of students with no understanding. This means that the students only got the correct answer by chance or at random. Furthermore, they don't have a grasp of the concept behind their answer as evidenced by the number of no understanding for the item. For Force of a Current in a Field, only item number 21, which targets the concept of Electric motors converting electrical energy to mechanical energy, has a student having a sound understanding, and the least number of students having no understanding. It also has the highest number of students with partial understanding. However, it does not have the highest number of correct responses as seen in Figure 1. This means that some students only know a part of the scientifically accepted concept. Item number 18, which targets the idea of the direction of the magnetic force a rectangular circuit experiences in a uniform magnetic field, has the least number of correct responses, and this corresponds with it having one of the second-highest numbers of no understanding. Item number 19, which targets the idea of the relationship between the current with the rotation of the loop of wire while keeping the magnetic field strength constant has the second least number of correct responses as seen in Figure 1, which corresponds to it also having the highest number of students with no understanding. Item number 20, which targets the idea of the relationship between the strength of the magnetic field with the rotation of the loop of wire while keeping the current constant, is tied with item number 15, which targets the idea of the magnetic force experienced by a current-carrying wire placed on a uniformed magnetic field, with the highest number of correct responses, but both are also tied with the third-highest numbers of no understanding. This means that the students only got the correct answer by chance or at random. Furthermore, they don't have a grasp of the concept behind their answer as evidenced by the number of no understanding for these items. For Electromagnetic Induction, only item number 25, which targets the idea of increasing the number of magnets will make it harder to push the inside a solenoid, has students with alternate conceptions. Item number 24, which targets the idea of the direction of the induced current in a coil moving away from a uniform magnetic field at constant speed, has only three students getting a correct response and item number 23, which targets the idea of the direction of the induced current if a magnet is at rest inside a coil of wire, has only five students getting a correct response, which corresponds with the number of students with no understanding (all 46 students). The rest of the items have nine or more students having correct responses, and students have no understanding of the concepts. This means that the students only got the correct answer by chance or at random. Furthermore, they don't have a grasp of the concept behind their answer. Comparing the results in Figure 1 and Table 5, the number of correct responses does not mean that the students will have a sound understanding or partial understanding of the concepts behind the answers for each item and some students are able to choose the correct answer even without a solid and correct conception of the topics in Electromagnetism. They can be correct based on chance or randomly choosing the correct response. They often answered most of the items with no explanation or they just copied exactly what was found in the choices.

To summarize, most of the students have no understanding of the concepts on Electromagnetism prior to the implementation of the lesson package. Most students have the difficulty of explaining their answers since most of the items with no understanding contain no explanations and copied words from the choices. This supports the findings of Arnold & Millar (1987), Mulhall, et al. (2001), and Miokovi, et al. (2012) that topics connected to Electromagnetism are challenging for students to understand due to their abstract nature. Also, students have some alternate conceptions, thus affirming the findings of Turgut, et al. (2011) and Li (2012) where students form views that differ from those that are held to be true scientifically in these topics. Though the students have not yet encountered the concepts of Electromagnetism, they already have gained ideas that are shaped by their experiences, and thus, needs to be confronted and changed into scientifically accepted ones. Furthermore, the alternate conceptions also need to be addressed since if not corrected, these will be carried by the students as they progress into a higher grade level. These were the concepts that were targeted to be changed or reduced by the implementation of the developed lesson package in Electromagnetism using CCBL Model.

Development of the Lesson Package in Electromagnetism Anchored on the Cognitive-Conflict Based Learning (CCBL) Model

Prior to obtaining the results of the pre-test, a lesson sequence in Electromagnetism was developed that followed the competencies specified in the K to 12 Science Curriculum Guide for

Grade 10 (DepEd, 2016) which was made following the ADDIE Model. Seven lesson plans comprised the lesson sequence which incorporated different teaching-learning strategies that were student-centered and followed the 5A format (Awareness, Activity, Analysis, Abstraction, Assessment).

After the students' initial conceptual understanding were determined, the lesson sequence was improved and made into a lesson package in Electromagnetism using Cognitive-Conflict Based Learning (CCBL) Model. The 5A format was integrated into the CCBL Model with Awareness placed under Syntax I, Activity under Syntax II, Analysis and Abstraction under Syntax III, and Assessment under Syntax IV (for description of each syntax, refer to Table 2). All concepts of Electromagnetism for Grade 10 were given emphasis on the lesson package. Based on the results of the pre-test, there were alternate conceptions that needs to be addressed and corrected into scientifically accepted ones for all major concepts (Magnetism, Magnetic Fields Produced by Currents, Force of a Current in a Field, and Electromagnetic Induction). In here, cognitive conflict strategy will play its role in giving students scenarios that counters their preconceived alternate conceptions, thus facilitating conceptual change. The lesson package consists of seven lessons that cover three weeks or twelve meetings. Each meeting consists of 60 minutes. The lesson package includes a lesson plan guide, a copy of the activities for each lesson, a summary of all the concepts that are covered for each lesson, and the answer key to all activities. The usage of Physlets® was integrated as an improvement for the lesson package and was utilized heavily for the discussion of concepts of Magnetic Fields Produced by Currents, Force of a Current in a Field, and Electromagnetic Induction. These concepts are abstract in nature and thereby need more visualization to be understood better by students. For Electromagnetic Induction, which was tackled on the sixth and seventh lessons, hands-on experiments were included for reinforcement of conceptual understanding since students mostly have no understanding of this major concept.

The lesson package was evaluated prior to the implementation to ensure the quality and accuracy of the concepts that are covered in it. Three individuals with at least a Master of Arts degree in education with a major in Physics were asked to rate the lesson package using the Evaluation Rating Sheet for Non-Print Materials from the Learning Resource Management and Development System of the Department of Education. The rating sheet has four criteria, but the third criterion was not included for it is not applicable to the rating of the lesson package. The criteria are as follows: Content Quality, Instructional Quality, and Other Findings (Conceptual errors, Factual errors, Grammatical and/or typographical errors, and other errors). The possible rating for each item is as follows: 4 - Very Satisfactory (VS); 3 - Satisfactory (S); 2 – Poor (P); and 1 – Not Satisfactory (NS).

Table 6. *Total Scores of Raters for each Criterion*

Rater	**Content Quality (40 points*)**	**Decision**	**Instructional Quality (40 points*)**	**Decision**	**Other Findings (16 points*)**	**Decision**
1	38	Passed	34	Passed	16	Passed
2	37	Passed	35	Passed	16	Passed
3	38	Passed	35	Passed	16	Passed

**maximum possible score*

Following the instruction for evaluating the lesson package for each criterion, a minimum total score of 30 points must be obtained for Content Quality and Instructional Quality and a perfect score of 16 points for Other Findings to consider the lesson package as Passed and be recommended for implementation. All three raters scored the lesson package above 30 points for Content Quality and Instructional Quality and 16 points for Other Findings, as seen in Table 20. This only means that the developed lesson package is ready for implementation and for future use.

Inter-rater reliability (IRR) was performed to ensure agreement among the raters. Fleiss' Kappa was employed for each criterion since there are three raters that evaluated the validity of the lesson package in Electromagnetism in three criteria. Fleiss' Kappa, κ (Fleiss, 1971; Fleiss

Kappa	Level of Agreement
> 0,8	Almost perfect
> 0,6	Substantial
> 0,4	Moderate
> 0,2	Fair
> 0	Slight
< 0	No agreement

Adapted from Landis and Koch (1977)

et al., 2003), is a measure of inter-rater agreement used to determine the level of agreement between two or more raters (also known as "judges" or "observers") when the method of assessment, known as the response variable, is measured on a categorical scale, which is appropriate for the evaluation tool that is used in this study. The interpretation, which is used by Altman (1999), and adapted from Landis and Koch (1977) is as follows:

Table 7 showed the inter-rater reliability of the three raters for criteria A of the rating sheet, which is on content quality, and for criteria B of the rating sheet, which is on instructional quality. There are 10 items for both criteria which evaluates the accuracy, quality of the content, and quality of the instruction of the lesson package.

Table 1. *Inter-Rater Reliability for Criteria A: Content Quality and Criteria B: Instructional Quality*

Criteria	**Overall Agreement***		
	Kappa	z	p-value
A ***(Content Quality)***	0.441	2.415	0.016
B ***(Instructional Quality)***	0.593	3.247	0.001

**Sample data contains 10 effective subjects and three raters.*

The Kappa value for criteria A is 0.441 which indicates a moderate strength of agreement among the three raters. The p-value is 0.016 which is <0.05, indicating that the result is statistically significant. The Kappa value for criteria B is 0.593 which indicates a moderate strength of agreement among the three raters. The p-value is also <0.05, indicating that the result is statistically significant.

For the third criterion on Other Findings, the raters have a perfect agreement since they have rated all items with the same score (4 on all items).

Students' Final Conception of Electromagnetism

To observe the conceptual understanding of students during the implementation of the lesson package in Electromagnetism, the students' scores were arranged from highest to lowest, and nine students were chosen. Three of them had the highest scores in the pre-test and will belong in the High group, three had the lowest scores and will belong in the Low group, and a random three students were chosen halfway in the middle and will compose the Middle group. This was done because all students except the two highest scorers scored low based on the proposed grouping, and the highest score was only 15 out of 30. The nine students undergo semi-structured interviews to check on their understanding while the implementation of the lesson on Electromagnetism was going on. Each student will be assigned pseudonyms to maintain the anonymity of their identity. The High group is composed of Anna (Student F-15), Mary (Student F-18), and John (Student M-3). The Middle group is composed of Thea (Student F-16), Henry (Student M-10), and Ben (Student M-24). The Low group is composed of Luke (Student M-4), Janice (Student F-11), and Jenny (Student F-20).

After the implementation of the lesson package in Electromagnetism, the students answered again the Conceptual Test on Electromagnetism as a post-test. To determine the conception of students after the implementation of the lesson package in Electromagnetism, the answers of the students in the second tier were scored 0-4 and categorized into Sound Understanding (SU), Partial Understanding (PU), Partial Understanding with Alternate Conception (PU-AC), Alternate Conception (AC), and No Understanding (NU. Qualitative Content Analysis (QCA) was employed on the answers that fall for each category to determine their conceptions.

Presented in Table 8 were the students' final conceptions of Magnetism (items 1 – 7 of the Conceptual Test for Electromagnetism) which were categorized into SU, PU, PU-AC, and AC.

Table 8. *Students' Final Conception of Magnetism*

Sound Understanding	**Partial Understanding**	**Partial Understanding with Alternate Conception**	**Alternate Conceptions**
1. Like poles repel, unlike poles attract.	1. The pattern in the diagram shows the direction of the	1. Electric charges attract and repel, while magnetic	1. Magnetic field is made of atoms.

2. The curved lines represent the magnetic field of a magnet, and its direction is from North Pole to South Pole. 3. Magnetic effect is caused by moving charges, while electric field is present in stationary charges. 4. A compass can be used to identify the poles of a magnet. The compass needle points to the North Pole of the magnet. 5. The magnetic field is strongest at the poles, where magnetic field lines are most concentrated. 6. Electric charges can exist alone while magnetic poles cannot	magnetic field, the same with what was seen in the simulation. 2. The end of the iron bar facing the North Pole of the magnet will be South Pole, and other end will be North Pole. 3. The magnetic pole where the compass needle point is the north pole. 4. The magnetic field surrounds the permanent magnet, and the direction is from North to South 5. Every magnet has North and South poles. 6. Electric charges both attract and repel. 7. Diagram derived from the magnetic board	poles only attract. 2. Electric charges can attract and repel while magnets only repel.	2. The strength is the same around the magnet. 3. Electric charges cannot exist on their own. 4. The curved line of magnetic field runs from North pole to North pole. 5. Magnetic field lines are straight from north to south pole. 6. Without magnetic field, there is no current. 7. Magnetic field is from the south pole going to the north pole. 8. North and South Poles will separate, and South and South poles will remain attached to each other. 9. The end of the iron that faces the north pole of the magnet will be the

because magnets are dipole. 7. As the permanent bar magnet is brought near the iron it will induce temporary magnetism in the iron. 8. The diagram derived from the magnetic board shows that the lines are curved and extend from one end to the other, thus indicating that there are two poles.	shows that there are two poles. 8. The magnet has magnetic field around it. 9. The middle part of the magnet has weak magnetic field. 10. Electric charges can exist alone. 11. When a permanent bar magnet is brought near a piece of iron, the iron becomes temporarily magnetized. 12. The magnetic field strength is not uniform around a magnet, and it varies at a different point around the magnet. 13. Magnetic field lines become more spread as it move away from the poles.		north pole, and its other end will be the south pole. 10. Magnetic North pole is always on the left side end of the magnet.

In Table 8, eight conceptions were categorized as sound understanding, in which the most common is, “Like poles repel, unlike poles attract.” with 71.74% of the total. There are a total of 8 concepts that were derived for this category, which is greater than the number of concepts the students got in the pre-test. The conceptions that the students had during the pre-test that were categorized under sound understanding were all retained after the post-test, and there were additional concepts that the students obtained after the implementation of the developed lesson package in Electromagnetism (see Appendix H). This was also reinforced by the conceptions that some students have during the implementation phase.

For the High Group, these were their responses that are considered sound understanding:

Anna:

- The way, or rather the direction of the magnetic field is from North to South.
  “kanang unsay way (...) sa magnet, ay, unsay direction sa magnetic field [asked the direction] North to South.”
- The magnetic field of a magnet is strongest at the north and south poles, as seen in the simulation.
  “Nakita nako sir, sa katong kuan sir, simulation, nga ang magnetic field sa magnet kay kinakusgan siya sa kuan……sa North ug South pole.”
- If they have the same or like poles, the magnets will repel. If North Pole and South Pole, they will attract.
  “Kung musame siya like poles kay murepel (…) ang magnets. [asked if North pole and South pole] mu attract.”

Mary:

- The direction of the magnetic field is from North to South.
  “Ang direction sa magnetic field kay from north to south”
- They will attract if opposite poles, then repel if like poles.
  “Muattract kung opposite poles, nya murepel kung like poles”
- Magnetic field is the area around the magnet where it attracts other magnets and objects.
  “Magnetic field is the area around the magnet (looks at the ceiling)……..where it attracts other magnets and (…) objects.”

John:

- Unlike poles will attract. Same poles repel.

“Unlike pole kay muattract, same pole kay repel”

- The magnetic field is strongest at the poles.
  “Ang magnetic field, kuan, kinakusgan siya basta naa sa poles.”
- A magnet will pass on magnetic properties on an object, and it is temporary.
  “Ang magnet kay mupasa siya ug magnetic properties sa usa ka object nya (…)temporary ra.”

For the Middle Group, these were their responses that are considered sound understanding:

Thea:

- There are two poles of a magnet, North and South poles.
  “Naay duha ka poles and magnet, kuan, North ug South pole.”
- The direction of the magnetic field is from North [pole] to South [pole].
  “Ang direction sa magnetic field kay (…) kuan……from North to South.”

Henry:

- A magnet has a North Pole and a South Pole.
  “Ang magnet kay naay kuan …… North Pole ug South Pole.”
- Two magnets will not attract if they have the same poles, and if unlike poles they will attract.
  “Dili muattract ug same sila ug poles ang duha ka magnet, nya kung unlike poles kay mu attract”

Ben:

- A magnet has two poles, North [pole] and South [pole].
  “Ang usa ka magnet kay naay duha ka poles, North ug South”
- [Magnets] will attract if they don’t have the same pole, then [they] will repel if same poles.
  “Mu attract kung dili same ug pole, nya murepel kung pareha ang poles”

For the Low Group, these were their responses that are considered sound understanding:

Luke:

- A magnet has two poles; North Pole and South Pole.
  “Ang magnet nay duha ka pole… North pole ug South Pole”
- The nail sticks more to the poles, so it is where the magnet is strongest.
  “Mas mupilit ang kuan sir, ang lansang (…) maong didto siguro pinakakusog mu…magnet”

Janice:

- A magnet has a North Pole and a South Pole.
  "Ang magnet kay naay North pole ug South Pole"

In the same table, there are a total of 15 conceptions that are categorized as partial understanding, in which the greatest number of students who got it is, "The pattern in the diagram shows the direction of the magnetic field, the same with what was seen in the simulation." with 65.22% of the total (see Appendix H). The large number of students who obtained this concept is evidence that the Physlet® app greatly helped students gain an understanding of the direction of the magnetic field. Some concepts the students had during the pre-test that are categorized under partial understanding were retained after the post-test and there were additional concepts that the students obtained after the implementation of the developed lesson package in Electromagnetism, signifying that the number increased compared with the pre-test. Students' conception during the implementation supported these.

For the High group, these were their responses that are considered partial understanding:

Anna:

- Induced magnetism will depend on a permanent magnet.
  "induced magnetism kay mag.......mag-agad siya sa permanent magnet"

Mary:

Induced magnetism is temporary; it will depend on the magnet. If there is no magnet, nothing will be magnetized.

"induced magnetism kay temporary…....mag-agad siya sa magnet, kung way magnet kay kuan……walay (…)mamagnet."

For the Middle group, these were their responses that are considered partial understanding:

Thea:

- The magnetic field is stronger at the poles [of a magnet].
  "Mas kusog ang kuan, sir, ang magnetic field……basta naa sa kuan (…) sa poles"

Ben:

- The nail only sticks to the poles [of the magnet]. It is where the magnetic [field] is strongest.
  "Ang nail kay adto ra jud siya mustick sa poles, kay adto pinakakusgan ang magnetic. "

For the Low group, these were their responses that are considered partial understanding:

Janice:

- If two magnets have different poles, they will attract. It's what I can only recall.
  "Kung ang duha ka magnets kay lahi-lahi ug pole……mu attract. Mao ray akong nahinumduman (giggles)"

Jenny:

- If two magnets will face each other, they will stick if North pole and South Pole are facing each other.
  "Kung mag-abot ang duha ka magnet kay, kuan……magpilit sila kung nag atubang…..ang kuan, North pole ug South Pole."

In the same table, two conceptions were categorized as partial understanding but with alternate conceptions, in which the most common conception was, "Electric charges attract and repel, while magnetic poles only attract." with 23.91% of the total. Only two conceptions from the pre-test have remained after the implementation of the lesson package in Electromagnetism. There was also a decrease in the number of conceptions in this category (see Appendix H). Ten conceptions were categorized as alternate conceptions, in which the most common conception was, "Magnetic field is made of atoms" with 6.52% of the total. During the implementation phase, only one student, which was in the Low group, has retained an alternate conception identified in the pre-test.

Jenny:

- If North Pole [is facing] North Pole, it will still stick.
  "Kung north pole ug north pole kay magpilit gihapon"

There is a decrease in the number of conceptions in this category. Some of the alternate conceptions identified in the pre-test are not anymore retained by the students. There are those that are retained and those that are identified only after the implementation phase but are unique to one student only. This corresponds to the increase in number of conceptions that are considered sound and partial understandings. This also means that most of the alternate conceptions identified in the pre-test are not anymore retained by the students.

Presented in Table 9 were the students' final conceptions of Magnetic Fields Produced by Currents (items 8 – 14 of the Conceptual Test for Electromagnetism) which were categorized into SU, PU, PU-AC, and AC.

