Development and Implementation of Science Boost Camp: Impact on Student's Science Conceptual Understanding and Motivation to Learn Science

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Abstract
After COVID-19, the teachers in Brunei have been busy trying to catch up on the learning loss faced during the pandemic, especially the Year 11 science students who will be sitting for their Cambridge's 'O' Level examination this year as the first cohort of the new 5129 Combined Science syllabus. Switching back from online learning during COVID19 to face-to-face learning in school has been a great challenge for the teachers. In this paper, the researcher is trying to understand what motivates these students to learn Science and to adapt back to face-to-face teaching and learning. This study employed mixed method research (MMR) to understand the assumed causes of low achievement in the qualifying examination of the Year 11 science students. This study also sought to understand how the science boost camp could be adopted to improve students' achievement in the 'O' level examination and how the camp could be evaluated for their effectiveness. The initial analysis shows that the Science Boost camp was able to increase students' motivation and understanding of science concepts, the advantages of group work and active learning. In addition, the effectiveness of the boost camp was discussed and evaluated for the next boost camp as part of students' intensive examination preparation for their upcoming 'O' level examination. This study summarized the essential attributes of a Science Boost Camp weekly course as the future development as one of the strategies for examination preparation.

Keywords: Science Achievement, Science Motivation, Mixed Method Research (MMR), Science Boost Camps, Science Conceptual Understanding

Introduction

Background of the Study

This study reported in the design of a mixed method study aims to evaluate the effectiveness of a revision strategy called Get Your Credit (GYC) Science Boost Camp for GCE O level preparation with cooperative learning. The purpose of this study is twofold: i) to assess the impact of boost camp designed activities for Bruneian secondary students learning combined science and ii) to examine the process of students' motivation in learning science. The boost camp designed activities are designed using Technological, Pedagogical and Content Knowledge (TPACK) framework and known as Technological Enriched Learning Activities (TELA) in this research.

Hands on activities can be used to help students to visualize the correct concepts that are so challenging for them, due to the abstract nature of scientific knowledge (Dhindsa & Treagust, 2009). The importance of understanding 'overloaded' abstract concepts of science has been emphasized by many researchers (Dhindsa & Treagust, 2009; Simon, 1975; Garegae, 2009). Similarly, Good and Berger (2005) noted that understanding scientific representations of our physical world is essential for the achievement of higher levels of scientific literacy. However, achieving higher levels of scientific literacy and helping students to understand abstract science concepts requires those learners to visualize the correct concepts to avoid misconceptions. Hence, teacher's lessons preparation is very crucial to implant the correct scientific concepts in students.

The importance of integrating a teacher's competence in pedagogy and content was initially emphasized and visualized in Schulman's (1986) Pedagogical Content Knowledge model (PCK) and this PCK model was further developed by Mishra and Koehler (2009) into what is known as the Technological, Pedagogical and Content Knowledge (TPACK) model. TPACK is a knowledge-based teaching method that teachers need for effective technology integration. (Kurt et al., 2014).

Literature Review

To test teachers' knowledge base for designing lessons using a TPACK framework, Harris and Hofer (2009) developed taxonomies of learning activities (pedagogy) for specific subject matter domains. They then related those taxonomies to possible uses of technology to support the instructional planning of teachers. Learning activities could then be used as a planning tool to develop and describe plans for technology-enhanced learning. To achieve this goal, teachers need to understand the most powerful ways of embedding technology-based experiences in science teaching and learning (McFarlane & Sakellariou, 2002).

Therefore, further research and more concerted efforts among policy makers, science education researchers, and science teachers are needed (Symington & Tytler, 2004). Similarly, Duit and Treagust (1998) pointed out that research investigating students' conceptual progress is limited. In the same paper the authors also noted that there is no study that has investigated how / if students' conceptions change after instructions. As there is no study that has specifically investigated how students develop conceptual understanding in science, this study will adopt and refer to the literature that reports investigations into conceptual understanding in science. Even in Brunei Darussalam, the current priority of the

Ministry of Education is to prepare the teachers to teach students the new skills needed to overcome the challenges of the new era (Othman, 2019).

In recent years, the number of students learning science in Brunei has diminished as can be seen in the Cambridge General Certification Ordinary Level (GCE O Level) examination results. Upper secondary science involves a three-year upper secondary science syllabus from the Cambridge General (GCE) Ordinary Level, taught in English language. The examination is sat by students from all over Asia, such as Bangladesh, Mauritius, Sri Lanka, Singapore, Malaysia and Brunei Darussalam, in order to prepare candidates for advanced study either locally or internationally. The low-level performance has also been reported for other countries which take combined science in the GCE O Level examinations as shown in Table 1 below. The cumulative world total grades for combined science over the past ten years are presented in the following Table 1.

Year	**Percentage of students obtaining grade C and above** *(Grade C or above = Credit and Distinction)*
2022	24.4
2021	*Not applicable* 38.3 *COVID-19 School Assessment Grade*
2020	27.2
2019	20.3
J2019	23.9
N2018	20.0
J2018	30.0
N2017	21.0
N2016	62.0
N2015	21.0
N2014	24.0
N2013	24.0
N2012	22.0
N2011	21.0
N2010	22.0
N2009	24.0
N2008	24.0
N2007	30.0

Table 1: GCE O Level world grades for Combined Science subjects from 2007 to 2022 (https://www.cambridgeinternational.org/programmes-and-qualifications/cambridge-upper-secondary/cambridge-o-level/results-statistics/)

The current problem faced by schools in Brunei and some other parts of the world is the failing grades of combined science in the General Certificate Examination (GCE) O Level. This is shown in the cumulative world total grades for combined science in the Cambridge Assessment International Education (CAIE) over the past ten years; from 2007 to 2022. The grades are constantly below 30% of the passing marks of 50% (*see Table 1*). A grade below 30% is ungraded, meaning students do not get an 'O' Level after being exposed to the subjects for three years in their upper secondary school years. Low achievement is the situation where a child fails to acquire basic skills while: a) they do not have any identified disability and b) have cognitive skills within the normal range. In those cases, low achievement may be considered as a failure of the education system to teach well, as much as the student to learn well (Report by Thematic Working Group on Mathematics, Science and Technology, 2010 – 2013).

