6 ICLEI 2016-25 Sallimah M. Salleh

Designing lessons using TPACK framework for developing Secondary Science Students' Conceptions and Higher-Order Thinking

Hana Shukriyah Sarkawi[a] & Sallimah M. Salleh*[b]
[b]Sultan Hassanal Bolkiah Institute of Education, Universiti Brunei Darussalam, Jalan Universiti, Bandar Seri Begawan, Brunei Darussalam
[a]Ministry of Education, Brunei Darussalam, Jalan Berakas, Bandar Seri Begawan, Brunei Darussalam
*Corresponding Author: sallimah.salleh@ubd.edu.bn

ABSTRACT

This study addressed science teachers' concern about the English as Second Language (ESL) students' difficulty in understanding the concept of measurements and their applications, which are the basic concepts in learning science. The purpose of this design-based research is to assess the impact of Technological Pedagogical Content Knowledge, (TPACK)-integrated lessons on students' understanding the concepts of measurements and their applications that require higher-order thinking skills. The research is designed for a constructivist learning environment where English is the medium of instruction. This study hypothesized that the TPACK-integrated lessons with technology- enriched instruction can overcome the language barrier and enhance students' understanding of science conceptions of measurement and develop higher order thinking skills. This study sought to answer two research questions: (1) How do Year 7 students' conceptions of measurement improved after each cycles of lessons designed with TPACK framework; (2) How do the TPACK-integrated lessons develop students' higher order thinking skills in the science classroom? Four cycles of intervention classes designed and planned for the respective knowledge dimensions of (viz. declarative, procedural, schematics and strategic) of the TPACK framework (Wiggins & McTighe, 2006) were mounted. Data were collected from two sources: pre- and post-tests scores, and students' interviews. Data from the test scores were analysed using SPSS one-way repeated measures ANOVA, whereas students' interviews were analysed qualitatively using thematic analysis by identifying themes that support results from the students' written tests. The results of this study demonstrated how the TPACK framework could be used to design lessons that integrate content knowledge (concepts of measurement), pedagogy (inquiry based learning) and technology (to reduce language barrier) to impact understanding and higher order thinking skills.

Keywords: TPACK framework, concept of measurements, higher order thinking skills, curriculum design

Introduction

Students' academic performance and achievement were shown to correlate positively to their engagement in lessons (Gerber, Mans-Kemp, & Schlechter, 2013; Lee, 2014; Marchand & Furrer, 2014; House & Telese, 2015). Successful understanding of the basic science concepts at the onset of the learning leads to sequential effective learning and enjoyment in studying science. Students need to properly grasp the basic scientific skills for them to be able to study science successfully. For students' effective and successful science learning, teachers need to be confident in integrating technology in their lessons (Graham et al., 2009; Sancar-Tokmak, Surmeli, & Ozgelen, 2014). Therefore, the current study evaluated how teachers could plan lessons using a framework that integrated teacher's content knowledge (CK), pedagogical knowledge (PK) with technological knowledge (TK). Using the Technological, Pedagogical, Content Knowledge (TPACK) framework, we conducted a design-based research which involved the planning of lessons using TPACK framework, implementing the lessons, and the reflecting on the effectiveness of the planned lessons in fostering students' understanding of the concept of measurement, as well as to identify how the lessons planned using the TPACK framework developed students higher order thinking.

TPACK framework, developed by Koehler and Mishra (2009), is the knowledge framework formed when teachers integrate their technological knowledge (TK) into their pedagogical knowledge (PK) and content knowledge (CK). Whilst studies have shown that TPACK is a useful framework for planning for improvement in students' conception in learning (Zucker & Hug, 2008; Chiu & Wu, 2009; Calik, Ozsevgec, Ebenezer, Artun, & Kucuk, 2014), increasing students' engagement and motivation for learning (Doering & Veletsianos, 2008; Smith, 2013; Calik, Ozsevgec, Ebenezer, Artun, & Kucuk, 2014) and enhancing learning (Khan, 2011; MaKinster & Trautmann, 2014), there are still paucity in research that reports students' academic achievement using the TPACK-designed lessons (Chai, Koh, & Tsai, 2013). In this study, we attempt to provide empirical evidence that lessons designed with TPACK framework promote students' understanding and achievement in developing higher thinking skills.

Purpose of the Study

The purpose of this design-based research was to investigate the effectiveness of the lessons planned using the TPACK framework that integrate content knowledge, pedagogical knowledge and technological knowledge at declarative, procedural, schematic and strategic knowledge dimensions respectively, to promote students' understanding of the science concept of measurement; and develop higher order thinking skills. The following research questions were formulated in order to achieve the aims of the study.