Table 9. *Students' Final Conceptions of Magnetic Fields Produced by Currents*

Sound Understanding	**Partial Understanding**	**Partial Understanding with Alternate Conception**	**Alternate Conceptions**
1. Without moving charges, there is no magnetic field. 2. The same poles of both electromagnets were placed near each other, it'll repel. 3. The magnetic field is proportional to the amount of current in the wire.	1. The loop is nearer to the center so magnetic field is stronger. 2. The electromagnets have the same side facing each other. 3. I used Right hand Rule in knowing the magnetic field direction. 4. The magnetic field direction in the straight wire is counterclockwise because the direction of current is going up. 5. More turns of coil of wire makes	1. Only permanent magnets produce magnetic field 2. Magnetic field are produced by electric charges.	1. The magnitude of magnetic field is the same for the three loops. 2. Electromagnets will move towards each other because the same sides are facing each other. 3. Current has the same direction with magnetic field as observed from the top. 4. Magnetic field direction is clockwise if current is going up. 5. Electromagnets will either attract or repel since same sides are facing each other.

	the magnetic field stronger. 6. The amount of the current doubled but the length of wire remains the same then the magnetic field will double. 7. Any material that has magnetism will have their own magnetic field. 8. When current flows through a long straight wire, it creates a magnetic field around it.	6. Making a loop will make the current stronger. 7. The strongest magnetic field is in the middle loop. 8. The forces cancel each other because the same ends are facing and they will not repel. 9. Magnetic field is made up of atoms. 10. Making the conductor more thinner it’s possible to make the magnetic field stronger. 11. The loops have the same length 12. Electromagnets will repel because the ends that face each other are not the same.

As seen from Table 9, there are a total of three concepts categorized as sound understanding. Among this, the most common concept is “Without moving charges, there is no magnetic field.” which constitutes 34.78% of students getting them. There are two concepts with only one or 2.17% of students knowing it (see Appendix H). Also, there were no concepts categorized as sound understanding before the implementation of the lesson package, which means that some students improved their understanding of the concepts of Magnetic Fields Produced by Currents. Also, one student from the high group was also able to give a response that is considered a conception that indicated sound understanding.

Mary:

- A changing electric field induces a magnetic field.
  “A changing electric field…….induces, kuan, a magnetic field.”

In the same table, we could observe that there were eight conceptions categorized as partial understanding. Among these, the most common concept is “The electromagnets have the same side facing each other” which constitutes 28.26% of students getting them. There are two concepts with only one or 2.17% of students knowing it. Some concepts the students had during the pre-test were retained after the post-test. There were additional concepts that the students obtained after the implementation of the developed lesson package in Electromagnetism (see Appendix H), signifying that the number increased compared with the pre-test. These were consistent with the students’ responses during the implementation phase.

For the High Group:

Anna:

- Oersted discovered that there is induced magnetic field if there is current.
  “Nadiscover ni Oersted nga naay kuan (…) induced magnetic basta naay current.
- The direction of the current and direction of the magnetic field are perpendicular to each other.
  “Ang direction sa current ug magnetic field kay perpendicular to each other.”

Mary:

- The direction of the magnetic field depends on the direction of the current.
  “Magdepende ang direction sa magnetic field sa direction sa current”
- We will use Right Hand Rule to determine the direction of the magnetic field in the wire.
  “Mugamit ug Right Hand Rule para kuan, makahibaw ta sa direction sa magnetic field sa wire.”

John:

- If there is current [in a wire], there is an induced magnetic field.

"Kung naay current, naay…… kuan, kanang induced nga magnetic field."

- We will look at the direction of the current to know the direction of the magnetic field. We will [use] the Right Hand Rule.

  "Tan-awon nato ang direction sa current para makahibaw sa direction sa magnetic field. Magkuan ta sa Right Hand Rule."

For the Middle group:

Thea:

- Because of moving charges, current flows [in the wire]. (

  "Tungod sa……moving (…) charges, naay current nga ni-kuan, (…) niflow"
- [We use] Right Hand Rule so that we will know the direction of the magnetic field, the direction of the current and the force.

  "Right hand rule……….kay makahibaw ta sa direction sa kuan, sa magnetic field, direction sa (…) current, ug sa kuan [was asked for the third one] force."

Henry:

- The direction of the magnetic field will depend on the force. No, it will instead depend on electricity.

  "Ang direction sa magnetic field kay mag agad sa…….. force, ay sa kuan diay, ahm, kurenti"
- There is magnetic field if there is electricity. (

  "Naay magnetic field kung naay electricity"
- The direction is perpendicular to each other. (student was asked what he means that is perpendicular) the current and magnetic [field].

  "Ang direction kay perpendicular sa usag-usa (student was asked what he means that is perpendicular) kuan…..current….ug (…) magnetic."

Ben:

- Electricity made the compass [needle] move when it was near the wire.

  "Ang kuryente kay nakapakuan…nakapalihok sa compass katong duol siya sa wire"
- There are moving charges in the wire, then there is magnetic field.

  "Naay moving charges sa wire, nya……..naay magnetic field"
- The direction of the magnetic [field] will depend on the direction of the current.

“Ang direction sa magnetic kay mag agad sa direction sa kuan (…) current”

For the Low group:

Luke:

- If there is current in the wire, there is magnetic [field].
  “Kung naay current sa wire sir, kuan………naay magnetic.”

Janice:

- I remembered about the experiment of Oersted that the compass [needle] moved because there is electricity.
  “Akong nahinumduman sa experiment ni Oersted……kuan, nilihok ang compass sir, nya, kuan……… naay kurenti.”

Jenny:

- The compass [needle] moved because there is electricity.
  “Nilihok ang compass sir kay naay kurenti”
- The direction of the magnetic field is perpendicular to the current.
  “Ang direction sa magnetic field, kay, ahm ………… perpendicular sir [student is asked to what it is perpendicular] sa current.”

In the same table, there are two conceptions that were categorized as partial understanding but with alternate conceptions, which were “Only permanent magnets produce magnetic field” with 4.35% of students getting it and “Magnetic field are produced by electric charges” with 2.17% of students getting it. Some students have still some alternate conceptions retained though they have gained some partial understanding of the concepts. However, it is important to note that the percentages of students having partial understanding with alternate conceptions decreased (see Appendix H). A total of 12 conceptions were considered alternate conceptions. The most common conception that the students have for this category is that “The magnitude of magnetic field is the same for the three loops” with 15.22% of students getting it. There are also a number of concepts that are unique to only one student or 2.17% (see Appendix H). Some conceptions that the students had that were considered alternate conceptions were still there after the implementation of the lesson package in Electromagnetism. This means that some students have still some alternate conceptions retained. There is also an increase in the number of alternate conceptions. Some students have also gained new alternate conceptions. During the implementation phase, alternate conception was identified in a student in the Low group.

Janice:

- The direction of the magnetic field is the same with the current (?) I'm confused. *"Ang direction sa magnetic field kay kuan sir, same (raises tone of voice like a question)……sa current. Galibog bitaw ko sir (giggles)."*

Presented in Table 10 were the students' final conceptions of Force of a Current in a Field (items 15 – 21 of the Conceptual Test for Electromagnetism) which were categorized into SU, PU, PU-AC, and AC.

Table 2. *Students' Final Conception of Force of a Current in a Field*

Sound Understanding	**Partial Understanding**	**Partial Understanding with Alternate Conception**	**Alternate Conceptions**
1. The wire will experience a force perpendicular to both the direction of current and magnetic field. 2. When a current-carrying wire is placed in a magnetic field, it experiences a magnetic force due to the interaction between the magnetic field and the moving	1. Electric motors need electrical energy to produce mechanical energy. 2. I used the Right Hand Rule and the outcome is that the magnetic force is going out of the paper. 3. Because of the electricity, the dynamo will rotate. 4. The current points upward,		1. The force is greatest if the current-carrying wire is not slanting with respect to the direction of magnetic field. 2. The magnetic field strength can't handle the amount of current that is doubled so the loop will stop rotating. 3. The current will change if the

charges in the wire. 3. Magnetic field is reduced to half since it is directly proportional to the length of wire.	and the induced magnetic field is directed counterclockwise, the direction of the force is out of the paper. 5. The loop rotation will double since current is stronger.		magnetic field is reduced. 4. The current-carrying wire will follow the direction of the magnetic field. 5. Magnetic field is going up, the current in the rectangular circuit will flow in the opposite direction. 6. The loop's rotation will not change since there is no change in the amount of wire.

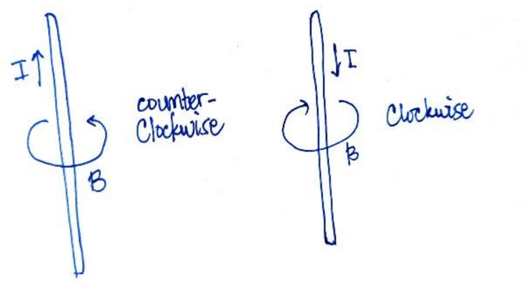
As observed in the table, three conceptions were categorized as sound understanding, in which the most common is “The wire will experience a force perpendicular to both the direction of current and magnetic field” which constituted 4.35% of students getting them and the other two had only one or 2.17% of students that knew them. The number of concepts considered as sound understanding increased after the implementation of the lesson package in electromagnetism (see Appendix H). This means that some students gained new conceptions that are scientifically accurate and had gained better understanding of the topic. However, the conception from the pre-test was not retained after the implementation.

In the same table, five conceptions were categorized as partial understanding, in which the most common was “The current points upward, and the induced magnetic field is directed counterclockwise, the direction of the force is out of the paper.” which constitutes 17.39% of students getting them. One concept is unique to only one student or 2.17% (see Appendix H).

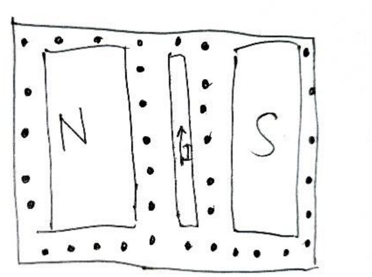
Some of the concepts that are considered partial understanding in the pre-test were retained after the implementation of the lesson package in Electromagnetism. This means that the students have ideas already of the concept before the implementation phase and are reinforced using the CCBL Model and the integration of Physlets®. These were reinforced by the students' responses in the High and Middle group.

For the High group, these are the responses:

Anna:

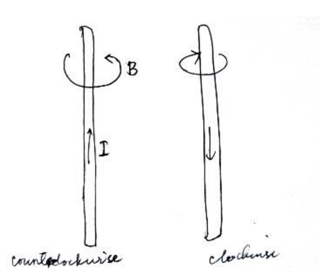


- The wires will repel since the direction of their magnetic field is not the same.
  "The wires will repel kay lahi-lahi ang direction sa kuan, magnetic field nila.
- The direction of the force will be also perpendicular to both current and magnetic field.
  "Ang direction sa force kay perpendicular sa current ug sa magnetic field"
- Electric motor is a device that uses electrical energy to produce mechanical energy.
  "Ang electric motor(…) is a device that uses electrical energy to produce mechanical energy.



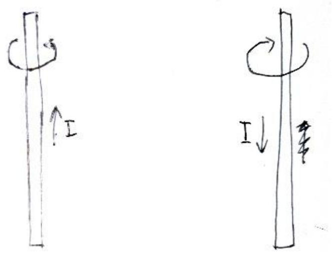
- [The direction of] the force will be into the paper. It will depend on the direction of the current.
  "Ang force sir kay into the paper. Mag-agad siya sa kuan sir, sa direction sa current."

Mary:



- The wires will repel each other.
  "Murepel ang wires sir"
- An electric motor produces mechanical energy if there is electricity.
  "Electric motor kay muproduce siya ug mechanical energy basta naay electricity."

John:

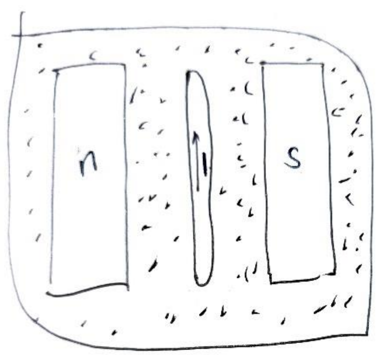


- The wires will repel. The magnetic field is of different direction.

“Murepel ang wires kay lahi ang direction sa kuan sir, magnetic field sa duha”

- An electric motor will produce mechanical energy if electricity is supplied [to it].

“Ang electric motor sir, it will produce mechanical energy if suplayan siya ug kurenti”

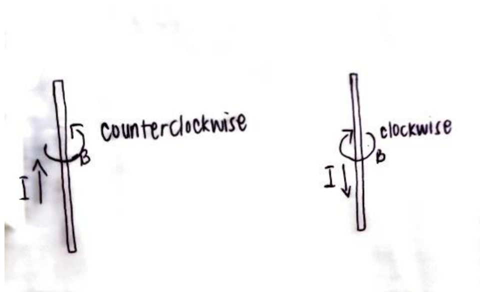


- The force will be into the paper.

“Ang force kay padung into the paper.

For the Middle group:

Thea:



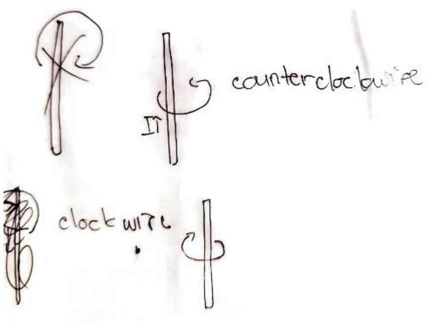
- The wires will repel. They have different direction of the magnetic field. (

“Mu-repel ang wires. Kuan, ahm…….lahi-lahi ang direction sa magnetic field”

- Electric motor will produce mechanical [energy].

“(scratches head) Ang electric motor kay kuan siya, kuan…….hmmmm (…) mukuan siya, muproduce ug mechanical.

Henry:



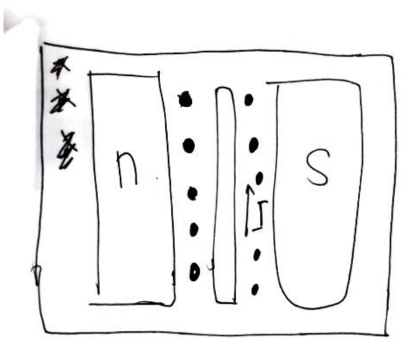
- The wires will repel because of the direction of the current.
"Kuan, murepel sir. [Asked the student why] Kay ang current, kuan….maga-agad siya sa current ug asa padung.

- The [electric] motor produces mechanical energy if there is electricity.

"Kuan sir…… hmmmm, basta naay kurenti, ang motor kay muproduce ug mechanical energy.

Ben:

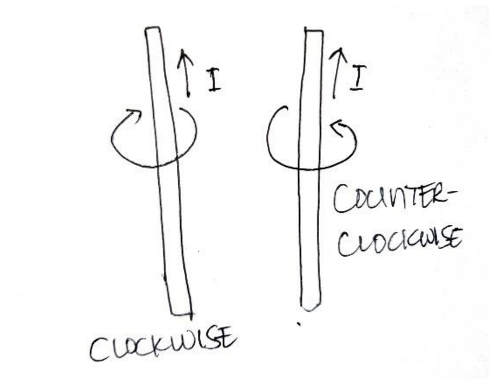
- The wires will repel, because the direction of their magnetic fields is in opposite direction to each other.
"Ang duha ka wire sir kay mukuan, murepel kay ang direction sa ilang magnetic fields kay(…) bali sa usag-usa."



- [The force will be] into the paper. The force will depend on the direction of the current in the wire.
" into the paper sir. Ang force kay magdepende sa direction sa kuan (…) sa current sa wire."
- The electric motor produces mechanical energy if connected to a source of electricity.
"Ang electric motor sir kay naay mechanical energy basta i-kuan, kanang isaksak ug naay kurenti"

In the same table, six conceptions were alternate conceptions, in which the most common was that "The force is greatest if the current-carrying wire is not slanting with respect to the direction of magnetic field" with 13.04% of students getting it. There are also a number of concepts that are unique to only one student or 2.17% (see Appendix H). There are the same number of concepts in the pre-test and after the implementation of the lesson package in Electromagnetism. However, we can see that the conceptions in the pre-test were not retained, and new conceptions are acquired after the implementation of the lesson package. This means that some students have also gained new alternate conceptions. These were observed also in the students' responses in the Low group during the implementation phase.

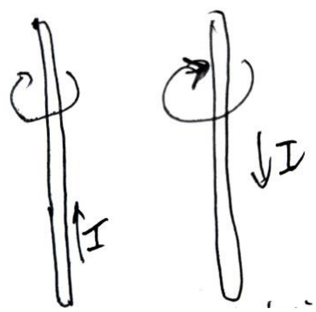
Luke:



- The wires will attract. One is going clockwise, the other is counterclockwise.

"Kuan sir, ang duha ka wire kay mu-attract………kay ang usa ka wire padung man clockwise, nya ang usa kay padung counterclockwise.

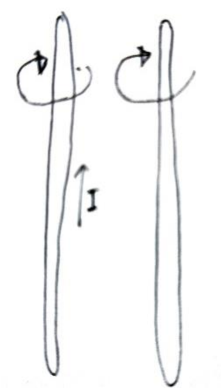
Janice:



- [The wires] will attract because they have the same direction.

"Mu-attract kay………parehas man sila ug kuan, sir, direction."

Jenny:



- The wires will repel but I'm confused. *

"Murepel ang wires sir…………..Galibog jud ko sir"

**it is labeled as an alternate conception though there is no explanation because of the direction of the magnetic field in the drawing.*

Presented in Table 11 were the students' final conceptions of Electromagnetic Induction (items 22 – 30 of the Conceptual Test for Electromagnetism) which were categorized into SU, PU, PU-AC, and AC.

Table 3. *Students' Final Conception of Electromagnetic Induction*

Sound Understanding	**Partial Understanding**	**Partial Understanding with Alternate Conception**	**Alternate Conceptions**

1. Using the right-hand rule, you'll know that direction of the induced current will be clockwise. 2. The induced current in the coil will be such that it creates a magnetic field that opposes the motion of the magnet. 3. The induced emf is directly proportional to the change of magnetic field. 4. When the magnet is at rest inside the coil, there is no change in magnetic flux and there is no induced current produced in the coil.	1. Both bars have the same size, so both will have induced emf. 2. If we add more magnet, the group of magnets will be repelled by the coil. 3. The velocity is going to the right so the direction of the current is clockwise. 4. Due to added magnets the induced magnetic field in the coil will also become stronger. 5. Since the bars are moving in the uniform magnetic field, there will be a change in area which induces emf for both. 6. The magnet is moving towards the loop of wire with a velocity perpendicular to the plane of the		1. More magnets make it easier to move inside the coil of wire. 2. The more the number of magnets goes faster when moved inside the coil. 3. The bar 2 will have the induced emf because its turning to the right in the uniform magnetic field. 4. Only the bar 2 somehow moves in the uniform magnetic field, so it only has the induced emf. 5. In order to have a current with only a magnetic field, you need to have emf.

	wire, so the bulb lights. 7. When the magnet is at rest inside the coil, there is no change in the magnetic field. 8. According to Faraday's Law, a changing magnetic field induces emf in a conductor. 9. Changing magnetic field will induce emf in the generator 10. The magnetic field strength doubled, so induced emf became twice as big. 11. I used the right hand rule to determine the direction of induced current in the loop.	

In the table, we can see that there were four conceptions categorized as sound understanding. Each concept is unique to only one or 2.17% of students knowing it (see Appendix H). There were no conceptions derived in the pre-test that are considered sound understanding. This means that some students have gained scientifically accurate understanding of concepts under Electromagnetic Induction. These are supported by the students' responses from the High group during the implementation phase.

Anna:

- Generator is a device that converts mechanical energy to electrical energy.
  "Ang generator kay device that converts mechanical energy to electrical energy."

Mary:

- A generator converts mechanical energy to supply electrical energy.
  "A generator converts (…) mechanical energy para musupply ug kuan, electrical energy."

John:

- A generator is a device that converts mechanical energy to electrical energy.
  "Ang generator kay device siya nga muconvert sa mechanical energy into electrical energy."

In the same table, we can see that there were eleven conceptions categorized as partial understanding, in which the most common concepts were "Both bars have the same size, so both will have induced emf" and "If we add more magnet, the group of magnets will be repelled by the coil" with 8.70% of students knowing it. There were some concepts unique to only one or 2.17% of students knowing it (see Appendix H). There are no concepts derived in the pre-test that are considered partial understanding. This means that some students have gained partially accurate conceptions of Electromagnetic Induction. During the implementation phase, the students were also observed to have gained partial understanding.