The cumulative grades of below 30% for upper secondary science (combined science) has shown that students seem to learn by rote rather than cognitive understanding of the taught subjects. Researchers who advocate teaching and learning science by understanding, are trying to find ways to determine in detail what is involved in a person's mind when he learns and understands something (Dhindsa & Treagust 2009; Simon, 1975). Furthermore, the students' understanding of the concepts learnt is a sign of achievement to the teachers while to the student it means a furtherance of his / her education, hence a brighter future (Garegae, 2009). Hence the importance of understanding science concepts has led to the teachers trying to develop techniques for transforming rote learning into meaningful learning (Simon, 1975). Schools in Brunei use a science syllabus like that used in Britain (Sharifah, 1999). Science instruction is in English, which is very difficult for most students, as English is their second/third language.

Objective of Research

Reports compiled by the Ministry of Education; Brunei (2015) shows that a very low exam achievement in the Cambridge General Certificate of Education (CGC E 'O ' level) in combined science was due to the failure of students to acquire a basic conceptual understanding of the topic (Report by Brunei's Ministry of Education, Education Data and Information Management Section, 2015). Those students had great problems with analyzing abstract scientific concepts and processes.

In addition, the Brunei Ministry of Education has been introducing strategies for teachers to recognize the importance of technologically enabled devices to format teaching in classrooms. One example is the implementation of the Brunei's Teacher Standard (BTS) used to provide professional developments for teachers to use technology to teach and collect data in classroom action research. Another example is Whole School ICT Development (WSID) project which is designed to help teachers to plan their lessons from low order to the higher order thinking stages as the students and Inquiry-based science education (IBSE) projects are implemented to guide science teachers to plan their science lessons based on inquiry-based teaching and learning approaches with comprehensive teaching resources provided as references. A recent example is the outbreak of COVID-19 epidemic, teachers are left with no choice to teach virtually at home. Informed by these strategies, planning lessons needs to be very specific and informative; where teachers are required to be at one with their pedagogical content knowledge (PCK) (McCrory, 2008).

Research Questions

This study focuses on the effectiveness of the designed activities lessons of TELA to develop students' conceptual understanding of science. The research also hopes to see whether such understanding is retained even after the interventions for lifelong learning. Thus, the main research question is:

"What are the effects of boost camp TELA on students' conceptual understanding of learning science?"

The main research question is used to understand how the science boost camps affect and develop students' conceptual understanding of science by comparing the pre-test as first (pre-test), second (post-test) and third (delayed post-tests) boost camps. The learning experiences themselves are understood by looking at students' interactions during the interventions in terms of KMO framework investigated.

As the study's research question needs to be answered both in numerical and narrative forms, a mixed methods research paradigm is used (Subedi, 2016; Yoshikawa and Kalil, 2008; Teddlie and Tashakkori, 2012 and Schulenberg, 2004).

Methodology Used

This research uses an explanatory sequential mixed methods approach to information gathering. The research model is designed to test the effectiveness of science boost camps lessons in developing a clear picture of combined science students' understanding of scientific concepts. As informed by Teddlie and Sines (2008), the quantitative and qualitative data are collected sequentially, analyzed separately, and then merged into a framework/ matrix/tabulation to reveal some indicators to the research questions' answers (*see Figure 1*).

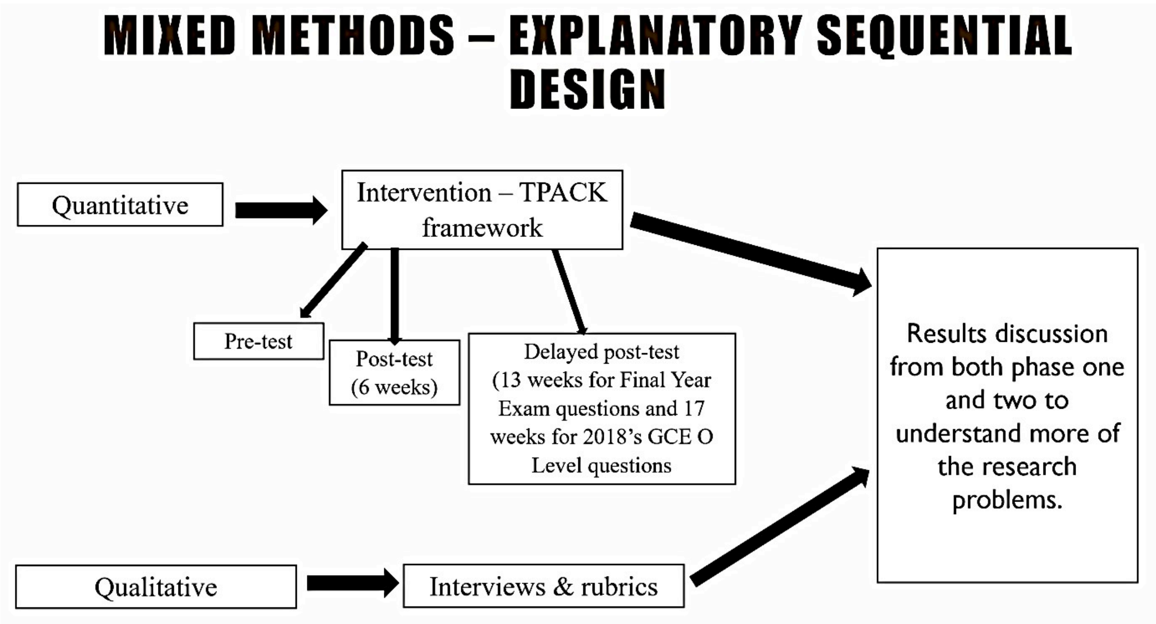

Figure 1: Diagrammatic process of the sequential study

The rationale for choosing a mixed-methods design is outlined below. To develop a clear conceptual understanding of the issues being investigated both quantitative and qualitative data are collected, because each method only provides a partial view of the complete picture (Creswell & Plano-Clark, 2011). This study will use data derived from both boost camps, together with students' feedback, as well as in-depth follow-up interviews of the involved students. The researcher can demonstrate the full benefits of using mixed analytical methods to highlight students' understanding of the concept of science during the interventions with the TPACK designed lessons.