For the High group:

Anna:

- If there is a change in the magnetic field, there will be an induced emf.
  "If there is a change in the magnetic field, kuan, there will be …… induced emf (raised voice, like a question)"
- Amount of induced emf depends on the change in the area, change in the magnetic field or change in both.
  "Amount of induced emf depends on the change in area, change sa kuan, magnetic field, ug change in both…."

Mary:

- If there is a change in the magnetic field, there will be an induced emf.
  "If there is a kuan, change in the magnetic field…..naay induced emf."

John:

- There is an induced emf if there is a changing magnetic field experienced by the coil of wire.
  "Naay induced emf kung……muchange ang magnetic field ng ana experience sa coil of wire"
- There is induced emf if there is a change in the area, change in magnetic field, or change in both.
  "Naay induced emf kung muchange ang kato tulo (asked the three factors) change in area, change in magnetic field…..ug change sa duha."

For the Middle group:

Thea:

- If there is a changing magnetic field, an electric [field] is induced.
  "Kung naay changing magnetic field……kuan, naay ma induce nga electric."
- A generator supplies electricity.
  "…………ang generator magsupply ug kuryente"

Henry:

- We will have induced emf in a conductor if there is a changing magnetic field.
  "Naa tay induced emf sa conductor, basta kuan……… naay magnetic field [asked to elaborate the magnetic field] changing siya sir."
- A generator supplies electricity using mechanical energy.
  "Ang generator sir kay musupply ug kurenti nya mugamit ug mechanical energy."

Ben:

- There is a current induced if there is a changing magnetic [field].
  "Naay current sir basta naay kuan, (…) changing magnetic."
- An electric generator produces electricity.
  "Ang generator sir kay muproduce siya ug kurenti."

For the Low group:

Luke:

- A generator is used during brownout to supply electricity.
  "Ang generator sir gamiton siya basta kuan, kanang brownout para naay kurenti"

Janice:

- A generator is used to supply electricity.
  "Ang generator sir, gamit siya para naay kurenti"

Jenny:

- We use generator sir if there is brownout.
  "Gamiton ang kuan sir, generator basta brownout."

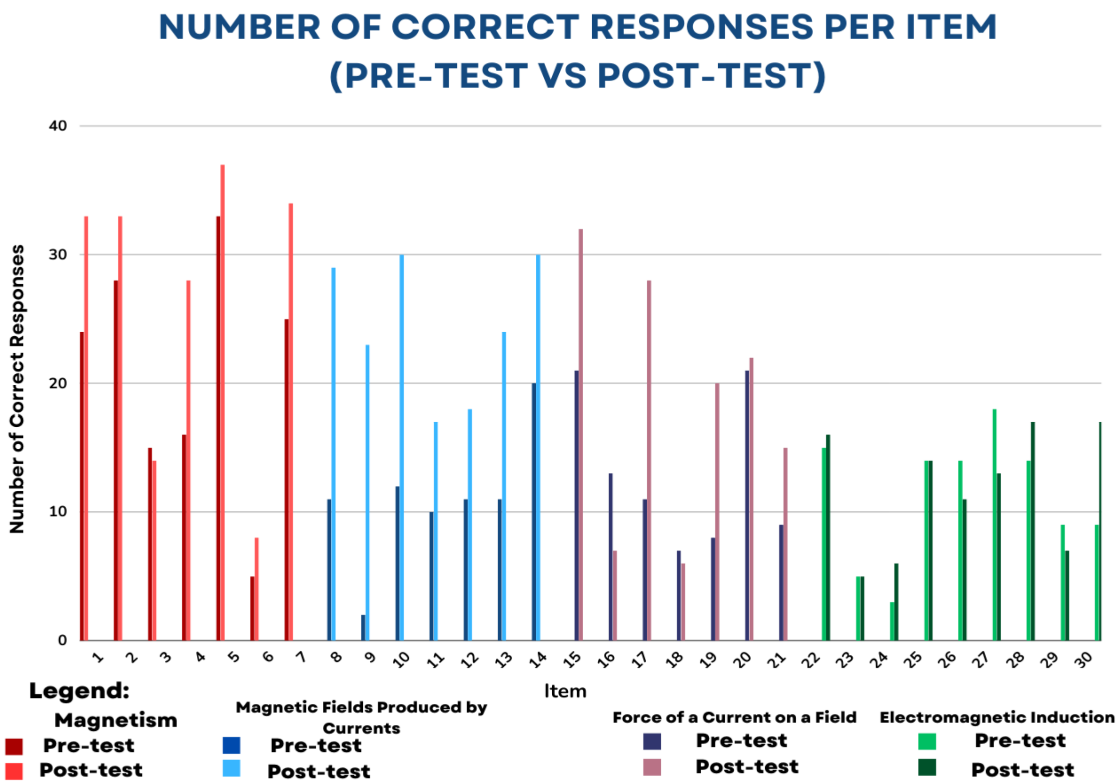
In the same table, we can see that there were five conceptions that were alternate conceptions, in which the most common was that "More magnets make it easier to move inside the coil of wire" with 13.04% of students getting it. There are also concepts that are unique to only one student or 2.17% (see Appendix H). The number of concepts considered as alternate conceptions increased after the implementation of the lesson package in electromagnetism. Also, the concept that was present in the pre-test was retained after the implementation of the lesson package. This means that some students gained conceptions that are not correct, and the number increased after the implementation of the lesson package. It was also observed in one student in the Low group.

Janice:

- If there is an induced emf, the current changes.
  "Kung naay induced emf, nachange ang current."

Figure 2 showed the number of correct responses per item number for the post-test as compared to the pre-test. The graph was also color-coded to represent the items that fall under each of the major concepts of Electromagnetism.

Figure 2. *Number of Correct Responses per Item (Pre-test vs Post-test)*



As shown in the graph (Figure 2), we could see that except for item number 3, which targets the idea of the magnetic field strength, we can see an increase in the number of correct responses for items 1-7. The students evidently had higher score on this set of items in the post-test compared to the pre-test for the concept of Magnetism. There was an increase of the number of correct responses for all items under Magnetic Fields Produced by Currents. This means that more students were able to get the correct answers for these items. There was an increase on the number of students getting the correct answer for the items under Force of a Current in a Field, except for items 16, which targets the relationship of the direction of the force to the direction of the magnetic field and current and item 18 which also targets the same idea with number 16. For Electromagnetic Induction (items 22-30), there is an increase in the number of students getting the correct answer for items 22 , 24, 28 which targets idea behind Faraday's and Lenz' Law , and 30 which targets the understanding of making an electric generator. There is a decrease in the number of students getting the correct answer for items 26, 27, and 29, and same number for items 23 and 25. There was an inconsistency in the increase and decrease in the number of correct responses for these items.

Table 12 shows the number of students per category of understanding during the post-test, which includes now the students having no understanding of the concepts of Electromagnetism.

Table 12. *Comparison of Number of Students for each Category of Understanding for the Concept of Magnetism (N=46)*

Item No.	**SU**		**PU**		**PU-AC**		**AC**		**NU**	
	Pre-test	**Post-test**	**Pre-test**	**Post-test**	**Pre-test**	**Post-test**	**Pre-test**	**Post-test**	**Pre-test**	**Post-test**
1	18	33			1		10	2	17	11
2		1	7	25			6	2	33	18
3		2	6	14			6	5	34	25
4	1	8	1	10			9	6	35	22
5	1	3	16	30	1		3		25	13
6		8	1	10	7	11	7	8	31	9
7		2	6	17			4	1	36	26
8		13	5	7	1	2	5	8	35	16
9		1		20			7	6	39	19
10		1		4	1		2		43	41
11		1	2	14		2	9	11	35	18
12			1	10	1		3	6	41	30
13			4	16	1	1	6	5	35	24
14			1	3		2	1	8	44	43
15		3	2	2			1	2	43	39
16				4			4	8	42	34
17				17			5		41	29
18			1	2			2	1	43	43
19		1	1	2				3	45	40
20			3	2				4	43	40

21	1		4	14			2	1	39	31
22				4				1	46	41
23		1		3					46	42
24		1		2					46	43
25				6			3	4	43	36
26		1		5					46	40
27				6				4	46	36
28		1		2					46	43
29				1					46	45
30		1		2				1	46	42

We could see in the table that for concept of Magnetism (items 1-7), there was an increase in the number of students having sound understanding and partial understanding in the post-test compared to the pre-test. There is also a decrease in the number of students having alternate conceptions and no understanding. However, there are still a lot of students that have no understanding of their answers on each item. For Magnetic Fields Produced by Currents (items 8-14), there was an increase in the number of students having sound understanding and partial understanding in the post-test compared to the pre-test. There was also an increase in the number of students having partial understanding with alternate conceptions and only alternate conceptions. This signifies that some students have improved their understanding of concepts of Magnetism, while some students also gained some alternate conceptions. However, there are still a lot of students that have no understanding of their answers on each item, but we can observe that the number decreased. For the concept of Force of a Current in a Field, we can observe that there is an increase in the number of students having sound understanding and partial understanding in the post-test compared to the pre-test. There is also an increase in the number of students having alternate conceptions. This signifies that some students have improved their understanding of concepts of Magnetism, while some students also gained some alternate conceptions. However, there are still a lot of students that have no understanding of their answers on each item, but we can observe that the number decreased. For the concept of Electromagnetic Induction, we can observe that there was an increase in the number of students having sound understanding and partial understanding in the post-test compared to the pre-test. There is also an increase in the number of students having alternate conceptions. This signifies that some students have improved their understanding of concepts of Electromagnetic Induction, while some students also gained some alternate conceptions. However, there are still a lot of students that have no understanding of their answers on each item, but we can observe that the number decreased. We can also observe that the concepts in these items are the ones the students have the most difficult time to understand. Overall, the increase in the number of students having sound and partial understanding could be attributed to the use of the CCBL Model in the lesson package and the integration of Physlets® simulations. However, the students who have still no understanding in all major concepts meant that they were just guessing answers or got the correct answers randomly or by chance.

As a summary, the students were able to gain a better understanding of the major concepts of Magnetism, Magnetic Fields Produced by Currents, and Force of a Current in a Field. There was a slight improvement in the understanding of the major concept of Electromagnetic Induction. Overall, there are still high number of students having no understanding of these concepts of Electromagnetism even after the implementation of the lesson package anchored on the Cognitive Conflict-Based Learning (CCBL) Model. This is consistent with what Li, et al. (2021) has said, which is because many misconceptions are robust and resistant to educational interventions and teaching approaches, science educators and practitioners have reported that it can be difficult to help students undergo conceptual change and have better understanding. Moreover, due to their abstract and complicated nature, topics connected to Electromagnetism are particularly challenging for students to understand (Arnold & Millar, 1987; Mulhall, et al., 2001; Miokovi, et al., 2012). However, the increase in the number of conceptions that are considered sound understanding and partial understanding on all major concepts after the implementation of the lesson package anchored on the Cognitive Conflict-Based Learning (CCBL) Model gives us the idea that it helped students gain a more accurate and scientifically correct understanding of concepts in Electromagnetism.

Comparison of Scores of Students in the Pre-test and Post-Test

The scores of the students in the post-test will be compared to their pre-test scores to check if there is a significant change in their performance. Table 16 shows the mean, standard deviation, and normality of the scores in the pre-test.

Table 4. *Mean, Standard Deviation, and Normality of the Pre-Test Scores of Students*

	Mean	Standard Deviation	Test of Normality (Shapiro-Wilk Test)	
			W	**Sig.**
Pre-Test	9.1	2.31	0.957	0.091

In the table, it could be seen that the mean score was 9.1, which is considered a low score. The highest score was 15, and the lowest score was 4. To check the normality of the scores, Shapiro-Wilk Test of Normality was employed since less than 50 students answered the test. The result was 0.957, with a significant value of 0.091 which is higher than 0.05. This indicates that the scores are normally distributed and do not deviate much from the mean score. The same test was done with the post-test scores, as seen in Table 17.

Table 14. *Mean, Standard Deviation, and Normality of the Post-Test Scores of Students*

	Mean	Standard Deviation	Test of Normality (Shapiro-Wilk Test)	
			W	**Sig.**
Post-Test	12.96	3.51	0.963	0.148

In the table, it was shown that the students got a mean score of 12.96, which was considered a low score. The highest score was 20, and the lowest score is 7. Shapiro-Wilk Test of Normality was employed to check if the scores are normally distributed since less than 50 students answered the test. The result was 0.963, with a significant value of 0.148 which is higher than 0.05. This indicates that the scores are normally distributed and do not deviate much from the mean score. However, it is important to note that compared to the pretest scores, the standard deviation is larger in the post-test, meaning that the scores increased but became slightly deviated from the mean compared to the pre-test scores.

Since both pre-test and post-test scores are normally distributed, we employ a paired-sample t-test to determine if there is a significant difference between the scores and determine the effect size using Cohen's d test.

Based on the results, the post-test scores (Mean = 12.96, SD = 3.51) has a statistically significant difference from the pre-test scores (Mean = 9.07, SD = 2.31) at t(46) = 6.362, df=45, and p<0.001. This means that the performance of the students based on their scores improved after the implementation of the lesson package in Electromagnetism. However, it is to be noted that the students' mean score is still considered low and is below the passing score of 18, which is 60% of the perfect score of 30.

Cohen's d test was employed to check the effect of the implementation of the lesson package in Electromagnetism on the significant difference in the students' scores between the pre-test and post-test, in which the effect size is interpreted using the following: small (0.2), medium (0.5) and large (0.8).

Table 15. *Cohen's d Test*

	Standardizer	**Point Estimate (d)**	**95 % Confidence Interval**	
			Lower	**Upper**
Post-test Pre-test	4.149	0.938	0.587	1.282

Based on the table, the obtained d = 0.938 is greater than 0.8 which indicates a large effect size. This means that the implementation of the lesson package helped significantly in improving the scores of the students in the Conceptual Test in Electromagnetism.

To summarize, the mean scores of the students is still considered low (below 15). However, their scores have improved as evidenced by the significant difference between the pre-test and post-test scores, and the effect size signifies that the implementation of the lesson package in Electromagnetism anchored on the Cognitive Conflict-Based Learning Model has been effective in improving the performance of students in the post-test.

Comparison of Number of Students per Category of Understanding

To check if the increase and/or decrease of the number of students were significant for each category of understanding from the pre-test to the post-test, z-test of proportions was conducted for each category.

Table 16 shows the z-test result of the comparison of the percentage of students in the pre-test and post-test per category for the items that involve the concept of Magnetism and the interpretation of the results.

Table 16. *Comparison of Pre-test and Post-test Percentage of Students for Each Category of Understanding for Magnetism*

Category of Conceptual Understanding	Pre-test (%)	Post-Test (%)	z-value	p-value	Interpretation
Sound Understanding	6.2	17.7	-4.4984	< 0.00001	Significant increase
Partial Understanding	11.5	32.9	-6.5337	< 0.00001	Significant increase
Partial Understanding with Alternate Conceptions	2.8	3.4	-0.4393	0.65994	Increase but not significant
Alternate Conceptions	14.0	7.5	2.6627	0.00782	Significant decrease
No Understanding	65.5	38.5	6.8573	< 0.00001	Significant decrease
Total	100	100			

We could see that the increase of the students having sound and partial understanding of Magnetism is significant. The significant increase for both categories were also affirmed by the significant decrease in the students having alternate conceptions and no understanding, which meant that the implementation of the lesson package on Electromagnetism using CCBL Model greatly helped improved some of the students understanding. We could say that there is an improvement of students' conceptual understanding of Magnetism.

Table 17 shows the z-test result of the comparison of the percentage of students in the pre-test and post-test per category for the items that involve the concept of Magnetic Fields Produced by Currents and the interpretation of the results.

Table 5. *Comparison of Pre-test and Post-test Percentage of Students for Each Category of Understanding for Magnetic Fields Produced by Currents*

Category of Conceptual Understanding	Pre-test (%)	Post-Test (%)	z-value	p-value	Interpretation
Sound Understanding	0.0	5.0	-4.0636	< 0.00001	Significant increase
Partial Understanding	4.0	23.0	-7.0549	< 0.00001	Significant increase
Partial Understanding with Alternate Conceptions	1.2	1.6	-0.432	0. 6672	Increase but not significant
Alternate Conceptions	10.3	11.2	-0.3687	0. 71138	Increase but not significant
No Understanding	84.5	59.3	7.1137	< 0.00001	Significant decrease
Total	100	100			

We could see that the increase of the students having sound and partial understanding of Magnetic Fields Produced by Currents is significant. The significant increase for both categories were also affirmed by the significant decrease in the students no understanding, which meant that the implementation of the lesson package on Electromagnetism using CCBL Model greatly helped improved some of the students understanding. There is an increase in the percentage of students with alternate conceptions, but it is not significant. We could say that there is an improvement of students' conceptual understanding of Magnetic Fields Produced by Currents.

Table 18 shows the z-test result of the comparison of the percentage of students in the pre-test and post-test per category for the items that involve the concept of Force of a Current on a Field and the interpretation of the results.

Table 6. *Comparison of Pre-test and Post-test Percentage of Students for Each Category of Understanding for Force of a Current on a Field*

Category of Conceptual Understanding	Pre-test (%)	Post-Test (%)	z-value	p-value	Interpretation
Sound Understanding	0.3	1.2	-1.3236	0. 18684	Increase but not significant
Partial Understanding	3.4	13.4	-4.5743	< 0.00001	Significant increase
Partial Understanding with Alternate Conceptions	0.0	0.0	-	-	No change
Alternate Conceptions	4.4	5.9	-0.8612	0. 38978	Increase but not significant
No Understanding	91.9	80.0	4.3451	< 0.00001	Significant decrease
Total	100	100			

We could see that the increase of the percentage of students having sound understanding is not significant, however the increase in the percentage of students having partial understanding of Force of a Current on a Field is significant. The significant increase for the partial understanding was affirmed by the significant decrease in the students no understanding, which meant that the implementation of the lesson package on Electromagnetism using CCBL Model greatly helped improved some of the students understanding. There is an increase in the percentage of students with alternate conceptions, but it is not significant. We could say that there is an improvement of students' conceptual understanding of Force of a Current on a Field. Despite this, the percentage of students having no understanding still is above 50%. In connection to this, a long-term implementation needs to be tested if the percentage will significantly decrease to 50%.

Table 19 shows the z-test result of the comparison of the percentage of students in the pre-test and post-test per category for the items that involve the concept of Electromagnetic Induction and the interpretation of the results.

Table 7. *Comparison of Pre-test and Post-test Percentage of Students for Each Category of Understanding for Electromagnetic Induction*

Category of Conceptual Understanding	**Pre-test (%)**	**Post-Test (%)**	**z-value**	**p-value**	**Interpretation**
Sound Understanding	0.0	1.2	-2.2356	0.0251	Significant increase
Partial Understanding	0.0	7.5	-5.6798	< 0.00001	Significant increase
Partial Understanding with Alternate Conceptions	0.0	0.0	-	-	No change
Alternate Conceptions	0.7	2.4	-1.98	0. 0477	Significant increase
No Understanding	99.3	88.9	6.3504	< 0.00001	Significant decrease
Total	100	100			

We could see that the increase of the students having sound and partial understanding of Electromagnetic Induction is significant. The significant increase for both categories were also affirmed by the significant decrease in the students having no understanding, which meant that the implementation of the lesson package on Electromagnetism using CCBL Model greatly helped improved some of the students' understanding. However, there is a significant increase in the percentage of students having alternate conceptions. We could say that this affirmed the slight improvement of students' conceptual understanding of Electromagnetic Induction. Despite this, the percentage of students having no understanding still is above 50%. In connection to this, a long-term implementation needs to be tested if the percentage will significantly decrease to 50%.