Using the sequential design, a complete picture can be developed to portray a clear understanding of the effect of the TPACK-in-TELA designed lessons on high school students' test scores in combined science and their conceptual understanding of science.

Merging the quantitative and qualitative sets of data, which are then analyzed, can reveal a general picture via their test scores of the extent to which students grasp and understand the science concept. The researcher can also interpret the students' learning experiences through the TPACK-in-TELA designed lessons.

Teddlie and Tashakkori (2012) pointed out that the decision to use mixed methods should be based on research questions instead of focusing on the link between epistemology and methods. Similarly, Schulenberg (2004) noted out that the research questions should be the paramount focus of any investigation, rather than the study's methods (see Figure 2).

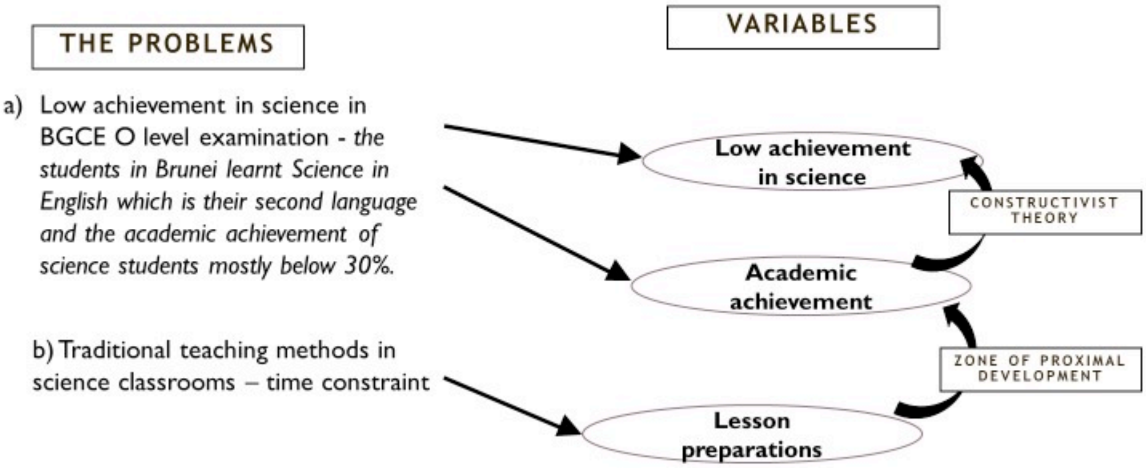

Figure 2: The representational diagram of this study's problems

This study frames the problems by incorporating the theory of Zone of Proximal Development and Constructivist Theory of learning. Both theories are important in this study as they are used as the guiding lens to capture the problem within the context of Bruneian's science classroom. In addition, students' conceptual understanding in TPACK-in-TELA as supported by Vygotsky's ZPD, will be seen through social interaction (in terms of gaining learning experiences) that will develop individual student's mental structures. The research questions and conceptual framework derived from the literature review combine to help develop the study's overall theoretical framework (*Figure 3*).

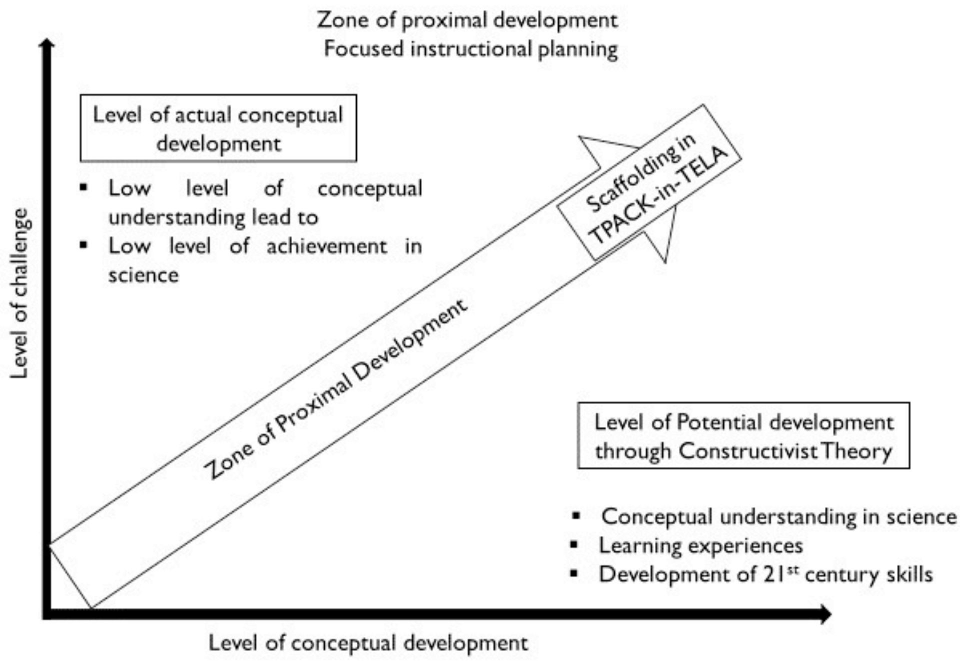

Figure 3: The theoretical framework of this study

As presented in the theoretical framework, the level of actual development in the study is affected by how the teacher planned the lessons. This process, according to a Vygotskian perspective, is helpful to expand a student's zone of proximal development (ZPD) to maximize their learning performance (Sharbini, 2016). Sharbini (2016) also stated that technology has shown itself to serve as a reliable source of scaffolding to facilitate positive changes in students' learning processes. In this study, the students' progress in their ZPD can be seen in their post-test achievement scores.