As a summary, the z-test results affirmed the findings that students were able to gain a better understanding of the major concepts of Magnetism, Magnetic Fields Produced by Currents, and Force of a Current in a Field, and a slight improvement in the understanding of the major concept of Electromagnetic Induction. It turns out that even using CCBL Model and integrating Physlets® in the lesson, the students find learning the concepts of Electromagnetic Induction the hardest compared with the other three major concepts.

Affordances and Challenges Encountered in Implementing the Lesson Package

To know the affordances and challenges encountered during the implementation of the lesson package, the students were interviewed, and Qualitative Content Analysis (QCA) was employed to get the common responses of the students. To confirm the students' experiences, the teacher-implementer answered a checklist based on the findings of the study by Wasriep and Ladium (2019, and observation notes were also done by the researcher during the implementation of the lesson package, and findings were compared with the students' responses.

From the students' responses, the following were derived:

- The simulations are of great help for us to understand the topics.
  Anna: *"Mas makasabot mi sa lesson kay naa man makita namo sa simulations."*
  Mary*: "Kuan sir mas makatabang siya sa pagsabot namo sa mga topics kaysa isulti lang sa teacher."*
  John: *"Mas dali mi makasabot unya makahibaw dayon mi kung sakot or sayop ang kuan (…) among answers."*
- The topics are sometimes too complicated, we have a difficulty in understanding the lessons. We need more time to fully understand them,
  Luke: *"Naglibog ko atong ubang topic sir ug sa katong kamot-kamot sir [right hand rule]"*
  Henry: *"kinanglan ko ug more time para masabtan pa jud [the topics]"*
  Jenny: *"(scratches head) maglisod ko usahay sa pagsabot sa topic kay lisod kayo (giggles)"*
- The simulations are fun to manipulate and is new for us.
  Thea: *"First time nako nga naka-experience ato nga naa makita sa kuan sir, sa computer, ang kato mga topic……pwede diay ingato nga makagamit mi sa kuan, sa computer."*

Janice: *“Nalingaw ko sa simulations sir, nga maka usab-usab mi sa kato area para makita ang change nga naa siyay induced emf”*

Ben: *“First time to nako sir nga makakita ug simulation ug makagamit sa computer ug ingato”*

From the teacher-implementers’ answers on the checklist, these were categorized into the affordances and challenges, which was presented in Table 20.

Table 8. *Affordances and Challenges Encountered by the Teacher-Implementer during the Implementation of the Lesson Package*

Affordances	Challenges
1. The teacher has a positive attitude towards the implementation of the lesson package in Electromagnetism.	1. The teacher has a difficult time in understanding the concepts at first since she is not a Physics major.
2. The activities facilitate critical thinking skills and cooperation in the classroom.	2. Some simulations are hard to explain, especially those involve Electromagnetic Induction
3. ICT integration is highly evident in the lessons.	3. Learners’ abilities differ.
4. The lesson plans are systematic.	4. ICT equipment are not enough.
5. The simulation is a great way to show concepts that are abstract.	

As seen in the table, the teacher-implementer is very optimistic and open-minded when she was chosen as the one to implement the lesson package. She was able to follow the sequence of the lesson plans and finds them systematic. She was also able to highlight that there is ICT integration in using the simulation and that these simulations helped visualize the abstract concepts involved in Electromagnetism. The teacher-implementer also have encountered some obstacles as some topics are hard for her since she is not a Physics major, and some simulations involve concepts that are not found in the Learner’s Material used in Grade 10. To overcome this, the researcher helps the teacher-implementer in some concepts that she had a hard time explaining before the she does the classes. Also, since the class are grouped heterogeneous with different level of learning pace, some students took extra time to understand the concepts. Also, there were times that the computer laboratory is not available, and the teacher-implementer would have to make do of using the TV in the classroom.

From the observation notes, the following were observed:

Challenges:

- The teacher sometimes struggles to manipulate the simulations.
- The teacher refers sometimes to the lesson package if she used the correct term or the exact definitions.
- The number of computers functioning in the computer laboratory is not enough for the number of students. The teacher has to group the students with three or four students per computer.
- Using the TV sometimes make it hard to show the simulations. Some students do not pay attention to it.

Affordances:

- The teacher manages the class well and calls out students that are not paying attention.
- The teacher utilizes the checking of conceptions well in the beginning of the lesson.
- The teacher also monitors the class well during group activities.

To consolidate, the affordances that the students mentioned were that the Physlets® simulation makes the learning of Electromagnetism fun and interactive, that the simulation also helped them understand the topics better, and that the CCBL Model helped them address their confusion of some concepts in Electromagnetism. The challenges identified were that some topics were difficult to immediately understand, and that additional time was needed for them to better grasp the concepts. Furthermore, the equipment was not available at times and the quantity was also lacking. These were consistent with the response of the teacher-implementer and what was observed during the lesson delivery. Overall, the affordances and challenges that were identified by the teacher-implementer, the observation notes and the interview results from the students coincided with each other.

Conclusion

Based on the findings of this study, the following can be concluded:

A lot of Grade 10 students have no prior knowledge of the concepts of Electromagnetism and only few students have knowledge of these concepts which are considered sound understanding and partial understanding. Furthermore, a number of alternate conceptions are also present in the students. This signifies that some students have already preconceived ideas of the concepts of Electromagnetism which are based on their experiences, which some are scientifically correct, and some are not.

To address the change of alternate conceptions to scientifically accurate ones, a lesson package in Electromagnetism using CCBL Model with the integration of Physlets® was developed and was rated by three experts. The developed lesson package was found to be valid and ready for implementation and for future use.

The developed lesson package using CCBL Model was implemented and as observed during the implementation phase, some students have developed sound understanding and partial understanding of concepts that are covered, and most of the alternate conceptions identified in the pre-test were eventually replaced by scientifically accurate and partly correct ones. However, new alternate conceptions were also identified. After the implementation phase, understanding of some students has significantly increased as the number of sound understanding and partial understanding increased in all four major concepts. However, there are some students who remained to have difficulty in understanding concepts of Electromagnetism, particularly the concept of Electromagnetic Induction, and new alternate conceptions were identified in all for major concepts of Electromagnetism. The score of the students in the pre-test and post-test were also compared and it was found out that there is a significant difference. This means that the scores of the students have significantly improved from the pre-test.

The affordances that were identified from students' responses were the following: the Physlets® simulation makes the learning of Electromagnetism fun and interactive, the simulation also helped them understand the topics better, and that the CCBL Model helped them address their confusion of some concepts in Electromagnetism. The challenges that were identified were the following: some topics were difficult to immediately understand, additional time was needed for them to better grasp the concepts, and the equipment was not available at times and the quantity was also lacking. These were consistent with the answers of the teacher-implementer and with the observation notes.

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Impact of Experienced Teachers and Science Educators Collaboration on Preservice Science Teachers' Development

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Impact of Experienced Teachers and Science Educators Collaboration on Preservice Science Teachers' Development

Abstract

Preservice science teachers are required to participate in early field experiences, which are taken alongside the science methods course. The main objective of these early field experiences is to provide preservice science teachers with a practical understanding of inquiry teaching and learning and the school community. These early field experiences allow them to integrate educational theories with practical experience by observing the experienced science teachers in schools. This study examines how preservice science teachers observe and reflect on inquiry-based teaching and learning during their early field experiences. The study involves 21 preservice science teachers who visited schools as a team of three to observe experienced science teachers. Data collection methods included reflective journals, observation notes, individual interviews, and group discussions, which were analyzed using thematic analysis. The findings revealed that most preservice science teachers reflected on teaching strategies related to inquiry and science classroom management, respectively. The preservice science teachers learned to notice and interpret science teaching phenomena with their teams and group discussions, which included experienced teachers, science educators, and peers. These results indicate that collaboration among experienced teachers and science educators in early field experiences and a science methods course is advantageous for developing preservice science teachers' noticing and reflection on science teaching and learning, especially regarding inquiry. Furthermore, the collaborative discussions within the group, including experienced teachers, science educators, and peers, played a pivotal role in enhancing the preservice science teachers' reflective practices. Through these interactions, preservice science teachers observed and identified effective teaching strategies and actively engaged in dialogue to interpret and contextualize the underlying educational theories.
Keywords: Preservice science teacher; Experienced teachers; Collaboration

Preservice science teacher preparation is critical to developing effective science teachers who can foster inquiry-based learning in schools (Bianchini et al., 2010; National Science Teaching Association, 2020). A science methods course provides opportunities for preservice science teachers to increase their understanding of relevant content (Hestness et al., 2011; Santau et al., 2014). Moreover, a science methods course was provided to promote preservice science teachers in many competencies and characteristics. For example, Riedinger et al. (2011) developed the Transforming Elementary Science Teacher Education by Bridging Formal and Informal Science Education in an Innovative Science Methods Course for promoting students' attitudes toward and views of science and science teaching, modeling innovative science teaching methods, and encouraging students to continue in teacher education. (Riedinger et al., 2011). Chien et al. (2021) improved pre-service teachers' ICT knowledge and skills via a course with MAGDAIRE (Chien et al., 2012).

Preservice teachers' noticing is important for observing and interpreting significant aspects of classroom interaction and student learning (Lee, 2021; Tekin-Sitrava et al., 2022). The preservice science teachers need to develop strong noticing skills. These skills are essential for preservice science teachers as they lay the foundation for effective teaching practices that support student learning, engagement, and well-being. Noticing is a critical skill for effective teaching, as it allows teachers to respond to students' needs and adjust their instructional strategies accordingly. For preservice teachers, developing this skill involves observing experienced teachers and reflecting on these observations in a structured and supportive environment to enhance instructional quality (Arias et al., 2024; Benedict-Chambers et al., 2023). It requires identifying important features in classroom interactions, interpreting their meaning, and deciding how to respond based on observations. However, developing teachers' noticing skills is not straightforward through experience. Novice and preservice teachers have difficulties interpreting situations in depth and consider only students' behaviors, classroom management, and classroom settings rather than their understanding (Tekin-Sitrava et al., 2022). Preservice teachers typically concentrate on the surface features of the classroom environment, such as physical conditions and classroom management, rather than student-teacher interactions or students' thinking. They describe and qualify student work but make fewer efforts to understand the underlying student ideas (Kilic & Dogan, 2022; Talanquer et al., 2015). Special professional development programs or intervention studies are needed to support teachers' noticing skills(Kilic & Dogan, 2022).

Many educators studied preservice teachers' noticing, especially for mathematics education. For example, Lam and Chan (2020) characterized the nature of pre-service science teachers' (PSTs') noticing skills of different forms of evidence of student thinking using video-based interviews (Lam & Chan, 2020). Lee (2021) developed preservice teachers' noticing skills in elementary mathematics pedagogy courses by implementing the Three-point framework (Key Point, Difficult Point, Critical Point) and three technology-aided interventions (online discussions, clinical interviews, and graphic lesson plan construction). Similarly, Pérez-Montilla and Arnal-Palacián (2023) provided preservice teacher training to enhance and nurture the professional knowledge of mathematics teacher educators (MTEs). They explored the preservice teachers' level of development in professional noticing because by integrating theoretical knowledge with practical experience, the preservice teachers can enhance their ability to notice and interpret critical aspects of teaching. (Pérez-Montilla & Arnal-Palacián, 2023a). Wang & Oliver (2023) explore preservice teachers' noticing in an authentic practical setting through a school-based practicum associated with a block of site-based science methods and curriculum courses.

Various frameworks exist for analyzing and developing preservice teachers' noticing. For example, there are three facets of noticing: attending, interpreting, and deciding how to respond (Arias et al., 2024; Kilic & Dogan, 2022; Lam & Chan, 2020; Tekin-Sitrava et al., 2022). This study accepts these facets of noticing from Arias et al. (2024). The process of noticing involves attending to significant interactions, interpreting and reasoning about one's instruction, and responding through deciding how to revise one's instruction.

However, few studies have examined teacher noticing in practical contexts (Wang & Oliver, 2023). Noticing critical features of practice involves identifying what is important, interpreting interactions, and deciding how to respond. It requires identifying important features in classroom interactions, interpreting their meaning, and deciding how to respond based on observations.

Early field experiences are designed to immerse preservice science teachers in natural classroom settings, allowing them to observe and interact with experienced science teachers' practice (Kwok & Bartanen, 2022). The early field experiences play a crucial role in the preparation of teachers (Anderson et al., 2005). These experiences are pivotal in helping the preservice teachers understand the dynamics of teaching and learning in diverse educational contexts. Through these observations, preservice teachers gain insights into effective classroom management, instructional strategies, and the implementation of inquiry-based learning approaches. For example, Subramaniam (2013) examined the preservice elementary teachers' reflections on their documented early field experiences of science teaching in authentic contexts. The study used an early field experience model focused on profiling an elementary science teacher as the practical merit of reflection. Preservice elementary teachers individually and collaboratively reflected on their early field experiences and used the resulting reflections to construct profiles of elementary science.

Similarly, Wynn and Kromrey (2000) examined and documented the developmental concerns of participants in a paired peer placement peer coaching program. The findings support practicum students' developmental growth across a continuum of concerns from survival self-concerns to curriculum/instructional concerns to pupils/impact on learning concerns. Cotner (2023) discusses the benefits of collaborative early field experiences for preservice teachers in art museums, emphasizing the relaxed teaching environment and individualized interactions with students. The relaxed teaching environment and individualized interactions with students in art museums were emphasized as beneficial aspects of the early field experience.

Collaboration among experienced teachers, science educators, and preservice teachers plays a significant role in the professional growth of preservice teachers ((Borowczak & Burrows, 2016; Havu-Nuutinen et al., 2019; Judith et al., 2020; Min et al., 2020; Pérez-Montilla & Arnal-Palacián, 2023b)). Through collaborative interactions, preservice teachers are exposed to various teaching styles and strategies, broadening their understanding of effective science instruction. Experienced teachers serve as mentors, providing guidance and feedback that help preservice teachers refine their teaching practices (Boateng & Tatira, 2023; Dull & Chase, 2022; Mafugu, 2022). By working in teams, preservice teachers benefit from peer support and sharing insights and challenges with their colleagues (Atasoy & Cakiroglu, 2019; Havu-Nuutinen et al., 2019; Herbert & Hobbs, 2018; Kervinen et al., 2016).

The collaborative interactions among preservice science teachers, experienced teachers, and science educators played a pivotal role in enhancing their reflective practices. By engaging in dialogue and sharing insights, preservice teachers deepened their understanding of effective teaching methods and refined their inquiry-based teaching and learning approach. However, no study has found the positive effects of collaboration among preservice science teachers, experienced teachers, and science educators. For example, Atasoy & Cakiroglu (2019) said there needed to be more data on collaboration among inservice teachers, science educators, and preservice teachers.

Early field experiences, integrated with a science methods course, provide an essential framework for preservice science teachers to bridge the gap between theoretical knowledge and practical application and provide a practical understanding of inquiry-based teaching and learning within the school community (Thompson & Emmer, 2019; Washburn et al., 2022). These experiences offer a unique opportunity for preservice teachers to integrate educational theories with real-world classroom observations under the guidance of experienced science teachers. By immersing themselves in these settings, preservice teachers can enhance their understanding of effective teaching strategies, classroom management, and inquiry-based learning practices.

For this present study, the preservice science teachers are required to participate in early field experiences, which are taken alongside the science methods course. The main objective of these early field experiences is to provide preservice science teachers with a practical understanding of inquiry teaching and learning and the school community. These early field experiences allow them to integrate educational theories with practical experience by observing the experienced science teachers in schools. The impact of collaboration between experienced teachers, science educators, and preservice science teachers during early field experiences was focused.

Research question

How do preservice science teachers observe and reflect on inquiry-based teaching and learning during their early field experiences?

Methodology

Inquiry-based learning is a pedagogical approach emphasizing the importance of students engaging in scientific inquiry. It involves posing questions, conducting investigations, and constructing knowledge through active participation. This approach enhances students' understanding of scientific concepts and fosters critical thinking and problem-solving skills. Observing experienced teachers who effectively implement inquiry-based strategies is crucial for preservice science teachers' preparation.

Participants

The study included 21 preservice science teachers taking a science methods course for undergraduate preservice science teachers. They were second-year students from the Faculty of Education at a university in Bangkok, Thailand. During the science methods course, they went to schools in a team of three to observe experienced science teachers.

Science methods course for preservice science teachers

The science methods course is mandatory for second-year undergraduate preservice science teachers. It spans 15 weeks and takes place in the second semester. The instructors of this course include three science educators, two primary school teachers, and ten mentor teachers. The schoolteachers are experienced science teachers from the university laboratory schools. They consist of both primary and secondary science teachers. They are assigned to stand by at schools for the preservice science teachers to observe.

Before the semester began, the science educators, main schoolteachers, and mentor teachers held several collaborative meetings. The purpose of these meetings was to explore effective strategies to engage with the preservice science teacher, provide comprehensive and constructive feedback, and cultivate the preservice teachers' noticing skills. Additionally, the educators delved into discussions about devising appropriate assessment methods for evaluating the progress and development of the preservice science teachers and establishing clear assessment criteria to ensure fairness and consistency in the evaluation process. These meetings were instrumental in fostering a supportive and enriching environment for the preservice science teacher and laying the groundwork for a successful and productive semester.

During weeks 5-7, preservice science teachers observed their mentor teacher's science teaching. From weeks 8-12, they assisted with teaching, planning, and preparing to teach science, as well as practiced team teaching under the mentor teacher’s guidance (in a team of three). Each preservice science teacher chooses to focus on primary, junior high school, or high school based on their interests.

Table 1. Science methods course activities.

Week	**Intervention**	**Activities**		**Instructors**		
		University based	**School based**	**Three science educators**	**Two main schoolteachers**	**10 schoolteachers**
1	Learning theory, Philosophy, and nature of science			/	/	

Week	Intervention	**Activities**		**Instructors**		
		University based	**School based**	**Three science educators**	**Two main schoolteachers**	**10 schoolteachers**
2	Science curriculum, scientific literacy, Science learing objective			/	/	
3	Scientific inquiry ▪ Definition ▪ Feature ▪ Questining			/	/	
4	Science learing media			/	/	
5	Assessment for science learning		Classroom observation 1	/	/	/
6	Lesson planning	The PSTs design the 1st lesson plan for teacing in week 8-9	Classroom observation 2	/	/	/
7	Classroom observation		Classroom observation 3			/
8-9	Teaching		Teaching			/
10	Inquiry-based learning			/	/	/
11	• 5E Learning cycle model	Revise lesson plan		/	/	

Week	Intervention	Activities		Instructors		
		University based	School based	Three science educators	Two main schoolteachers	10 schoolteachers
	• 7E Learning cycle and instructional model					
12	Argument-Driven Inquiry: ADI			/	/	
13	6E Learning byDeSIGN™ model			/	/	
14-15	• The 2nd Lesson plan presentation • Refleciton and feedback			/	/	

Data collection and analysis

The preservice science teachers were assigned to write reflective journals every week, and in weeks 5 to 7, they were assigned to write observation notes at least two times. During weeks 5 to 6, the science educators and two main schoolteachers discussed with preservice science teachers what they learned from schools. The researchers investigated preservice science teachers' noticing when reflecting on experienced teachers' classroom observations during the collaborative discussions among science educators, schoolteachers, and preservice science teachers.

Data collection methods included reflective journals, observation notes, individual interviews, and group discussions. Thematic analysis was employed to analyze the collected data, focusing on the reflections and observations of preservice science teachers during their early field experiences. This qualitative study uses multiple data collection methods to capture the experiences and reflections of preservice science teachers. Reflective journals and observation notes provided insights into their observations and reflections on inquiry-based teaching. Individual interviews allowed for a deeper exploration of their experiences, while group discussions provided a platform for collaborative reflection and knowledge construction.

Thematic analysis (Joffe & Yardley, 2004) was used to analyze the data, identifying key themes related to the preservice science teachers' development of noticing and reflection skills. This method allowed the researchers to systematically explore the data and uncover patterns that highlight the impact of collaborative interactions on the preservice science teachers' professional growth.