Evidence from the literature review highlights some of the following research gaps. Kafyulilo (2010) identifies that teachers are not properly integrating/incorporating TPACK components into their teaching. Chai et al. (2013) pointed out that TPACK is not used in lessons to measure students' achievements. However, Janssen and Lazonder (2016) claim that teachers' current TPACK use levels can act as a starting point for designing TPACK integrated lessons. Janssen and Lazonder (2016) also point out that there is very little evidence in the literature that can really demonstrate how teachers with developed TPACK knowledge can apply that knowledge to teach students to achieve better scores in science.

Study Sample

The sample of this study is selected from Bruneian year 11 students taking combined science who will be sitting for the O level examination in October 2023 as the first cohort of the new revised syllabus of 5129 combined science subject. The student sample was selected by using a probability sampling technique that aims to achieve reliable representation (Teddlie and Yu, 2007) of year 11 combined science students from selected schools. The sampling procedure for this study is to have students with different academic achievements participating in the tests/designed lessons so they have equal chances to experience revising science in boost camps of TPACK-in-TELA designed lessons.

Having achieved the desired sample, this study used stratified probability sampling to understand the existing relationships between TPACK-in-TELA designed lessons and students' learning experiences, as shown in Figure 8 below. There are 4 classes/groups of year 11 students who are going to take the combined science GCE O Level examination in 2023. The 4 classes are streamed/ chosen based on their achievements in English, Science and Mathematics from the lower secondary assessment in 2020 during COVID-19. These classes include students of 11A (general science education) and 3 classes of students taking 'general applied education': namely students of 11B, 11C1 and 11C2.

Students taking general applied classes (11B to 11C2) had scored below 40% in their lower secondary science assessment, whereas those students of 11 A achieved science scores of between 41% - 59%. Hence the students were selected from the same academic achievements/grades. Therefore, the students are already selected and arranged into groups of academic achievement levels in each of the 4 classes. In this case, the arrangement was employed simply to choose a representative sample from each stratum. The sampling process is further be clarified in Figure 4 below:

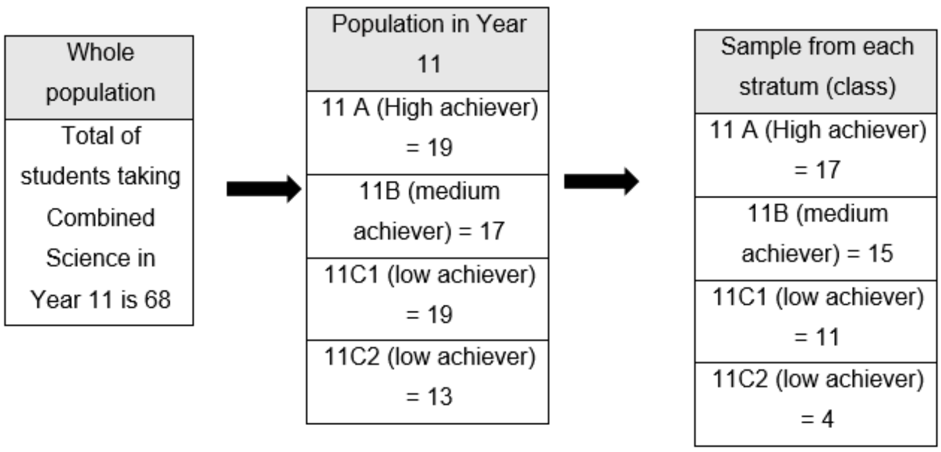

Figure 4: The process of probability stratified sampling

These students began learning science in the English language when they were still in the primary school. Combined science begins at the upper secondary level, i.e., year 9 until year 11; towards the end of the programme, students will be sitting for the Brunei Cambridge "O" Level examination. Schools in Brunei use the same science syllabus as is used in the United Kingdom (UK) (Sharifah, 1999). The objectives of assessment for this subject are focused mainly on conceptual understanding, handling scientific information, and solving problems related to daily life situations. The challenges that teachers faced during teaching the science lessons is that these objectives cannot be precisely specified in the syllabus content. Questions used in testing such skills are based on information which is unfamiliar to the students. In answering such questions, students are required to use principles and concepts that are within the syllabus and apply them to a novel situation in a logical, deductive manner.

The boost camps TELA lessons were designed using TPACK framework informed by constructivist theory. With the TPACK framework, Technological Enriched Learning Activities (TELA as the scaffolding) are injected into the boost camps lessons interventions in the four cycles of TPACK knowledge/learning programmes. The development of the interventions is explained in detail in the next section.

The third cycle was called the schematic knowledge dimensions where the students were required to collaborate with their peers to explain the solutions of the questions given to them. This boost camp took about 3 hours. The final cycle reflected on the strategic knowledge dimension of the TPACK framework focused on students' knowledge of 'where' and 'when'. At this phase, students learnt to apply the knowledge that they acquired from the previous cycles to come up with their solutions. The students are required to present their methodology using PowerPoint slides or video apps in the second boost camps. When all the cycles were done, the students were given post-tests.

Data Collection of Mixed Method

The sample for the qualitative data of this study was determined only after the post-tests; students with highest, medium, and lowest marks were chosen. The highest mark was the top scorer, medium was between 50% - 60%, whereas the lowest scorer was below 30%.