Result

The findings revealed that most preservice science teachers reflect on teaching strategies related to inquiry and science classroom management, respectively. Moreover, it was found that most PSTs paid attention to teacher and student interactions when their responses were categorized based on the PSTs' noticing coding scheme adapted from Arias et al. (2024)

Table 1. The preservice science teachers' reflections.

Theme	**Example**	**Number of PSTs**
Inquiry	"…Teachers organize inquiry-based learning and encourage the students to work in groups. She gave the students an activity sheet together to calculate genotypes and phenotypes. It was found that the students were enthusiastic, fun, and good at solving problems when working with friends. …(PST7)"	11
Scientific quesitoning	"...Teachers used mostly open-ended questions. The teacher emphasized on scientific reasoning, such as how many groups of animals do you classify? What criteria are used for classification? …(PST5)"	11
Science classroom management	"…There were 40 students in the classroom. The teacher arranged the seats by alternating between male and female students. The teacher	14

Theme	Example	Number of PSTs
	used microphones to keep students interested in learning when the students lost their attention… (PST 11)”	
Media	“…Teachers used easily understandable and uncomplicated media to help Grade 5 students comprehend science. They also utilized media that piqued interest, such as colorful plant cartoons, to help students understand the structure of plants… (PST 15)”	12
Constructivism	“…The teacher taught about the definitions of pull and push forces without imparting knowledge. Instead, the teacher used hands-on activities, hint games, and driving questions, allowing students to construct their knowledge independently… (PST 13)”	3
Assessment	“…The teacher assessed student learning by having the students create artifacts… (PST 08)”	1
Student outcomes	“…Students designed electrical circuits in series and parallel. The teacher allowed students to design their own electrical circuits to suit their needs, which helped students learn scientific concepts and develop creativity. … (PST 19)”	3

From Table 1, the thematic analysis in this study involved inductive coding of the preservice science teachers’ attention. Most preservice science teachers (14 PSTs) focused on science classroom management, with only one PST focusing on assessment. This indicates a strong notice of preservice science teachers on inquiry-based learning, scientific questioning, classroom management, and the use of media in science education. On the other hand, fewer preservice science teachers emphasize constructivism, alternative assessments, and student outcomes.

Please remember the text below. TEXT:

To elaborate on the preservice science teachers' responses to find out more about their attention. The coding scheme was created based on Arias et al. (2024). The preservice science teachers' responses are categorized into three groups, namely 1) Attention to teacher and student interactions, 2) Interpretation, and 3) Emphasis on students' integrated sensemaking in decisions about revisions. Each group is divided into sub-groups. The result details are presented in Table 2 (1) – (3).

The coding scheme derived from the study by Arias et al. (2024) provides a comprehensive framework to analyze and evaluate the attention of preservice science teachers. This framework allows for the systematic categorization of their responses into distinct groups and sub-groups, contributing to a more nuanced understanding of their focus and engagement in the learning process.

Within the first group, "Attention to teacher and student interactions," the responses are further subdivided based on the nature of the interactions observed and the impact on learning outcomes. This allows for a detailed exploration of how preservice science teachers perceive and prioritize different forms of interaction within the classroom environment.

In the second group, "Interpretation," the coding scheme delves into the interpretations made by preservice science teachers regarding the content, pedagogical strategies, and student responses. This deeper analysis sheds light on the cognitive processes and decision-making factors that underpin their teaching approach.

The third group, "Emphasis on students' integrated sensemaking in decisions about revisions," offers insights into the importance preservice science teachers assign to students' sensemaking and how it influences their decision-making process when considering revisions to instructional plans and materials. This encompasses a critical aspect of student-centered teaching and learning perspectives.

The presentation of the result details in Table 2 (1) – (3) serves as a visual aid to complement the textual analysis, providing a structured format for easy reference and comparison of the categorized responses. By organizing the findings in this manner, the nuances and patterns within the preservice science teachers' attention become more apparent, facilitating a more in-depth interpretation of the data.

Table 2 (1) Coding scheme of the preservice science teachers (PST) responses: Attention to teacher and student interactions

Sub-groups		Desciptions	Examples of PSTs' responses	Number of PSTs
1	Teacher-only	A reflection that only attends to the teacher's ideas or actions	"…It was found that teachers had set agreements for learning. This is one way to bring students back.... (PST2)"	8
2	Student-only	A reflection that only attends to the student(s)' ideas or actions	"…The students focused on the cross-sectional of the plant to see it. …(PST9)"	6
3	Interactions between teacher-student and student	A reflection that attends to the interactions between the teacher and student or between students.	"…Teachers organize inquiry-based learning and encourage the students to work in groups. She gave the students an activity sheet together to calculate genotypes and phenotypes. It was found that the students were enthusiastic, fun, and good at solving problems when working with friends. …(PST7)"	10

Table 2 (2) Coding scheme of the preservice science teachers (PST) responses: Interpretation

Sub-groups		Desciptions	Examples of PSTs' responses	Number of PSTs
1	Describe	Describe the events in the classroom	"…Teachers used media and experimental equipment to promote science learning. He divided students into groups to work together and evaluate	5

Sub-groups		Desciptions	Examples of PSTs' responses	Number of PSTs
			learning by having children build circuits … (PST8)"	
2	Evaluate	Include an evaluative statement without evidence	"…Teacher has good techniques for introducing lessons and are well prepared for teaching. The teacher also motivates students by giving them snacks. …(PST4)"	2
3	Beginning to interpret	Interpret the events of the classroom without using evidence of what students said or did	"…Teacher organized the classroom by placing equipment in an orderly manner, with proper lighting, temperature, and smells. The teachers organized the classroom to help students work well. The teacher gave the students stickers if they had good manners and did good jobs. …(PST3)"	8
4	Interpret with evidence and reasoning	Interpret the actions in the classroom with evidence of what students said or did and provide reasoning that connects the evidence to the	"…The classroom was well organized. The students showed respect, obeyed teachers, and followed the rules. When the teachers gave the extra points if the students did good deeds, I noticed that the students did even better. This showed the effect of motivation …(PST6)."	4

Sub-groups		Desciptions	Examples of PSTs' responses	Number of PSTs
		claim about their teaching.		

Table 2 (3) Coding scheme of the preservice science teachers (PST) responses: Emphasis on students' integrated sensemaking in decisions about revisions

Sub-groups		Desciptions	Examples of PSTs' responses	Number of PSTs
1	Privileging students integrated scientific sensemaking	The PST identifies a revision that supports students to use science practices to engage in sensemaking about disciplinary core ideas or crosscutting concepts	"…The students showed they had key concepts because they could explain the electricity concept and were enthusiastic about experimenting. The teachers also encouraged each group of students to make electric circuits in other ways. If I were him, I would encourage students to create electric circuits in many ways.… (PST19)"	1
2	Using one-dimensional view of science teaching	The PST identifies a revision important for science teaching, but the revision does not help students to use science practices to build science	-	0

Sub-groups		Desciptions	Examples of PSTs' responses	Number of PSTs
		understanding or engage in sensemaking		
3	Focusing on general pedagogy	The revision could be applied to any content area or any class, a truly general observation about teaching	"…Students develop inquiry skills via group activities. They practiced being leaders and followers and listening to others. The students could apply this collaborative and teamwork competency to their real lives. I will incorporate this teaching technique into my teaching…(PST4)"	2
4	A focus that misappropriates science teaching or science content	The PST suggests a teaching practice that is not recommended for science teaching, possibly because s/he is taking a deficit view of students or is focused on telling the students the correct answer or adopting a didactic approach.	-	0

Table 2 (1) – (3) shows the coding scheme of the preservice science teachers' responses. The preservice science teachers' responses are categorized into three groups, namely 1) Attention to teacher and student interactions, 2) Interpretation, and 3) Emphasis on students' integrated sensemaking in decisions about revisions. Each group is divided into sub-groups.

The first coding scheme of the preservice science teachers' responses is the attention to teacher and student interactions. This group focuses on what teachers attend to. Three sub-groups, namely Teacher-only, relate to reflection and only attend to the teacher's ideas or actions. Student-only is about reflection that only attends to the student(s)' ideas or actions. The last group is Interactions between teacher and student; student-student reflection attends to interactions between teachers and students or between students. The 2nd group is interpretation, focusing on teachers' interpretations about what they selectively attend to. It is divided into four sub-groups namely Describe is about describing the events in the classroom. Evaluate include an evaluative statement without evidence. Beginning to interpret is related to interpreting the events of the clip without using evidence of what students said or did. Interpret evidence and reasoning related to interpreting the actions in the classroom with evidence of what students said or did and provide reasoning that connects the evidence to the claim about their teaching—the last group Emphasis on students' integrated sensemaking in Decisions about Revisions. There are four sub-groups; namely, Privileging students integrated scientific sensemaking PST identifies a revision that supports students using science practices to engage in sensemaking about disciplinary core ideas or crosscutting concepts. The 2nd sub-group uses a one-dimensional view of science teaching. The PST identifies revision as necessary for science teaching, but revision does not help students use science practices to build scientific understanding or engage in sensemaking. There is no preservice science teacher (PST) in this sub-group. The 3rd group focuses on general pedagogy. The revision could be applied to any content area or class, which is a truly general observation about teaching. The last sub-group is A focus that misappropriates science teaching or science content. This group focuses on a combination of three actions: attending to, interpreting, and responding to classroom events.

The findings indicate that preservice science teachers noticed science teaching phenomena by engaging in team and group discussions. These discussions involved a diverse group of participants, including experienced teachers, science educators, and peers. The collaborative nature of these interactions was found to be advantageous for the development of preservice science teachers' abilities to notice and reflect on science teaching and learning, with a particular emphasis on inquiry-based learning. The involvement of experienced teachers and science educators in early field experiences and a dedicated science methods course was shown to be beneficial for the professional growth of preservice science teachers. Such collaborative experiences provided valuable insights and practical knowledge, fostering the development of effective teaching strategies and instructional techniques. Furthermore, the role of collaborative discussions within the group was underscored as pivotal in enhancing the reflective practices of preservice science teachers. Engaging in dialogue with experienced teachers, science educators, and peers enabled preservice science teachers to not only observe and identify effective teaching strategies but also provided an opportunity to delve into and contextualize the underlying educational theories. This process of active engagement within the collaborative setting contributed significantly to the professional development of preservice science teachers. In conclusion, the research underscores the significance of collaboration between experienced teachers and science educators in shaping the development of preservice science teachers. Through early field experiences and collaborative discussions, preservice science teachers can enhance their noticing and reflection on science teaching and learning, particularly in inquiry-based learning.

Discussion

During their observations in the classroom, the preservice science teachers paid close attention to various aspects, with most of their focus on classroom management (Tekin-Sitrava et al., 2022). However, this emphasis on classroom management only provided a superficial understanding and did not delve into the students' comprehension. Through collaborative discussions with science educators and experienced teachers, the preservice science teachers were able to notice different dimensions during the three classroom observations (Wang & Oliver, 2023). experienced school science teachers play a crucial role in helping teacher candidates by engaging them in reflective discourse following experienced practices (Lewis, 2019).

Collaboration among experienced teachers and science educators in early field experiences and a science methods course is beneficial for developing preservice science teachers' ability to observe and reflect on science teaching and learning, particularly with regard to inquiry. In these collaborations, preservice science teachers gain insights into effective classroom management, instructional strategies, and the implementation of inquiry-based learning (Subramaniam, 2013; Wynn & Kromrey, 2000; Cotner, 2023). Typically, preservice science teachers tend to focus on the surface features of the classroom environment and overlook students' scientific ideas (Kilic & Dogan, 2022; Talanquer et al., 2015).

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The current state of Pre-service science teachers' supervision in the school partnership of Phetchaburi Rajabhat University

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The current state of Pre-service science teachers' supervision in the school partnership of Phetchaburi Rajabhat University

Abstract

Supervision is the one of process for enhancing pre-service science teachers' competency, among the different supervisory methods needed in a particular context. This research aims to explore the current state of pre-service science teachers' supervision in Rajabhat university. The participants were 45 instructors, and 33 cooperating teachers who work in school partnership were obtained by purposive selection. The data were gathered from questionnaire about current state and appropriate way of pre-service science teachers' supervision. Content analysis and descriptive statistics were employed to interpret the data. The results showed that most supervisor experience were between 11-15 years. Supervisors used mainly onsite supervision. The average of pre-service science teachers to supervisor ratio for all school was 3 pre-service science teachers to 1 supervisor. In addition, the top three activities that supervisors done most were a) opening channels for pre-service science teachers to contact and inquire, b) observing pre-service science teachers teaching, and c) correcting lesson plans before teaching, respectively. From this study also found that a rare activity was the opportunity for other pre-service teachers to participate in the observation, the supervisors and pre-service science teachers' time did not match, the pre-service science teachers lacked preparing lesson plans, and the supervisors had insufficient knowledge of supervision. However, most supervisors advised thus: training with excellent role models teacher, using a lesson study model, training for cooperating teachers and instructors who do not have a degree in specific teaching, and defined specific supervision model clearly.

Keywords: Supervision; Cooperating Teacher; School Partnership

Introduction

One crucial aspect of teacher professional development is teaching supervision, it effective assessment tool for improve teaching and learning. Supervision is a tool that can promote student learning, because it is a process that develops teachers' competencies, such as designing effective learning activities, knowledge of assessment, knowledge of curriculum, and knowledge about the learner's learning. Therefore, effective supervision will help teachers develop these competencies.

Although, the supervision process has appropriate and efficient principles. However, their application in various contexts still fails to comply with the principles fully. Specifically, challenges arise from insufficient cooperation among school partnerships, impacting the development of pre-service teachers. As a result, the purpose of this study was to investigate the current state of supervision process in school partnership, and the ways to promote pre-service science teachers' competency through supervision process.

Context of this study

In the context of this study, the teacher preparation program represents a specific model (Program specification, PBRU., 2019). This program is under the Faculty of Science where focuses on specific subjects such as physics, chemistry, and biology, including science methods courses, and supervised practical training. Conversely, the Faculty of Education oversees the teaching of educational subjects such as curriculum development and general pedagogy, as well as educational psychology. These faculties collaborate to produce proficient pre-service science teachers. Despite their collaboration, challenges persist for instance, some instructors from the Faculty of Science may lack a comprehensive understanding of the supervision process due to their limited background in education. Therefore, there is a need for training to ensure that pre-service science teacher receive guidance from supervisors who meet established criteria for qualifications.

Research Method

The aims of this study, to explore the current state of pre-service science teachers' supervision in school partnership, where collaborated with the Rajabhat University. This study adopted the mixed method exploratory research design (Creswell, 2007) and involved 78 samples, were 45 instructors and 33 cooperating teachers selected by purposive sampling. The participant' criteria are instructors in teacher preparation program and must have previously supervised pre-service science teachers, and cooperating teachers must have prior experience supervising pre-service science teachers and work in school partnership. Data collection was done through questionnaire and focus group interviews, which were subsequently reviewed by three experts. The study data obtained were analyzed through the content analysis and descriptive statistics.

Result

The findings from the analysis of the questionnaire findings and focus group interviews in current state of supervision process, have been broken down into two main parts. The first part included a survey of participants' general information, such as their work experience, supervision channels, and the number of students they had previously supervised in teaching. The second part focused on supervision activities, utilizing an online questionnaire to investigate the practices of both cooperating teachers and instructors in their supervision roles. These findings are discussed below.

Table 1. The general information of this study

Participant	**Percent**
Cooperating teachers	42.31
Instructor	57.69
Experience (year)	**Percent**
1-5	8.70
6-10	23.90
11-15	41.30
> 15	28.30
Supervising channel	**Percent**
Online	2.20
Onsite	56.50
Hybrid	41.30
Number of pre-service teachers	**Percent**
none	6.52
1-3	50.00
4-6	26.09
7-9	15.22
>10	2.17

According to table 1, 33 cooperating teacher and 45 instructors responded to the questionnaire, resulting in response rates of 42.31% and 57.69%, respectively. Most participants, had between 11 and 15 years of experience of 41.30%, Onsite supervision was utilized by 56.50% of the participants, and most of them supervise 1-3 pre-service teachers, comprising 50.00% of the total.

Table 2. Current activities in the supervision of pre-service teachers.

Activity	**Practice level (percent)**		
	3	**2**	**1**
1. Design a collaborative lesson planning between cooperating teachers, pre-service teachers, and instructors	37.18	39.74	23.08
2. Preparatory meeting before teaching of pre-service teachers every semester	70.51	23.08	6.41
3. Check lesson plan and give feedback every time	82.05	17.95	0
4. Teaching observation, give suggestion and feedback after the pre-service teachers teaching immediately	88.46	11.54	0
5. Members of the supervision process include administrators, cooperating teachers, and instructors	32.05	56.41	11.54
6. Pre-service teachers have the opportunity to reflect after every instruction	80.77	17.95	1.28
7. The cooperating teachers and instructors meet periodically to follow up on the supervision results	38.46	41.03	20.51
8. The supervisor reviews the implementation of the recommendations' results in the next teaching session	69.23	24.36	6.41
9. There are channels of contact besides face-to-face interaction, such as facebook, line, etc.	91.31	6.41	1.28
10. Provide opportunities for other pre-service teachers to observe their friends	19.23	26.92	53.85

Note: Scale ranges from 1= strongly disagree, 2= neutral, and 3= strongly agree

Therefore, this study sought to examine supervision practices by investigating supervisory activities. The result showed that, there are a total of six activities that supervisors perform at the highest level, consisting of meeting before the pre-service teachers' teaching every semester, the supervisor has checked lesson plan and give feedback, observe, give suggestion and feedback after the pre-service teachers teaching immediately, the pre-service teachers have the opportunity to reflect after every teaching, the supervisor reviews the implementation of the recommendations' results in the next teaching session, and pre-service teachers have additional channels of contact besides face-to-face interaction. The neutral activities included collaborative lesson planning among cooperating teachers, pre-service teachers, and instructor, the supervision of pre-service teachers always consists of cooperating teacher, administrator, and instructor, and the cooperating teachers and instructors meet periodically to follow up on the supervision outcomes. However, the lowest activity from this survey is, providing opportunities for other pre-service teachers to observe their friends. This is the results from the questionnaire about the activities supervisors undertake while supervising pre-service teachers. These results will help identify how these activities impact the teaching competencies of student teachers, highlight their strengths and weaknesses, and provide guidelines for promoting their competency, which will be discussed next.

Discussion, Recommendation

This study was conducted to uunderstand the current state of supervision process in specific context, including difficulty of supervision practice, because this process could help supervisors and the teacher preparation program develop effective concepts and practice into the real implementation of teaching supervision in schools. Thus might better inform the teacher preparation program reform efforts and policy decisions. The result showed that, the informant is an instructor rather than a cooperating teacher, and most of the supervisors are highly experienced due to the teacher council's regulations that require cooperating teachers to have previous experience, as well as, supervisors use onsite supervision more than any other approach now that the COVID-19 pandemic has subsided. However, we found that online supervision still persists. Focus group interviews revealed reasons for this, such as the instructors' time constraints and workloads, which often do not align with the pre-service teachers' teaching schedules, and the appropriate number of students who need to be supervised is between one and three.