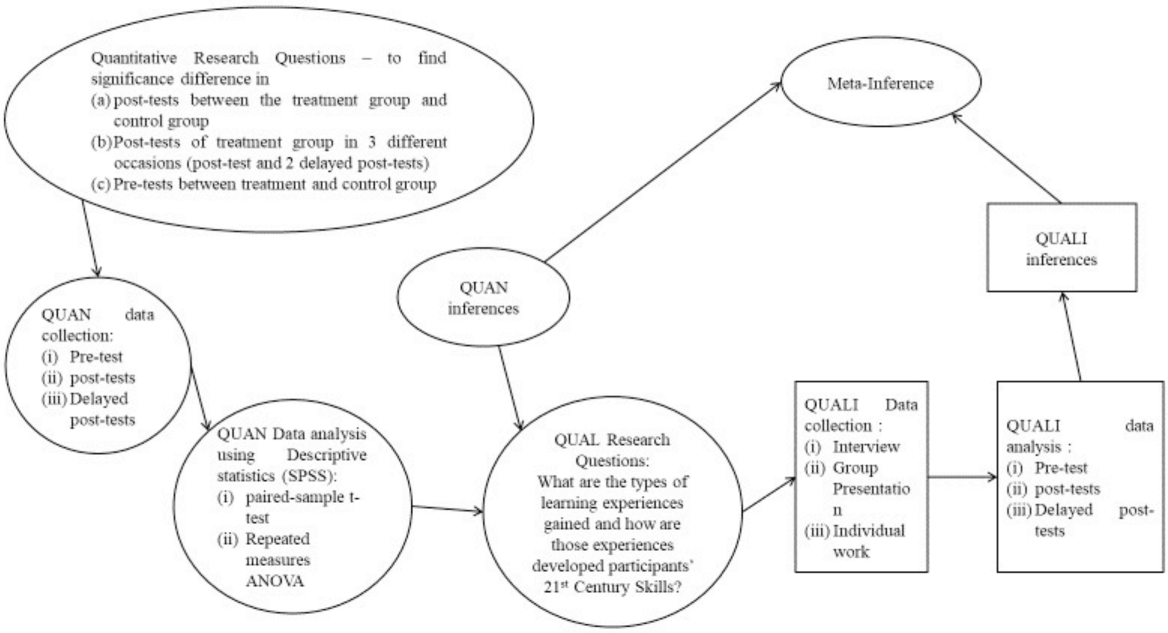

Figure 5: The sequential mixed methods design in which the research question of the second strand (QUAL) emerges from the findings of the first QUAN research questions. (QUAL = qualitative, QUAN = quantitative)

As for the types of quantitative and qualitative data collected, Figure 6 outlines the methods employed. There are 3 main types of data sources: i) test questionnaires (including pre-, post-, and delayed post-tests), ii) interviews and iii) direct observation during boost camps TELA lessons.

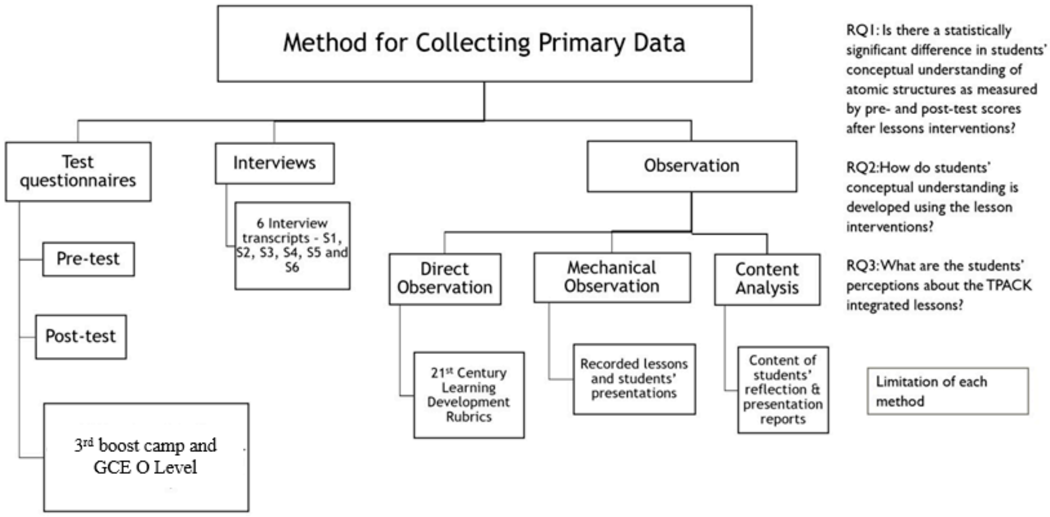

Figure 6: Methods for collection primary data

Details of the overall data collection and analysis are presented in the analytical framework, as shown in Table 2 below:

Phase	Procedure	Product
QUAN data collection	Pre-tests, posts-tests questions	Numeric data
QUAN data analysis	Descriptive statistics - paired-samples t-test or repeated measures ANOVA.	p value
Connecting QUAN and QUALI phase	Participants selection (random) and interview protocol development	Interview protocol
QUALI data collection	In-depth interview 21st Century LEAP learning rubrics	Textual data
QUALI data analysis	Coding and thematic analysis Theme development Cross thematic analysis	Codes and themes
Integration of both the QUAN and QUALI data	Interpretation and explanation of the QUAN and QUALI results	Discussion Implication Further research

Table 2: Analytical framework of this study

The initial analysis shows that the Science Boost camp was able to increase students' motivation and understanding of science concepts, the advantages of group work and active learning. In addition, the effectiveness of the boost camp was discussed and evaluated for the next boost camp as part of students' intensive examination preparation for O level. This study summarized the essential attributes for a Science Boost Camp weekly course as the future development as one of the strategies for O level preparation.

This study adopts the process of mixing data from a method developed by Creamer (2018) to fully understand the effects of TPACK-in-TELA boost camps lessons on students' conceptual understanding of science and on their learning experiences. The process of mixing is summarized in Table 3 below:

Stages in this study	**Strategies used to apply mixing**
Research questions	The research questions are devised into 2 quantitative questions and 1 qualitative question, and 1 mixed method research question, denotes mixed method research questions.
Data collection	Analysis of the quantitative data in the first phase shapes the data collected in the second phase. Sequential mixed method (Creamer, 2018).
Sampling	Both the quantitative and qualitative samples are from the same sample. Stratified probability sampling is used.
Analysis	Merging both the quantitative and qualitative to answer mixed method research questions.
Interpretation and conclusions	Use of meta-inference to explain special phenomena discovered during analyses of both strands. Inconsistencies and consistencies are explained.
Reporting	Data analyses results are linked to the literature.

Table 3: The process of mixing of this study

Creamer (2018) mentioned the strategy of mixing both the quantitative and qualitative data during the analysis and interpretative stage to complement mixed methods research. She mentioned that both data can be integrated to produce a meta-inference that shows the whole phenomena of the study.

Cases	strategy	analytic focus	product
Each individual case: S1, S2, S3, S4, S5 & S6	Analytical immersion of each interview to identify important aspect of learning experiences	Within each case, close reading of each individual interview transcripts and summaries	Identification of learning experiences; coding themes
Across and within 2 high achievers, 2 medium achievers and 2 low achievers	Identify variations around themes of learning experiences across and within achievers	Data coding and representations	subthemes
Across all interview transcripts	Compares the themes of learning experiences across the 6 students	Meta matrices and cases summaries	Overall interpretations of learning experiences gained and 21st centuries skills developed.

Table 4: The analytical framework used in qualitative data analysis.

The interview transcripts labelled as S1, S2, S3, S4, S5 and S6 are transcribed by listening to the tape recorder again to look for themes related to the answer to the qualitative research question 3 of this study. This will be explained further after analysis of the interview transcripts and observation notes.

Research Question	Research objectives	Data sources	analysis
What are the types of learning experiences gained and how can those experiences be developed into participants' 21st century skills?'	To analyse the types of learning experiences that students gained in the interventions and to learn how those experiences shaped or helped the development of their 21st century skills.	(i) Students' interviews (ii) Students group presentations on their 3D model (iii) Observation notes	(i) Categorise each interview according to the types of learning experiences gained (ii) Use of 21st centuries and learning dimensions (CLD) presentation rubrics to look for types of 21st century skills developed. (iii) Re-categorise comments and notes that might indicate learning experiences or 21st century skills.

Table 5: The links between the research question, data sources and data analysis

Meta matrices approach of qualitative data analysis was employed to understand students' learning experiences gained in the study and how the students used these learning experiences to develop their 21st century skills for lifelong learning. This approach is done by combining microanalysis of the development of 21st century skills, the types of learning experiences gained and students' conceptual understanding of science as well as researcher's own experiences based on the strategy combinations listed in Table 5 above.