In regards to supervision activities, supervisors' practice most of items, such as the pre-service teachers can contact their supervisors through various channels, whether Facebook, line etc. This is convenient and easy for pre-service teachers when they need teaching advice, giving feedback after teaching immediately, check lesson plan and give feedback, as well as pre-service teachers can reflect after teaching, and there is a meeting before supervision every semester. This finding aligns to other studies that report the importance of supervision process, as well as process of enhancing the pre-service teachers through supervision activities (Mette et al., 2015; Yutakom et al., 2016; Choicharoen et al., 2020; Azrani Mohd Zain et al., 2021). In addition, we also found that providing student teachers with the opportunity to observe their peers teaching is an activity that rarely occurs during supervision. Although, that is a form of professional development that improves teaching practices and pre-service teacher performance. Peer observation offers significant benefits for pre-service teachers, promoting a culture of continuous improvement and collaboration. It provides diverse perspectives on teaching techniques, allowing teachers to learn new strategies and reflect on their own practices. This practice also supports a collaborative community, enhancing mutual support and constructive feedback among teachers (Hendry and Oliver, 2012). Therefore, to effectively develop pre-service teachers' teaching competencies, supervisors should prioritize incorporating peer observation techniques into their training programs. In addition, the survey revealed several issues in the supervision process: mismatched schedules between instructors and cooperating teachers, pre-service teachers failing to submit lesson plans on time and often using plans from the internet, a lack of interest in acquiring new knowledge, insufficient knowledge among supervisors about effective supervision, non-participation of cooperating teachers in the teaching supervision, and excessive workloads for supervisors (Hoben, 2021; Choicharoen and Pruekpramool, 2020; Khaocharoen et al., 2018).

Finally, effective supervision of pre-service teachers is crucial for their professional development. Current state of supervision practice includes scheduling conflicts between instructors and cooperating teachers, pre-service teachers delayed and inadequate lesson planning, a lack of enthusiasm for learning new approaches, insufficient supervisory knowledge, and heavy workloads for supervisors. Addressing these issues requires better coordination, enhanced training for supervisors, and greater involvement of cooperating teachers in the supervision process to ensure a supportive and productive learning environment for pre-service teachers. From the above results, institutes of education can develop clear supervision guidelines. These could include implementing a lesson study process, professional learning communities (PLC), and training both instructors and cooperating teachers in effective supervision skills. Additionally, they should establish regular meetings with school partners to ensure a clear understanding of roles and to provide ongoing support for joint academic initiatives.

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The Study of Satisfaction with Inquiry-Based Learning Combined with Using Educational Board Games in the Science Subject of Eleventh-Grade Students in Thailand

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The study of satisfaction with inquiry learning combined with using educational board games in the science subject of eleventh-grade students in Thailand

Abstract

The objective of this research was to investigate the satisfaction with inquiry learning management combined with the use of educational board games for teaching science among eleventh-grade high school students in Thailand. The participants consisted of 38 eleventh-grade high school students from Yangtaladwittayakarn School, Kalasin Province, Thailand, who were studying science in the first semester of the academic year 2023. They were selected through cluster random sampling. The research instruments included: 1) six Biology lesson plans on the topic of reproduction of flowering plants, 2) six biology board games, and 3) a satisfaction assessment questionnaire regarding inquiry learning management with the use of board games for science teaching. Statistical analysis utilized mean and standard deviation.

The research findings revealed that students who engaged in inquiry learning management with the use of board games for science education were highly satisfied with the overall learning activities (M. = 4.51, S.D. = 0.68). Upon examining specific aspects, it was found that the top three areas where students expressed the highest satisfaction were as follows: firstly, teacher instruction, which garnered the highest satisfaction level among students (M. = 4.71, S.D. = 0.60); secondly, the attractiveness of the board games used for learning management, which students found highly satisfying (M. = 4.63, S.D. = 0.67); and thirdly, the clarity and ease of understanding of the game instructions provided for learning activities, which also received the highest satisfaction rating from students (M. = 4.55, S.D. = 0.68).

Keywords: inquiry-based learning; Biology Board Game; Satisfaction

1.Introduction

Studying science and technology is crucial for the development of individuals and nations. It is evident that countries which are stable and capable of economic development prioritize science and technology significantly. This is because the nature of biological science, particularly in Plant Breeding, involves highly abstract content with considerable complexity, potentially leading to confusion among students and erroneous concepts (Thanarat, Sangkhamani, and Pairoj, 2015). Typically, teaching is conducted through lectures and slide presentations, fostering rote memorization rather than understanding. Students are often passive learners, following instructions from teachers, lacking instructional media to enhance clarity and stimulate interest. Emphasis on content over practical application may result in dull classroom atmospheres, reducing student satisfaction with learning. Consequently, students may exhibit short-term interest in the subject, leading to incomplete retention of knowledge from each learning unit. Therefore, it is the responsibility of teachers to cultivate students' satisfaction in learning science, as they serve as catalysts for fostering students' desire to learn, thereby achieving success and fulfilling set goals.

Implementing inquiry-based learning is a teaching process that enables students to construct their own knowledge, engage in hands-on activities, exchange knowledge within groups, and ultimately create new knowledge by linking existing foundational knowledge with new knowledge. Teachers play a crucial role in promoting learning and organizing activities to develop students' knowledge, understanding, and interest in science subjects (Ministry of Education, 2009).

From studying learning activities using board games, it is considered another method that helps students become more enthusiastic and interested in learning. The board games used in education transform students from mere recipients of information from teachers to "players" in simulated game scenarios where they experiment with planning and management tasks to accomplish various missions under the rules of the game. Students who engage in playing games immediately see the outcomes of their decisions and understand how each decision affects the overall outcome in the long run. This is a learning process through board game mechanics that stimulates players to stay focused and interested by competing while having fun (Ratchaneewan Tangpakdee, 2022). Additionally, it helps to increase concentration in learning, emotional stability, relaxation from stress, enjoyment, better emotional control, and introduces them to new friends (Kingkan Buoronsinwatthana, 2019).

When comparing learning through games with traditional lecture-based teaching, it is found that teaching through games has many advantages. For example, there is higher student participation, increased eagerness to learn, immediate feedback can be provided to students, and students can more easily relate lessons or games to real-life contexts (Trybus, J., 2014). Consistent with Waraphon Limprem and Kantaphon Thammawat (2017), organizing learning activities using board games helps in brain training, enhances creativity, improves problem-solving skills, and fosters better decision-making. Board games also help increase concentration in learning.

From the aforementioned study, the researchers have explored strategies for improving the format of inquiry-based learning activities combined with the use of board games for education. By incorporating board games into teaching activities, the aim is to make learning more enjoyable and engaging for students, and to serve as a guideline for enhancing effective science learning and for the ongoing development of science teaching and learning. Therefore, the results obtained from this research can be utilized as data to develop learning activities for science teachers and stakeholders, serving as a guide for improving science learning practices to benefit future students.

2. Research Objective

To investigate satisfaction with inquiry-based learning combined with the use of board games in the subject of Biology among eleventh-grade students in Thailand.

3. Research Methodology

3.1 Sample Group

Eleventh-grade students from Yangtaladwittayakarn School, Yang Talat Subdistrict, Yang Talat District, Kalasin Province, Thailand, who are enrolled in the Science subject in the first semester of the academic year 2023. There were 38 students selected through Cluster Random Sampling.

3.2 Research Tools

The research tools consisted of 3 types:

(1) Lesson plans for Biology on the topic of Reproduction of Flowering Plants for eleventh-grade students, totaling 6 lesson plans, with a total duration of 9 hours. The details are as follows:

- Lesson Plan 1: Structure of Flowering Plants, 2 hours

- Lesson Plan 2: Life Cycle of Flowering Plants, 1 hour
- Lesson Plan 3: Plant Reproduction Cell Formation, 2 hours
- Lesson Plan 4: Pollination and Fertilization, 1 hour
- Lesson Plan 5: Fruit and Seed Formation, 2 hours
- Lesson Plan 6: Utilization of Different Structures of Fruits and Seeds, 1 hour

The quality of these lesson plans was assessed using an evaluation form for lesson plan appropriateness, evaluated by 5 experts. It was found that all 6 lesson plans had average scores ranging from 4.64 to 4.75, and standard deviations ranging from 0.51 to 0.57. In conclusion, all 6 lesson plans were of the highest quality and highly appropriate.

(2) Biology Board Games: These are board games designed and developed by the researchers to align with the content of the biology curriculum on the topic of reproduction of flowering plants. There are a total of 6 board games as follows:

- Board Game 1: "Flowers & Fruit" - This is a strategy board game that incorporates knowledge about the structure of flowering plants and types of fruits. It can be played by 2-6 players within 45 minutes and is used in conjunction with Lesson Plan 1.
- Board Game 2: "Pirate's Life: Flowering Plant Life Cycle" - This is a strategy board game that integrates knowledge about the alternating life cycle of flowering plants. It can be played by 3-6 players within 30-45 minutes and is used with Lesson Plan 2.
- Board Game 3: "Check-In @ YW" - This is a strategy board game that includes knowledge about the process of plant reproduction cell formation. It can be played by 2-6 players within 45-60 minutes and is used alongside Lesson Plan 3.
- Board Game 4: "Adventure of Pollen" - This is a strategy game that incorporates knowledge about pollen dispersal and pollination in flowering plants. It can be played by 2-6 players within 30 minutes and is used with Lesson Plan 4.
- Board Game 5: "Fruit and Seed" - This is a strategy board game that includes knowledge about fruit and seed formation, including seed components. It can be played by 4-6 players within 15-45 minutes and is used with Lesson Plan 5.

- Board Game 6: "Yang Talat Market" - This is a strategy board game that integrates knowledge about the various uses of seed structures. It can be played by 2-5 players within 30-45 minutes and is used with Lesson Plan 6.

Figure 1: Biology Board Games - 6 board games developed by the researchers.

To assess the quality of all these board games, a board game quality assessment was conducted by three board game experts. It was found that all six board games had average scores ranging from 4.30 to 4.55, with standard deviations ranging from 0.48 to 0.74. In summary, the developed Biology board games, all six of them, are of high quality.

(3) Satisfaction Assessment: This assessment is based on a 5-level rating scale consisting of 9 items. The quality of this satisfaction assessment was evaluated using Cronbach's alpha coefficient, resulting in a confidence level of 0.71. In conclusion, the assessment is deemed to be of good quality.

3.3 Data Collection

A study of the satisfaction of eleventh-grade students with inquiry learning combined with using educational board games. The researcher conducted a study on the satisfaction of eleventh-grade students in the first semester of the 2022 academic year, totaling 38 students, for 4 weeks during the month. November–December 2023, with details as follows:

(1) The researcher has created a tool consisting of a learning management plan. Regarding the reproduction of flowering plants, biology board games, and satisfaction assessments.

(2) Write a letter from the University to request permission from the director of Yangtaladwittayakarn School. In the process of collecting data and conducting experiments

(3) Conducting a learning experiment with a sample group of students. using inquiry learning combined with using educational board games on the topic of reproduction of flowering plants, 6 learning plans, and 9 hours, according to the following steps:

- Step 1: Introduction involved explaining the game rules and regulations.
- Step 2: Exploration and investigation: Students play board games that the researchers have developed based on the content of each learning plan.
- Step 3: Explanation involved posing questions to initiate discussions about the knowledge or insights gained by the students.
- Step 4: Elaboration involved students expanding their understanding of concepts and process skills through additional activities to create new experiences.
- Step 5: Evaluation involved assessing the learning activity outcomes according to the objectives.

(4) At the end of the six learning activity plans, the researchers surveyed the students' satisfaction after learning with inquiry learning combined with using educational board games. Using a satisfaction assessment of inquiry learning combined with using educational board games. It is a 5-level rating scale comprising 9 items. to use scores to analyze to find satisfaction levels.

3.4 Data Analysis

Data analysis of students' satisfaction with inquiry learning management with the use of board games on the topic of reproduction of flowering plants for eleven-grade students. In this research, analysis was conducted by finding a statistical analysis utilizing the mean and standard deviation

4. Research Findings

The research findings indicate that students who engage in inquiry learning management with the use of board games for science education exhibit the highest level of satisfaction towards the overall learning activities (M. = 4.51, S.D. = 0.68). Upon closer examination, the top three aspects in which students express the highest satisfaction are as follows:

1. Teaching by the instructor: Students express the highest level of satisfaction (M. = 4.71, S.D. = 0.60).

2. Aesthetic appeal and attractiveness of the board games used in learning management: Students express the highest level of satisfaction (M. = 4.63, S.D. = 0.67).

3. Clarity and ease of understanding in the instructions and details of gameplay provided by the board games used in activities: Students express the highest level of satisfaction (M. = 4.55, S.D. = 0.68).

As shown in Table 1:

Table 1: Satisfaction of eleven-grade high school students towards inquiry learning management with the use of board games in Biology: Reproduction of Flowering Plants.

Criteria	**(n=38)**	**S.D.**	**Satisfaction Level**
Enjoyment in learning management	4.53	0.68	Very High
Satisfaction with teacher's teaching	4.71	0.60	Very High
Content used in learning management is not overly difficult	4.24	0.67	High
Able to apply knowledge in daily life	4.39	0.71	High
Inquiry learning with board games enhances understanding of content	4.42	0.82	High
Instructions on board games for activities are clear and easy to understand	4.55	0.68	Very High
Adequate duration for gameplay, not too long	4.47	0.75	High
Board games used in learning management are aesthetically appealing and captivating	4.63	0.67	Very High

Criteria	**(n=38)**	**S.D.**	**Satisfaction Level**
Board games used in learning management promote systematic thinking	4.37	0.67	High
Overall satisfaction	4.48	0.69	High

Additionally, there are further suggestions from students' feedback regarding inquiry learning management with the use of game boards. They express that learning in this format makes understanding biology content easier. They wish for teachers to incorporate games into their teaching regularly. They feel happy and enjoy playing games with their classmates. Learning alongside playing board games helps them analyze answers more quickly and fosters a greater sense of dedication to learning. However, some board games pose questions that are too difficult for test knowledge.

5. Conclusion and Discussion

Eleventh-grade high school students in Thailand who have experienced inquiry learning management with the use of board games express high satisfaction towards the overall learning activities (M. = 4.48, S.D. = 0.69). Upon examining individual aspects, it is found that the highest level of satisfaction lies in students' contentment with teachers' teaching (M. = 4.71, S.D. = 0.60), which is the highest satisfaction level. Following closely is the satisfaction with the aesthetically pleasing and captivating board games used (M. = 4.63, S.D. = 0.67), also at the highest satisfaction level. Additionally, students highly appreciate the clear and easy-to-understand instructions provided by the board games for activities (M. = 4.55, S.D. = 0.68), again at the highest satisfaction level. This is attributed to the interesting nature of the inquiry learning activities with game boards, the use of visuals, and language that is easy to comprehend, enabling students to learn independently. and because the inquiry process engages students' insatiable curiosity. Traditional teaching methods, which simply present scientific facts, result in less engagement from students, causing them to lose interest quickly. In contrast, inquiry places students at the center of the experiment, giving them a sense of responsibility for the outcomes. Throughout the study, the classroom environment changed from apprehensive and disengaged to active discussion and participation. (Nuangchalerm, P., & Thammasena, B, 2009) Furthermore, students engage in discussions and consultations with peers during learning activities using game boards, encountering challenges with each game session, which sustains their interest and prevents boredom. This creates a novel learning atmosphere that stimulates students' enjoyment in learning, leading to subsequent positive learning outcomes, such as impressing students and enhancing their satisfaction with learning management. aligns with Varaporn Limpremwattana and Kantapol Thamwattann (2017). Said that the impact of game board play on adolescents, suggests increased attention and relaxation, enhanced emotional control, and the development of new friendships. Furthermore, when comparing teaching through games to traditional lecture-based teaching, game-based teaching offers several advantages, including higher student participation, increased student enthusiasm for learning, immediate feedback provision, and easier integration of lessons or games into real-life contexts. (Kingkarn Buranasinvattanakul, 2019). and Yu et al. 2021. said Educational games can enhance student engagement by providing interactive and enjoyable learning experiences. Elements such as team debriefing can boost student motivation and engagement in learning activities. This increased engagement often leads to improved academic achievements and better instructional outcomes. as well as Sitthikrai et al. 2023 said The study concluded that using inquiry-based learning combined with educational games significantly enhances academic achievement and student satisfaction in science education. This approach also increased student engagement and satisfaction high satisfaction scores.

The researchers hope that this study will serve as an interesting research direction for educators to study and develop teaching strategies in science subjects in various dimensions, including knowledge transmission, the development of various higher-order thinking skills, and the creation of more enjoyable learning environments in science classrooms. This could extend to teaching at various grade levels and across different disciplines in the future.

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Re-examining the role of language in Chemistry in the senior secondary curriculum of Hong Kong with Content and Language Integrated Learning (CLIL) Approach

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Re-examining the role of language in Chemistry in the senior secondary curriculum of Hong Kong with Content and Language Integrated Learning (CLIL) Approach

Abstract

Hong Kong Diploma of Secondary Education examinations (HKEAA) are used to recognise students' abilities for their future pathways after secondary education. When teachers want to review the teaching effectiveness of their curriculum design, candidates' performance reports in public exams are essential tools for educators to reflect on their teaching effectiveness. According to the candidates' performance reports of chemistry (HKEAA, 2012 – 2022), students have been working to tackle subject misconceptions. However, students are still weak in communicating subject matters through English at word, sentence and text levels. This presents an opportunity for educators to implement a more comprehensive teaching programme to tackle the linguistic challenges of students, with Content and Language Integrated Learning (CLIL) offering a promising solution.

This action research with multiple cycles includes a 2-year longitudinal study, a significant undertaking, of how content and language integrated learning (CLIL) approaches such as literate talk (Luk & Lin, 2015) with modified multimodalities and entextualisation cycle (MEC) (Lin, 2016) were employed in a Hong Kong Chemistry classroom from Grade 10 to Grade 11 to facilitate meaning-making processes between the teacher-researcher and students. Students' summative assessment data were collected and analysed qualitatively and quantitively. Results show that students kept their academic standards even when chemistry content knowledge became increasingly difficult. Moreover, the majority of the students achieved most of the elements in the 4Cs in CLIL, as suggested by Coyle *et al.*, (2010), implying that the framework is useful in increasing students' content and language proficiency while eliminating most of the mistakes suggested by the HKEAA.

Keywords: chemistry teaching, content and language integrated learning (CLIL), multimodalities and entextualisation cycle (MEC)

Introduction

English, as the most dominant language in the world, offers students a significant competitive advantage in their future careers or further studies. It opens doors to a plethora of opportunities in the globalized job market. Therefore, it is imperative that students achieve a high level of English language proficiency, and education plays a crucial role in this pursuit.

In the educational context, it is crucial to have a language-embedded environment for students to learn English at all times. This means that English learning should not be confined to English lessons but should also be integrated into content lessons using English as a medium of instruction. While European educators are pioneering the Content and Language Integrated Learning (CLIL) approach, our responsibility as educators in Hong Kong is to observe and adapt this approach to create a better teaching pedagogy for our students. The CLIL approach enhances language learning and promotes a deeper understanding of content subjects. Therefore, we need to cultivate more language-responsive teachers, even if they do not teach English subjects, to create a more comprehensive learning environment.

However, there are still arguments among subject teachers that language is not the primary concern in lesson delivery, as reflected by time reduction in language emphasis in lessons. Nevertheless, according to the examination reports from the examination authority in Hong Kong (HKEAA, 2012 – 2022), students have been criticized for not paying too much attention to the language aspect. That means the arguments mentioned above do not seem that concrete and sound. Consequently, it is essential to cultivate more linguistically aware teachers to increase students' language accuracy.

In this study, the teacher-researcher acted as a linguistically aware teacher to help students increase their language proficiency in Chemistry without sacrificing their learning in content subjects. The goal was to show that CLIL is a plausible option for Chemistry teachers in Hong Kong.

Research question:

In what extent can a chemistry teacher increase students’ language proficiency in Chemical communication through English in various (word / sentence / text) levels with increasing content proficiency?

Literature Review

Candidate Performance in Public Examinations

In Hong Kong, there is one kind of public examination, the Hong Kong Diploma of Secondary Education (HKDSE) examination, for recognizing students' abilities for their future pathways, whether they are capable of being admitted the university degree, sub-degree levels (higher diploma degrees or associate degrees) or other vocational pathways (diplomas or finding jobs). When teachers review the teaching effectiveness of their curriculum design, candidates' performance reports in public exams are essential tools for educators to reflect on their teaching efficacies. According to the candidates' performance reports (HKEAA, 2012 – 2022), it is not difficult to discover that students have been working hard on tackling subject misconceptions. However, students are still weak in communicating subject matters through English. For instance, in the HKDSE chemistry examination, students often struggle with understanding and using scientific terminology in English, which hinders their ability to express their knowledge effectively. The table below summarizes the common mistakes that chemistry students have made since 2012.