Results

Quantitative Results

The intervention is designed to increase students' science conceptual understanding. Students were given a range of questions on science concepts that required lower order thinking through to higher order thinking. The two variables used from the data were labelled as pre-testA and post-testA. Table 6 shows the results of the analyses from the pre- and post-tests of the students involved in the study.

```
T-TEST PAIRS=prtstA WITH posttstA (PAIRED)
  /CRITERIA=CI(.9500)
  /MISSING=ANALYSIS.
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T-Test

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[DataSet1] C:\Users\Yvonne YCC\Desktop\PhD\UBD_PhD\PhD thesis\2019\Data\9B1Treatment Grp.sav
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Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre-Test A	24.37	38	18.171	2.948
	Post-Test A	70.95	38	21.824	3.540

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Pre-Test A & Post-Test A	38	.371	.022

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Pre-Test A - Post-Test A	-46.579	22.640	3.673	-54.020	-39.137	-12.683	37	.000

Table 6: The results for the pre- and post-tests of the students involved in the study

The results, as shown in Table 6, were interpreted. A paired-samples t-test was conducted to evaluate the impact of the intervention on students' test scores regarding their science conceptual understanding. There was a statistically significant increase in the test scores from pre-test (M= 24.37, SD=18.17) to post-test (M=70.95, SD=21.82), $t\ (37) = 12.68$, $p < .001$ (two-tailed). The mean increase in test scores was 46.58 with a 95% confidence interval ranging from 54.02 to 39.14. The eta squared statistics (.81) indicated a large effect size.

An analysis of the post-tests of the students who participated in the science boost camp for the three sessions is presented next. The research question is:

Quantitative research question 2: Is there a change in the 'conceptual understanding' test scores of the boost camp TELA interventions group over the three time periods?

Hypothesis: There is a significant difference in students' science conceptual understandings, as measured by the pre-tests, post-tests, and the delayed post-tests.

Quantitative research question 2 was used to evaluate the ability of students to retain science conceptual understanding; making sure students' learning was not just for the examination but lifelong. It was necessary to see the effectiveness of the boost camps intervention in the ability of the students to retain their science conceptual understanding on the same continuous scale at three different times through post-tests after: i) intervention, ii) end-of-year school examinations and iii) O- level examinations). To achieve this central objective one-way repeated-measures ANOVA analysis of variance was used to measure the test scores of the same participants at different points in time (within-subjects design).

A one-way analysis was employed because this study is looking at the impact of only one independent variable on the dependent variable. This technique will tell if or where there is a significant difference among the three sets of scores. Hence, a one-way repeated measure ANOVA was conducted to compares scores on the conceptual understanding with tests given at: a) pre-test (before the first boost camp intervention), b) post-test (after the first boost camp intervention) and c) the delayed post-tests (three weeks follow-up of third boost camp) on science concepts. The means and standard deviation are presented in Table 10. There was a significant effect of time as demonstrated by Wilks' Lambda = .02, F (2,35) = 7.43, p > .001, multivariate partial eta squared = .30 (refer to Table 7 below).

Within-Subjects Factors

Measure: MEASURE_1

Time	Dependent Variable
1	posttstA
2	EoYB
3	OLevelC

Descriptive Statistics

	Mean	Std. Deviation	N
Post-Test A	70.35	21.809	37
End-of-Year Exams	64.14	17.789	37
BGCE O Level Exam	75.68	23.575	37

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Time	Pillai's Trace	.298	7.432[b]	2.000	35.000	.002	.298
	Wilks' Lambda	.702	7.432[b]	2.000	35.000	.002	.298
	Hotelling's Trace	.425	7.432[b]	2.000	35.000	.002	.298
	Roy's Largest Root	.425	7.432[b]	2.000	35.000	.002	.298

a. Design: Intercept
Within Subjects Design: Time

b. Exact statistic

Table 7: Descriptive Statistics for test scores in conceptual understanding before, during and 3 weeks follow-up of the boost camps interventions

To see whether there are significant differences of test scores: i) before the first boost camp, ii) during the second boost camp and iii) after the three weeks follow-up third boost camp, a ‘pairwise comparison’ was conducted, with the results being shown in Table 8.

Time

Estimates

Measure: MEASURE_1

Time	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1	70.351	3.585	63.080	77.623
2	64.135	2.925	58.204	70.066
3	75.676	3.876	67.815	83.536

Pairwise Comparisons

Measure: MEASURE_1

(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	95% Confidence Interval for Difference[b] Upper Bound
1	2	6.216	3.037	.144	-1.409	13.841
	3	-5.324	3.845	.524	-14.978	4.330
2	1	-6.216	3.037	.144	-13.841	1.409
	3	-11.541*	3.119	.002	-19.372	-3.709
3	1	5.324	3.845	.524	-4.330	14.978
	2	11.541*	3.119	.002	3.709	19.372

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Pillai's trace	.298	7.432[a]	2.000	35.000	.002	.298
Wilks' lambda	.702	7.432[a]	2.000	35.000	.002	.298
Hotelling's trace	.425	7.432[a]	2.000	35.000	.002	.298
Roy's largest root	.425	7.432[a]	2.000	35.000	.002	.298

Each F tests the multivariate effect of Time. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

Table 8: The differences of each pair of time point showing students' conceptual understanding of science concepts

From Table 8 above, the differences between each pair of time points shown are all significant values of less than .05; thereby indicating that each of the differences is significant. The p value is less than .05; therefore, it can be concluded that there is a statistically significant effect for time. This outcome suggests that the students were able to retain their science conceptual understanding throughout the delay period described above. The results of analyses of the quantitative data have filled the gap relating to the ways in which teachers can design their lessons using a TPACK framework to improve students' conceptual understanding of complex scientific concepts.

Qualitative Results

The use of themes is driven to seek answers to the research questions by summarizing and analyzing the qualitative data from: a) the group presentations and b) interview transcripts of the six cases into the two central themes: i) learning experiences and ii) motivation to learn science. The case-based and theme-based approach is built on the visual display of data in a matrix of primary data summarization formed from: i) the group presentations, ii) the interview transcripts and iii) the observation notes.

In this study, 3 main themes were constructed to allow multiple data sources related to each student's learning experiences and motivation to be collated. Both the learning experiences and the student's motivation that was acquired are presented in terms of quotations from: a) the interview extracts, b) the students' work and c) the observation notes. This enabled to link student's individual's learning experiences to their development of 21st century skills which lead them to acquire the conceptual understanding of science.

As informed by the research questions driving this study, the themes that emerged from the interview data analysis are grouped into three categories: i) learning experiences, ii) development of conceptual understanding and iii) motivation to learn science.

Points of Mixing for Mixed Methods