Table 1. Common mistakes that chemistry students have made (HKEAA, 2012 – 2022)

Language functions	Common mistakes
Word level	Wrong spelling
	Misuse of terms
Sentence level	Incomplete description
Text level	Illogical presentation of text
	Unsystematic presentation of text

One spectacular scenario is that a proportion of students misspelt the word 'substitution' in 2019 Paper I Question 5(c). However, the same problem appeared in 2015 Paper I Question 6(a) and 2017 Paper I Question 12(b)(ii) (HKEAA, 2015, 2017, 2019). While students have been making efforts to eradicate common misconceptions in chemistry, spelling mistakes have been a prevalent problem throughout the years. When students cannot communicate chemistry through words, it seems more difficult for them to communicate logically and systematically through text. Consequently, teachers should implement a more comprehensive teaching programme to tackle students' linguistic challenges. Content and language-integrated learning should be a way to help.

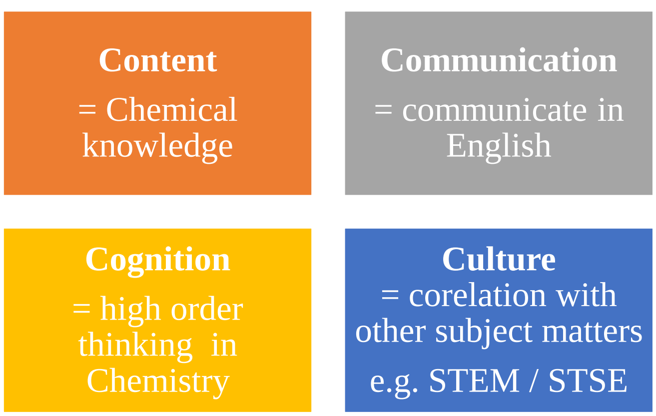
From Language across the Curriculum to Content and Language Integrated Learning

While the language across the curriculum (LAC) approach, in use since the 1960s, effectively emphasizes the dual focus of language and content, it falls short in addressing the multifaceted demands of modern education. Overemphasizing content and language alone can impede the acquisition of high-order cognitive skills. This underscores the necessity for a more comprehensive model like Content and Language Integrated Learning (CLIL).

Content and Language Integrated Learning (CLIL) is a comprehensive model that encompasses various approaches, including content-based instruction, immersion classes, and bilingual education. Its primary goal is to provide robust language support, making it a highly effective model.

The CLIL model, with its four dimensions of content, communication, cognition, and culture, is not only superior to a conventional LAC model but also highly adaptable. It encourages the development of high-order thinking skills in cognition and fosters interdependence with other subjects, such as the STEM approach and STSE education. This adaptability makes it a viable option for various educational contexts, including Hong Kong.

Figure 1. The CLIL model modified for the educational context in Hong Kong (Coyle, 2010)



Research Gap to be filled

While few studies have explored the connection between Chemistry and language, our study offers a new and potentially impactful approach. For instance, Risnita and Bashori (2020) investigated how learning methods influenced essay writing performance in Chemistry.

However, their experimental approach, while informative, may not fully resonate with chemistry educators. In contrast, our action research approach has the potential to inspire fresh insights and more significant pedagogical implications, which could be of great interest to the audience.

Theoretical framework

In this study, student content proficiency and language proficiency were assessed. The 4Cs model of CLIL, a framework developed by Coyle (2010), emerged as the most appropriate. It aligns with students' chemistry writing contents, which consist of fundamental chemical knowledge and higher-order thinking skills, representing 'content' and 'cognition' in the 4Cs model, respectively. The language used by the students is reflected in the 'communication' part of the 4Cs model. Therefore, the 4Cs model of CLIL from Coyle (2010) is not just useful, but absolutely essential in evaluating students' performance in Chemistry in this study.

Methodology

Research design

Experimental design might produce rigorous data, but students might need to learn in an artificial environment, which could hinder their learning. Therefore, action research was employed in this study.

In this action research, it exists of four stages:

Planning

The teacher-researcher was responsible for outlining the content and language objectives essential in chemistry learning before the teaching stage, i.e., summer and winter breaks.

Action

The teacher-researcher conducted the lesson using the bridging pedagogies described on the next page.

Observation

The teacher-researcher communicated verbally and in writing with students about their progress to evaluate the topic's teaching and learning effectiveness.

Reflection

After evaluation, the teacher-researcher needed to review the teaching progress.

When the teaching and learning effectiveness were satisfactory, the teacher-researcher could proceed to the action stage of another action research cycle. However, when it was not, the teacher-researcher needed to plan the lessons again to assist students in learning, meaning that the action research cycle would be repeated. Therefore, there were multiple action research cycles during the two-year longitudinal study.

Research Setting and Participants

Participants (n = 47) were drawn from Grade 10 and 11 (15 – 17 years old) students studying Chemistry in a secondary school in Hong Kong for two years. Participants were divided into two classes in each form. Class A consisted of students studying at least two science subjects (Chemistry and Physics), while Class B consisted of students studying at least Chemistry as the science subject.

Methods of Data Collection

Papers from post-tests in Grade 10 and one delayed post-test in Grade 12 were collected. Students' marks were analysed quantitatively, and their essay-type writing was analysed qualitatively.

Bridging Pedagogies of a Classroom with Rich Language Support

Although the participants were in the elite class, they may still need to be more accustomed to a sudden change in the medium of instruction. Therefore, Luk & Lin (2015) and Lin (2016) suggested that some bridging pedagogies were employed to relieve students' pressure when they suddenly had a CLIL class.

Modified Multimodalities and Entextualisation Cycle

Lin (2016) demonstrated the use of multimodalities and entextualisation cycle with the enrichment of context by using multimodalities such as adding digitals and visuals to lessons as the first step. Then, students were asked to take notes for writing with scaffolds afterwards. This cycle was elaborated with the teaching and learning cycle by Rose and Martin (2012) in this research to increase the teachers' understanding of how to decrease the scaffolds to release students' learners' responsibility to facilitate themselves as independent learners. First, teachers provide multimodalities to enrich the context in teaching and learning. In Chemistry classrooms, other than ordinary multimodalities like photos or videos, experiments were usually employed as a kind of multimodalities to explain chemical concepts in macroscopic way. When students hoped to understand more in sub-microscopic sense, models were used as another kind of multimodalities. Next, teachers need to break down texts into vocabulary items that are helpful in learning, such as subject-specific vocabulary, general academic vocabulary and signalling words for students by deconstruction. For example,

> Question: Suggest experimental steps for preparing calcium sulphate.
>
> First, mix the calcium chloride solution and sodium sulphate solution in a beaker.

Next, filter off the precipitate from the reaction mixture.

Then, wash the precipitate with a large amount of cold distilled water.

Finally, dry the precipitate by pieces of filter paper.

Subject specific academic vocabulary

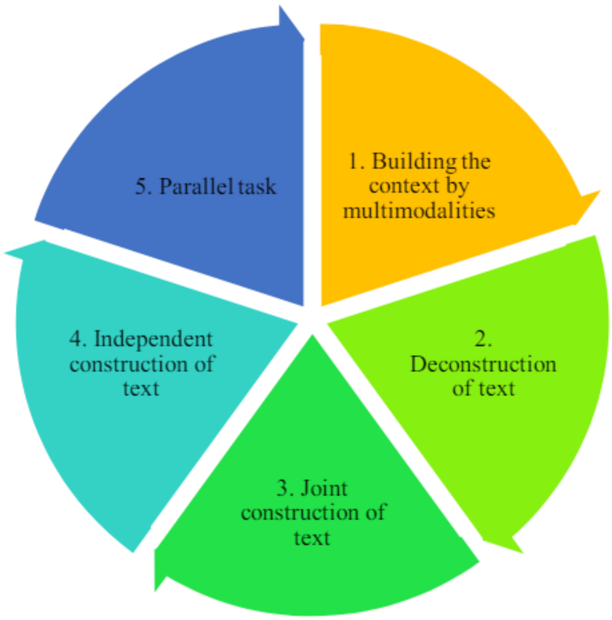
General academic vocabulary

Signaling words

Then, teachers and students engage in a collaborative verbal and written joint construction. This teamwork is crucial in building a coherent text that reflects what students have learnt, with the content and language support from teachers. For example, instead of asking students to prepare calcium sulphate, they were tasked with preparing lead(II) sulphate. The chemical was altered slightly (from calcium to lead(II)), but the experimental steps remained similar.

Finally, students independently work on a text to evaluate the effectiveness of teaching and learning. Similar to joint construction, the compounds prepared were changed slightly. Derewianka (2003) emphasized the importance of follow-up tasks, also known as parallel tasks, in the teaching and learning cycle. These tasks are designed to check students' understanding with slight variations in questions, but with similar answers in format. This process provides educators with reassurance about student comprehension. In other words, students were asked to write the essay for more than three times for consolidation. In summary, the teaching and learning cycle was modified as follows.

Figure 2. The Teaching and Learning Cycle (Tsang, 2020) modified from Multimodalities and Entextualisation Cycle (Lin, 2016)



In the two-year of studies, students tried a large variety of text types, as listed below.

Table 2. Writing topics done in two years of study

Writing topic	Text type
Compare melting points of two substances	Comparison report
Deduce reactivity of metals	Deduction
Comparison between strong / weak acid / alkali	Procedure
Preparation of salts	Procedure
Preparation of solutions	Procedure
Properties of homologous series	Descriptive report
Comparing density between water and ice	Comparison report

Code-switching between Chinese and English

In this study period, classes were held for the participants as they encountered some abstract chemical concepts. Therefore, these words were introduced with a Chinese translation that was near the English vocabulary, for example, chemical kinetics (化學動力學) and equilibrium position (平衡位置). For words that repeatedly appear in the lesson, this scaffold was removed in the latter part to allow students to be more accustomed to learning Chemistry in English.

Promoting literate talk

Some subject-specific vocabulary can be explained from students' schemata as they learned English words in English lessons for daily scenarios. For instance, when a teacher-researcher explained the meaning of 'rate of reaction':

We would like to know something about the rate of reaction, but you may wonder, 'Ah? What is the rate of reaction?' So, let us start with something more general first. Actually, we would like to know something, ah, some reactions, which one is faster, which one is slower. So, actually, we would like to know how fast is the reaction (the reaction is). So, we would like to know something about the speed of reaction. However, when we talk about the speed of reaction, it is too general, not scientific enough. So, we tend to talk about the rate of reaction.

The teacher-researcher started introducing the term rate of reaction by words they have learnt in English lessons (which one is faster, which one is slower). Then, he summarised the phrase as 'how fast the reaction'. He used a more technical term, 'the speed of reaction', but he emphasised that it was not a term that should be used in the high school chemistry context. He used 45 seconds to introduce the term 'rate of reaction' from daily oral language to oral and written academic language.

Using diagrams as multimodalities

When students learned about some experimental set-ups used to monitor the rate of reaction, diagrams with further explanations were shown to them. As they had learned the relevant chemistry concepts in formal lessons, these diagrams describing the experimental set-up served as the bridge between students' prior knowledge in Chinese and the knowledge to be learnt in English.

Results

Descriptive Statistics

In this study, students' performance in two post-tests was analysed to show their teaching and learning progress. In addition to the essay-type questions, writing definitions and chemical calculations were also analysed to show different question types.

Table 3. Questions to be analysed in the two post-tests

Question	Question Type
Definition of isotopes	Writing definition (sentence level)
Finding relative atomic mass	Calculation

Comparing melting points	Comparison report (text level)
Deduction of reactivity	Deduction (text level)

Table 4. Average marks of selected questions in Grade 10 post-tests

Class	Mean scores of			
	Definition of isotope		Calculation: relative atomic mass	
	1st Exam	2nd Exam	1st Exam	2nd Exam
A	74%	89%	79%	80%
B	60%	72%	58%	60%

Class	Mean scores of			
	Comparing melting point		Deduction of reactivity	
	1st Exam	2nd Exam	1st Exam	2nd Exam
A	80%	56%	84%	90%
B	42%	36%	55%	45%

The table above shows the academic performance of two classes in two post-tests. In general, the students maintained their academic standards after three and nine months of teaching, respectively, meaning that retention time is long enough for students to answer questions accurately.

Table 5. Average marks of selected questions in Grade 12 delayed post-tests

Question / Class	Compare the melting point of two compounds	Describe the formation of addition polymer	Effective Communication
A	66%	41%	36%
B	69%	17%	6%

Question Class	Illustrate characteristics of transition metal	Effective Communication
A	52%	28%
B	35%	25%

Question Class	**Optimal conditions of temperature and pressure in equilibrium**	**Structural determination of organic compound (chemical test + IR + MS)**
A	35%	52%
B	5%	22%

However, when analysing Grade 12 delayed post-tests, students did not achieve satisfactory results in comparing the boiling point of two compounds, which is a familiar question type. Students also performed other questions in unfamiliar situations that were not as good as the familiar questions. Detailed analysis will be discussed in the next section.

Analysis of students' work

In this study, three essay questions covering the essential knowledge of Grade 10, Grade 11, and Grade 12 were analysed qualitatively.

The first question was about the comparison between the melting point of two compounds, magnesium chloride ($MgCl_2$, compound A) and oxygen dichloride (OCl_2, compound B), which they had learnt in Grade 10. Although students were not that familiar with OCl_2, their thinking skills were easy to follow as OCl_2 is covalent, but it is not graphite, diamond, quartz, or silicon; it should be a simple molecular structure. Students were required to write comparison reports using 'but' or 'while' for contrasting chemical terms.

The second question, which required students to describe addition polymerization, a concept they had learned in Grade 11, was a test of their perseverance. Despite their unfamiliarity with 'Teflon', students were able to write a systematic description of the process, even without hints. This task was challenging, but the students' determination was evident, which should make educators feel proud and inspired by the students' efforts.

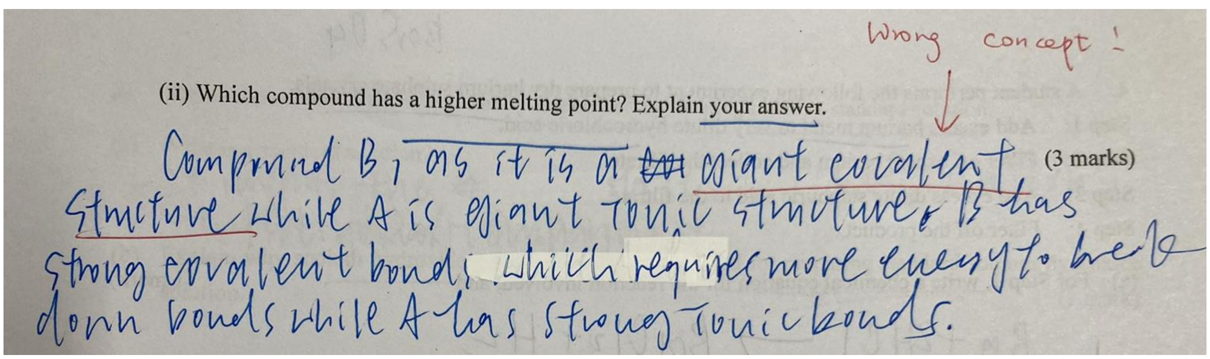
The third question, which required students to determine the structure of organic compounds using data from chemical tests, infrared spectroscopy, and mass spectrometry, was a challenging task. This was a new topic for the students, and they had only recently learned it before the delayed post-test. While some students may not have been competent in answering such a question at this stage, it is crucial to recognize their potential for improvement with further study and practice. This recognition should instill a sense of hope and optimism in educators, knowing that with the right support, students can overcome such challenges.

Lower achievers

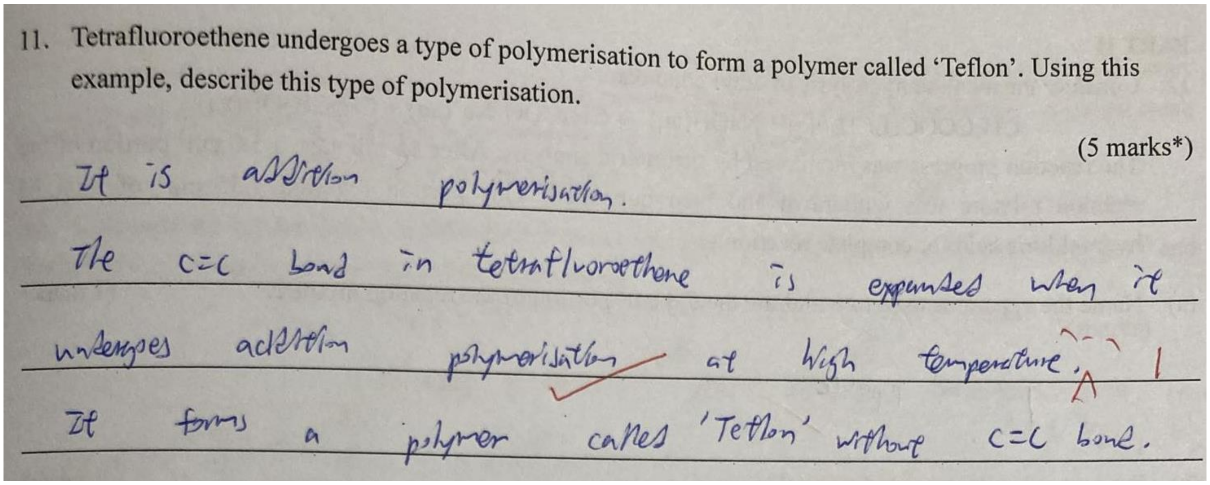
There are no spelling mistakes in chemical terms, which did not hinder understanding. However, students of lower achievers sometimes need help understanding basic chemical concepts. For example, OCl_2 is a simple molecular structure, but the student wrote ‘giant covalent structure’. Moreover, students did not know how to write descriptive reports systematically. That is the reason why the chemical concepts were scattered in the text. In writing deductions, students could infer information from accessible sources, e.g., infrared spectroscopy and chemical tests. However, the student could not elaborate on the information.

Figure 3. Writing of lower achievers in (a) comparing the melting point (b) describing the addition polymerisation (c) deducing the organic compound from information given

(a)



(b)



11. Tetrafluoroethene undergoes a type of polymerisation to form a polymer called 'Teflon'. Using this example, describe this type of polymerisation.

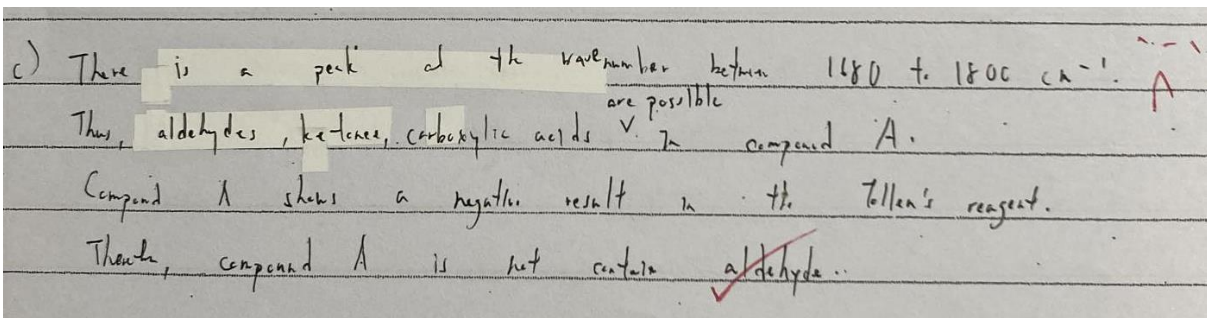
(5 marks*)

It is addition polymerisation.

The C=C bond in tetrafluoroethene is expansed when it undergoes addition polymerisation at high temperature.