The process of mixing differing classifications of data in an analysis, by merging both the quantitative and qualitative, is to answer the mixed method research question (Creamer, 2018). Creamer (2018) describes five strategies for mixing quantitative and qualitative data and analytical strategies: (i) blending, (ii) converting, (iii) extreme case sampling, (iv) cross-case comparisons, and (v) meta-inferences. For this study, to complement a mixed method study, data transformation is achieved by quantifying the qualitative data, in the form of frequency counts, to enable statistical analysis to take place whereas the mixing strategy used is meta-inferences.

This study found that besides understanding the science concepts, the students need pedagogical knowledge (PK) to explain to their peers the content knowledge (CK) of science concepts. It was interesting that from the data analysis, the students have a good background knowledge of using the internet and ICT (technological knowledge, TK) to prepare their solutions and technological pedagogical knowledge (PCK) when they prepared their group presentations.

The final synthesis from meta-inferences was collectively drawn from the findings that were yielded by both approaches. The quantitative findings suggest that the TPACK-in-TELA has helped to develop students' science conceptual understanding; particularly as students were able to retain their understanding over extended periods of time. This outcome suggests that TPACK-in-TELA can be used by science teachers to teach science to facilitate lifelong learning with and for their students. Based on the analysis, the meta-inferences for each individual case were constructed to link the learning experience to development of 21st century skills. The final categories were learning experiences in Content Knowledge (CK), Technological Knowledge (TK), Pedagogical Knowledge (PK) and Technological Content Knowledge (TCK).

As shown by the data analyses in this study, learning experiences gained by the students are associated with motivation to understand the concepts they learn in science. The students' conceptual understanding was shown through their 21st century skills development. The students gained science conceptual understanding when they develop their communication, knowledge building, self-regulation, the use of ICT, collaboration, and real-world problem-solving skills. The emergence of students' learning experiences and motivation from the qualitative data analysis are linked in meta-inferences in the next section to show a deeper understanding of those students' achievements in science.

The quantitative findings suggest that students' conceptual understanding changes after the boost camps interventions with TELA. Analysis from the qualitative interviews provided some evidence as to the possible changes. First, those students explained the learning experiences helped them to achieve science conceptual understanding. Second, the case study enhances our understanding that students with different abilities were able to increase the motivation to learn science and improve their 21st century skills through the learning experiences they described in the interviews. As informed by the results of both the qualitative and quantitative data analyses, the stages of developing students' science conceptual understanding during this study are summarized in Figure 7,

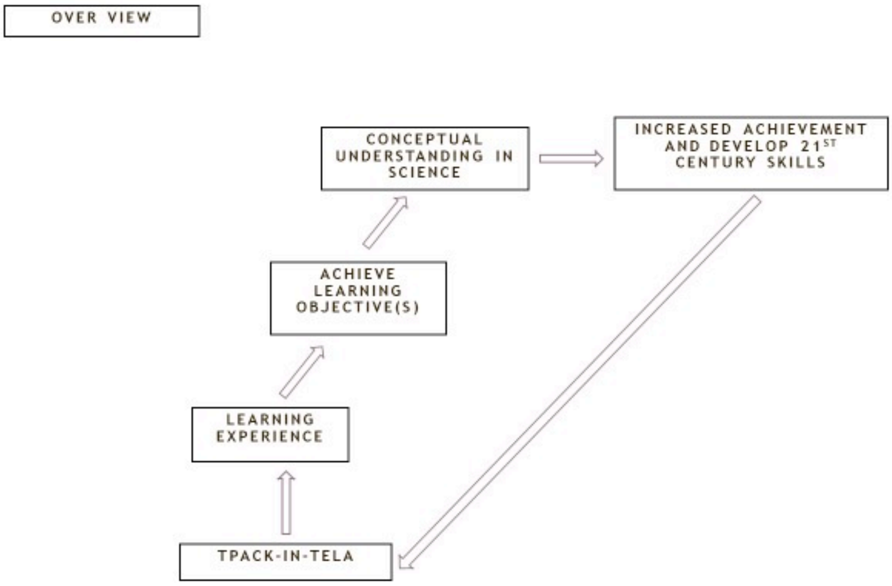
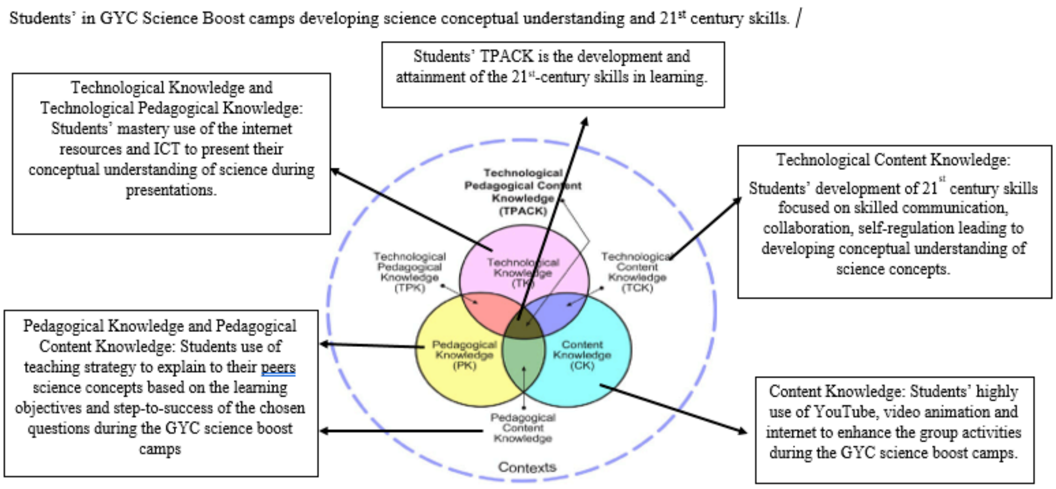


Figure 7: the stages of developing students' science conceptual understanding during this study

Third, the definition of the CK, TK, PK and TCK of TPACK components in the findings of this study based on Mishra and Koehler (2006) is presented in Figure 8, which shows the relationships between the students' PK, CK, TK and PCK in this study.



Note: Based on Mishra, P., & Koehler, M.J. (2006) Technological Pedagogical Content Knowledge: A new framework for teacher knowledge. Teachers College Record, 108(6), 1017-1054.

Figure 8: Results of this study based on Mishra, P., & Koehler, M.J. (2006) Technological Pedagogical Content Knowledge: A new framework for teacher knowledge. (Teachers College Record, 108(6), 1017-1054.)

The results of this study have shown that hands on activities helped students visualize science concepts and make connections between the concepts and the solutions to the questions. The effectiveness of the learning activities and instructions requires students to be able to visualize and make connections between representations of the same phenomena (Ardac and Akaygun, 2003). Second, the hands-on activities in the boost camps have shown that teachers can use these interventions to measure students' achievement in science filling the gap raised by Chai, *et.al.,* 2013 and Janssen and Lazonder, 2016. In line with the government's vision to improve students' achievement in the BGCE 'O' Level Examination in Combined Science, the results will also provide useful insights to policymakers or educators to design curriculum based on TPACK framework.

Supported by literature review in this paper, the ability of the students shown in constructing their presentation slides from their prior knowledge gained in the declarative stage fits into the constructivist framework which emphasize the importance of building on the learner's prior knowledge to construct new knowledge.

Discussion and Conclusion

The use of technology in teaching and preparation of technologically enriched learning environments in this study required high motivation from the teachers. The need to start to respond to the challenges of globalization and the digital age of teaching and learning as the world has been developing very rapidly with industrial revolution 4.0 resulting in all sectors seek to apply and integrate technology (Purwaningsih, et.al., 2019).

It can be concluded that teachers need to be given more trainings to plan their lessons using technology in curriculum design by giving them more professional development in technology integration. Correspondingly, Purwaningsih, et.al., (2019) mentioned that teachers must experience a paradigm shift in teaching and learning where technology does not only serve as a tool to aid instructions but also function as a tool that benefits students' learning.

Even Mishra and Koehler (2006) argued that TPACK knowledge is created when teachers employ their technological, pedagogical, and content knowledge to create specific technology integration strategies. Hence, the use of TELA in this study, the specific technology-integration strategies referred to pedagogical strategies in creating TELA for Bruneian students in learning science. Likewise, the integration of technological knowledge, pedagogical knowledge and content knowledge in TELA helped to accelerate students' conceptual understanding, improve students' motivation to learn science and develop students' attainment of 21st -century skills.

To develop and implement teaching techniques for meaningful learning, each teacher needs to be fully knowledgeable in terms of his or her content knowledge (CK) and pedagogical knowledge (PK). Even researchers (Mishra & Koehler, 2006; McCrory, 2008) have argued that besides CK and PK teachers also need to master technological knowledge (TK). When combined, these three bodies of knowledge (CK, PK and TK) form a framework for technological inclusion (Mishra & Koehler, 2006). Therefore, it is suggested that, when it comes to science subjects, science teachers need to upgrade not just their content knowledge and pedagogical knowledge, but also their technological knowledge.

The present study indicates that student achievements can be enhanced through TELA that are student-centred and characterised by TPACK's backward designs. Based on the findings of this approach, it could serve as a guide for teachers to implement the TELA, especially amongst students with different academic abilities, because the elements of the approach are suited for learners with different abilities (Arıkan, 2018).

Nevertheless, to drive the Brunei's Wawasan 2035 all parties (Ministry of Education, school leaders, teachers, researchers, students and parents) are interdependent of each other, and teachers can help the change by providing evidence from their own authentic classroom settings through the *ecology of educational change* (Deng, 2019).

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