It forms a polymer called 'Teflon' without C=C bond.

(c)



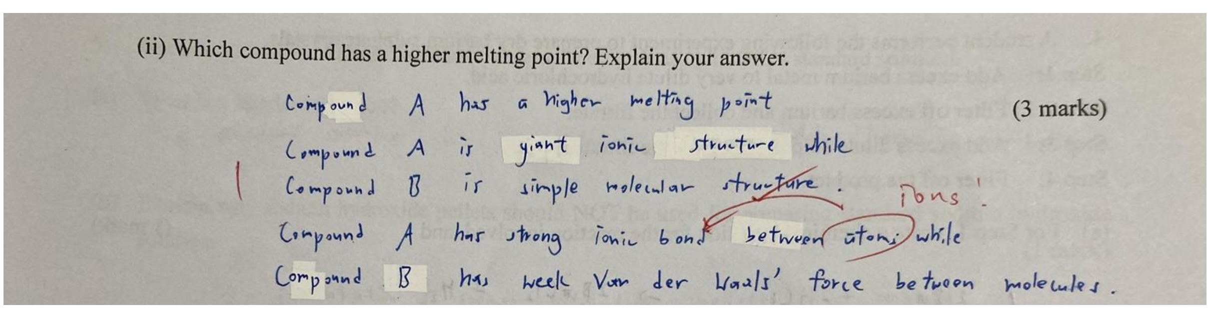
c) There is a peak at the wavenumber between 1680 to 1800 cm^{-1}. Thus, aldehydes, ketones, carboxylic acids are possible in compound A. Compound A shows a negative result in the Tollen's reagent. Therefore, compound A is not contain aldehyde.

Middle achievers

Like the lower achievers, there are no spelling mistakes in chemical terms, which did not hinder understanding. However, middle-achieving students might still have some misconceptions. For example, there are strong ionic bonds between 'ions', not 'atoms'. Moreover, students could write descriptive reports and deductions systematically, with incomplete explanations.

Figure 4. Writing of middle achievers in (a) comparing the melting point (b) describing the addition polymerisation (c) deducing the organic compound from information given

(a)



(ii) Which compound has a higher melting point? Explain your answer.

(3 marks)

Compound A has a higher melting point

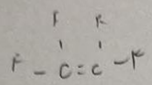
Compound A is giant ionic structure while

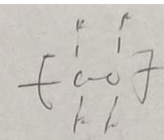
Compound B is simple molecular structure.

Compound A has strong ionic bond between atoms while (ions)

Compound B has week Van der Waals' force between molecules.

(b)



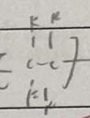


11. Tetrafluoroethene undergoes a type of polymerisation to form a polymer called 'Teflon'. Using this example, describe this type of polymerisation.

(5 marks*)

First, break the C=C bond of C_2F_4,

Next, undergo addition polymerization.

The monomer has the same repeating unit of 

Then, it is needed a catalyst to speed up the realtion.

(c)

3c) From the Infra-red spectrum.

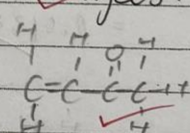
It has a sharp peak at wavenumber 2840–3095 cm^{-1}. That means C-H is presented. The compound may be alkanes, alkenes or arenes.

It also has a sharp peat at wave number 1680–1800 cm^{-1}. That means that C=O is presented. The compound may be aldehydes, ketones, carboxylic acid and derivatives.

ester or amides

The molecular formular of A is C_4H_6O. Only one oxygen atoms. A must not be carboxylic acid and its derivatives. A may be aldehydes or ketones.

~~The~~ A show a negative result in Tollen's reagent, showing that A is not aldehydes. A is ketones.

∴ The structure of A is: 

寫於邊界以外的答案，將不予評閱。

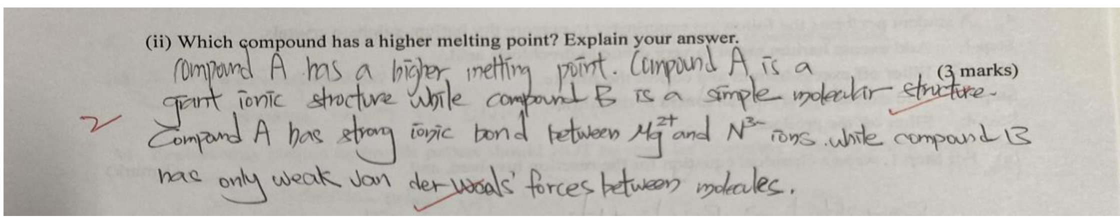
Answers written in the margins will not be marked.

Higher achievers

Like the lower and middle achievers, there are no spelling mistakes in chemical terms, which did not hinder understanding. Moreover, high achievers wrote chemical terms accurately. Furthermore, they presented the descriptive report systematically and included all information required for inferring the organic compound asked in the question. It is noted that higher achievers could infer the data entirely from mass spectrometry, which is not easily to be inferred by direct observations, meaning that students used high-order thinking to tackle such kinds of questions.

Figure 5. Writing of higher achievers in (a) comparing the melting point (b) describing the addition polymerisation (c) deducing the organic compound from information given

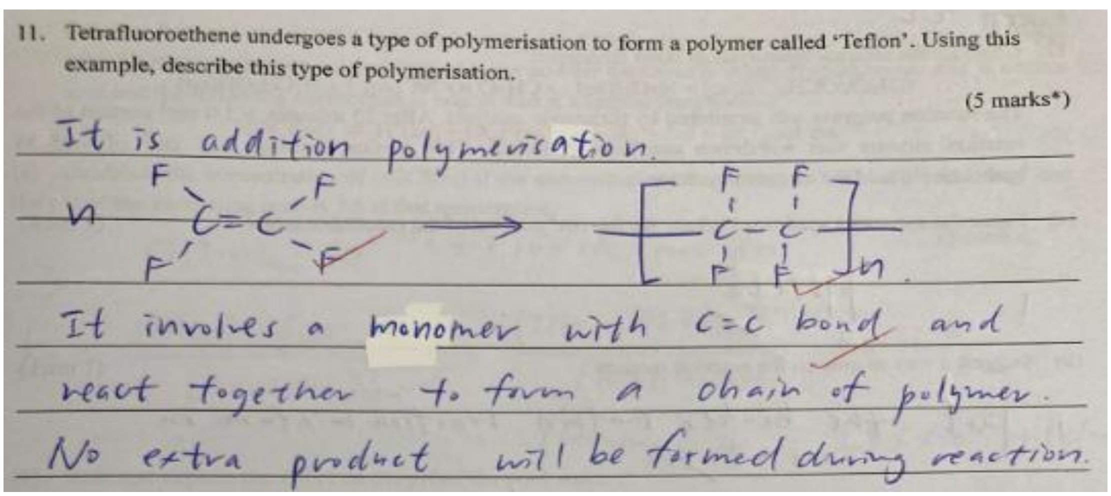
(a)



(ii) Which compound has a higher melting point? Explain your answer. (3 marks)

Compound A has a higher melting point. Compound A is a giant ionic structure while compound B is a simple molecular structure. Compound A has strong ionic bond between Mg^{2+} and N^{3-} ions while compound B has only weak van der Waals' forces between molecules.

(b)

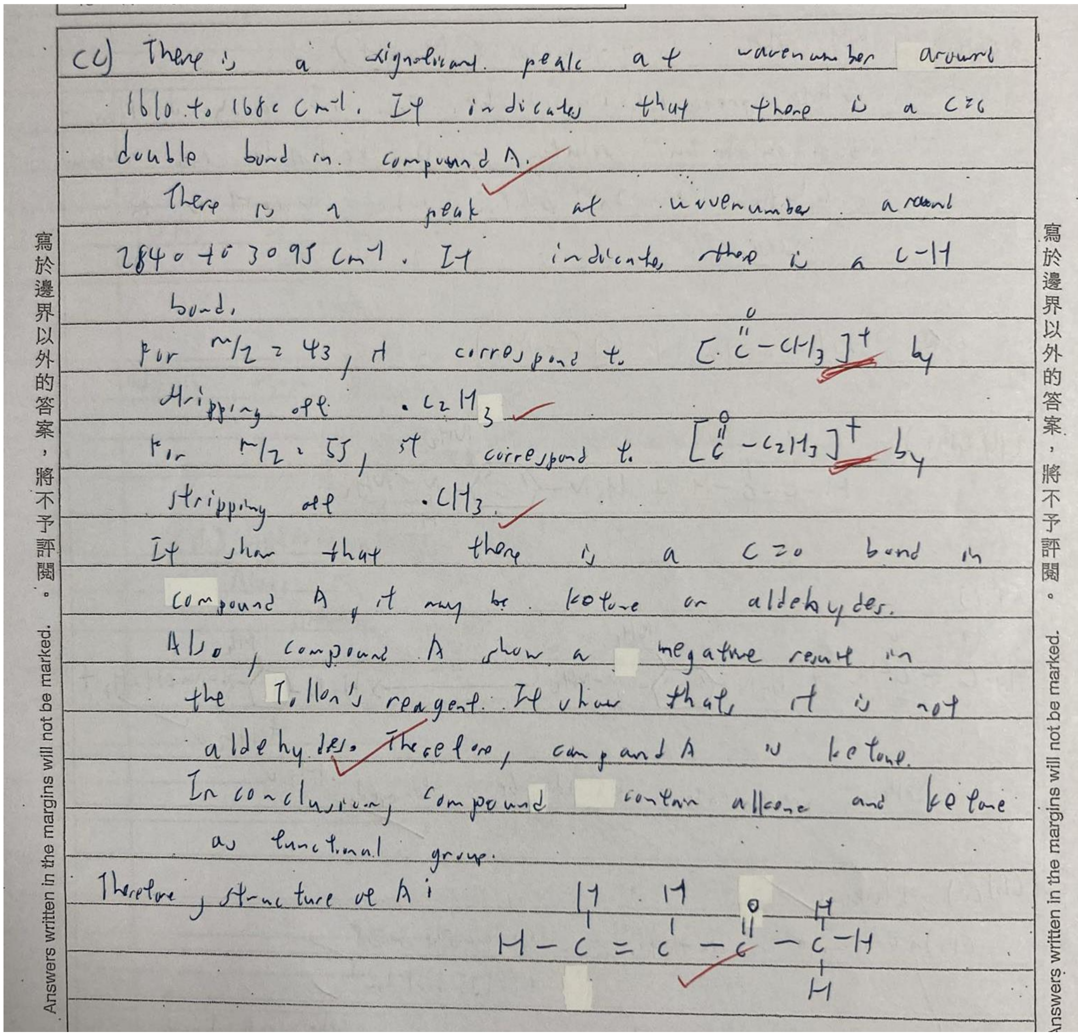


11. Tetrafluoroethene undergoes a type of polymerisation to form a polymer called 'Teflon'. Using this example, describe this type of polymerisation. (5 marks*)

It is addition polymerisation.

It involves a monomer with C=C bond and react together to form a chain of polymer. No extra product will be formed during reaction.

(c)


c(i) There is a significant peak at wavenumber around 1610 to 1680 cm-1. It indicates that there is a C=C double bond in compound A.
There is a peak at wavenumber around 2840 to 3095 cm-1. It indicates there is a C-H bond.
For m/z = 43, it correspond to [C(=O)-CH3]+ by stripping off ·C2H3
For m/z = 55, it correspond to [C(=O)-C2H3]+ by stripping off ·CH3
It show that there is a C=O bond in compound A, it may be ketone or aldehydes.
Also, compound A show a negative result in the Tollen's reagent. It show that, it is not aldehydes. Therefore, compound A is ketone.
In conclusion, compound contain alkene and ketone as functional group.
Therefore, structure of A is
H-C(H)=C(H)-C(=O)-C(H)(H)-H

Discussions and Implications

Responding to the candidate performance report of HKEAA, after two years of teaching, most students achieved high accuracy in spelling. Middle achievers and higher achievers could write logically and systematically in texts. However, middle achievers sometimes needed to write descriptions as thoroughly as possible, as they thought they had conveyed their message completely. Moreover, lower and middle achievers might need to use appropriate chemical terms more accurately.

Regarding the CLIL approach, most students communicated well in English, and at least little misunderstanding occurred when reading their writings. Therefore, students worked well in communication, the second C (communication) in the 4Cs cycle from Coyle (2010), which emphasizes the importance of effective language use. Moreover, most students understood the fundamental chemical concepts, and it was reflected in students' writings. Therefore, students worked well in content, the first C (content) in the 4Cs cycle from Coyle (2010), which focuses on understanding and applying subject matter. However, the accuracy of the writings of middle and lower achievers dropped when they faced unfamiliar situations, meaning that they did not master the higher-order thinking skills well. Therefore, only higher achievers accomplish cognition, the third C (cognition) in the 4Cs cycle from Coyle (2010), which involves critical thinking and problem-solving.

The teacher-researcher will need to plan in detail to address student writing discrepancies for the following teaching cycle, better preparing with the CLIL approach to helping students reach new heights.

Conclusion

This study primarily responded to the calls from the candidate performance report from the HKEAA to help eliminate students' mistakes in Chemistry writing. Therefore, the teacher-researchers employed multiple cycles of action research to increase students' accuracy in writing Chemistry using MEC, code-switching, and literate talk as examples to help students increase their cognitive and language proficiency.

The study yielded significant practical implications, with students demonstrating a strong retention of knowledge in Chemistry after two post-tests. They were also able to apply their learning to familiar situations, writing with high accuracy and logical structure. This suggests that the CLIL approach can effectively equip students with the language and content skills necessary for effective communication in Chemistry.

In conclusion, the CLIL approach has shown promise in increasing students' language and basic content proficiency. However, further investigation is crucial to enhance students' high-order thinking skills in the CLIL setting. This ongoing research keeps us all engaged in the continuous improvement of Chemistry education.

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Science Museum-School Collaboration: A case study of coastal line field trip

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Science Museum-School Collaboration: a case study of coastal line field trip

Abstract

Field trips can enhance student's life experience and motivate them to learn. Not all schools have access to a qualified heritage guide agency that can arrange educational field trips. This study explored how the National Museum of Natural Science (NMNS) in Taichung, Taiwan, acts as field trip collaborator to devise field trip plans with schools and domestic community organizations to promote elementary school students' awareness of the relationships between humans, nature, and conservation efforts while experiencing natural heritage. The NMNS sporadically holds fossil camps for students at a harbor-side outcrop fossil layer in Miaoli, Taiwan.The schools expect that the NMNS can organize a field trip plan incorporating reflective thinking about humans and nature rather than offering a simple guided tour of the fossil layer. The present study applied the sociocultural approach to illustration the field trip plan and determine how the museum collaborates with domestic community organizations to encourage the interpretation of local culture and natural heritage and how the museum cooperates with partner schools to refine the teaching plan of a field trip. There were 618 students participated the field trip between February 10 to October 26, 2021. The students' post-trip group interviews and journals revealed that the students noticed the changes to the landscape made by past and contemporary people. On the basis of this case study, postpractice reflections were discussed, and models relating to regional resources, science museums, and schools establishing sociocultural contexts and cross-disciplinary linkages in outdoor science education were proposed.

Keywords: informal science teaching, marine and outdoor education, sociocultural theory

RESEARCH BACKGROUND

ational Museum of Natural Science (NMNS) proposed an out-door field trip project under the Taiwan Ministry of Education granted. The field trip offered primary and secondary schools. The main purpose of the project was bringing the participants focus on the relation between human and nature by the field trip. NMNS invited several partner schools engaging in project proposing. The Covid 19 is not yet outbreak in Taiwan, the consensus among schools was keep the field trip as an out-door activity and followed all Epidemic Prevention Regulations during the trip.

The field: potentially connect natural history to the modern history of Taiwan

In the past decade, NMNS sporadically took fossil camps for students at a harbor-side outcrop fossil layer in Miaoli, Taiwan. The fossil layer is the evidence that the island of Taiwan rises from the ocean floor in 120 thousand years before and it was document since 1923, in a railway construction project during the Japanese colonial period. The colony governor assigned the fossil layer as a natural heritage and re-planned the rail track to protected it.

Domestic situation: potentially connect the trip with social scientific issues

The coastal line between fossil layer to Mazu Temple Baishatun is the first Onshore Wind Turbine Test Site in Taiwan, and the offshore will include in the business scale offshore wind turbine field. The nearby fishing village population are around 4000, average age is 63-year-old. Though there are not many fish boats keeping work regularly, there is a Cost Guard Branch office in charge of custom.

The framework of study

In this study, the activity theory as the basic framework to illustrate how science museum collaborate with school and local community for the field trip.

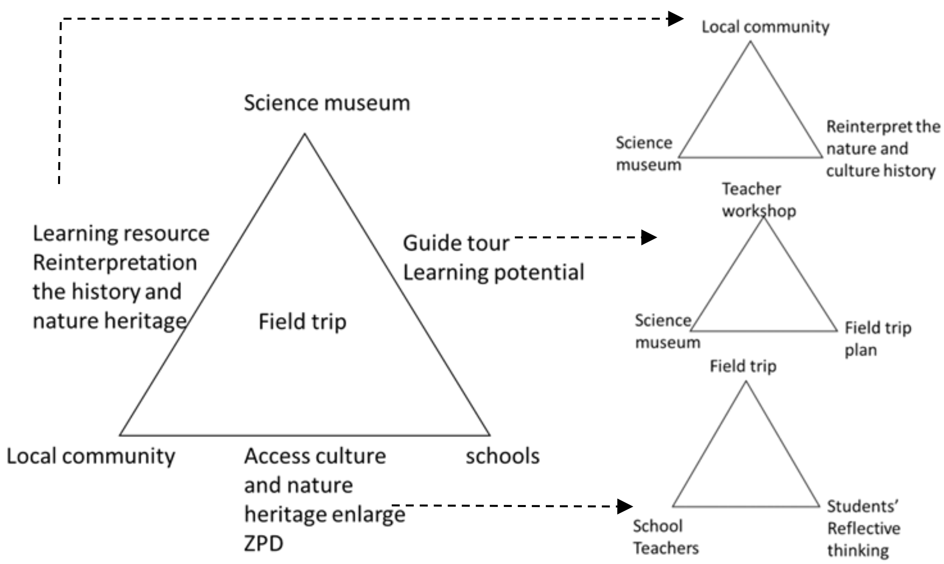

Figure.1 Main framework of the study

The relation between science museum, school and community explored in the triangle in figure 1. Each side of the biggest triangle represents two actors' relationship and the triangle pointed by the dotted line expresses the goal which they collaborate in the field trip. This study concerned on the triangle Science Museum-Teacher Workshop-Field Trip plan which the museum curator interacted with school teachers to identify the main factors should include in field trip. Then the science museum checked each activity in the field trip satisfied these factors.

Teacher workshop and data collection

There were 19 schools, total 53 teachers participating in 12 pre-field trip workshops. Each workshop invited teachers came from schools with similar context, such as same classes of grade4 students, urban/suburb schools. The NMNS introduced the place to teachers, then went through round table discussion to collect teachers opines and they need some event for extending to after trip school classes. After teacher workshop, the teachers' consensus regarding.*Heading 3: Use this style for level three headings*
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Results

Field trip plan

The field trip included a nature hiking, wind turbine model making, museum visit and coast guard office visit.

Figure 2 left: hiking along the hill where fossil layer under the path; right: fossil layer beside the train tunnel.

Figure 3 students' wind turbine making.

FINDING

1. The main factors should have in the field are : fit for National Curriculum Guide Line, with the experience of STEM, offer content knowledge about environmental issue, interaction with the lecturer.
2. There were 4 teachers extending the wind turbine activity to their science class, two teachers integrated the field trip experience into students' computer science class.
3. Students impressed with wind turbine making and coast guards introduction. Both activities included hand on factors insite.
4. The field trip grouped students to measure the height of the fosil layer and the height of the train tunnel. It connected the experience with mathematic in classroom.

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