Research questions

1. How do Year 7 students' conceptions of measurement improved after each cycles of lessons designed with TPACK framework?
2. How do the TPACK-integrated lessons develop students' higher order thinking skills in the science classroom?

Theoretical Framework

Up to date, extensive research has been done since Koehler and Mishra (2005) introduced the term Technological, Pedagogical, Content Knowledge (TPACK) in 2005. TPACK is a conceptual framework has been shown to be effective in developing teachers' knowledge about technology integration with content knowledge and pedagogy, and the teachers accept the concept easily. Technology plays a major part in the everyday lives of 21st century citizens, therefore its integration in students' learning sessions generally causes positive impacts towards their learning experience (Doering & Veletsianos, 2008; Khan, 2011; Calik, Ozsevgec, Ebenezer, Artun, & Kucuk, 2014). There are numerous studies that proved the positive effect of integrating TPACK knowledge dimensions into students' learning. For instance, Doering & Veletsianos (2008) did a study on 65 middle school geography students to examine their experiences with real-time authentic geospatial data provided through a hybrid adventure-learning environment. Analyses from students' work and interviews in the study showed that students gained better conception and motivation for learning with the use of the technology in their learning session. Khan's (2011) case study showed that TPACK framework was used and implemented in the classroom has the positive effect on students' learning. Through classroom observation over three semesters, teacher interviews and student surveys, the study also found that first-year students in a North American public university were taught chemistry using computer simulations in a unique instructional cycle of "generate-evaluate-modify" across 11 topics in the curriculum. This method of teaching enhanced students' conceptual understanding on chemistry.

The current study has applied the TPACK framework in the designing of the lessons on measurement, and proposed to inform literature on the TPACK effectiveness in promoting understanding and student higher order thinking skills for ESL students.

Inquiry-Based Learning

Inquiry-based-learning (IBL) was originated by J. Richard Suchman (1968) and is widely used in the teaching of science (cited in Khan, Hussain, Ali, Majoka, & Ramzan, 2011; Demirbag & Gunel, 2014; Salehizadeh & Behin-Aein, 2014; Sever & Guven, 2014; Kogan & Laursen, 2014; Demircioglu & Ucar, 2015; Walan & Chang, 2015; Soltis, Verlinden, Kruger, Carroll, & Trumbo, 2015). Researchers found mainly positive effect of IBL, and that it is more effective compared to the traditional method of instruction. For example, Khan, Hussain, Ali, Majoka and Ramzan (2011) studied the effect of inquiry method on students' achievement in secondary level chemistry. From pre- and post-test data, they found that students who previously had high achievement showed significantly better performance, while there is no significant difference for the low achievers. These results are contradictory to that was found by Kogan and Laursen (2014) in a study to examine the impact of IBL on undergraduates' subsequent grades. Through the analysis of observation, survey, interview and test data gathered from mathematics undergraduates at two institutions, they found that there is a significant and persistent positive impact on previously low-achieving students' grades. Kogan and Laursen's (2014) findings on the persistence of the impact, can be compared with the findings from a study by Sever and Guven (2014) who investigated the effect of IBL on students' resistance behaviour on science and technology course. While they found from tests, observation, and interview data that IBL improved students' behaviour in learning, they also discovered that these positive changes in attitude were not persistent in the subsequent classes where IBL was not implemented. The current study attempted to investigate the effect of IBL enhanced by technology on ESL students' understanding of the concept of measurement.

Literature Review

TPACK Framework in an Inquiry-Based Learning Environment

Ebscohost search engine was used to search for literature using the keywords: inquiry based learning, constructivist, student-centred pedagogy, technology-embedded, technology-enriched, technology-enhanced, science concepts, thinking skills, and achievement. Table 1 shows the review of seven studies that are focused on science concepts, and technology-embedded inquiry-based learning.

Table 1
Review of Several Studies Examining The Effect of Technology-Embedded Inquiry-Based Learning

Theme	Author(s)	Title	Method(s)	Main finding(s)
TPACK framework in inquiry setting	Kim (2006)	Effect of 3D Virtual Reality of Plate Tectonics on Fifth Grade Students' Achievement and Attitude Toward Science	Pre- and Post-Test scores and surveys	Significantly higher achievement by experimental group and positive change of attitude towards science found in both experimental and control groups.
	Lin, Hsu & Yeh (2012)	The Role of Computer Simulation in an Inquiry-Based Learning Environment: Reconstructing Geological Events as Geologists	Pre- and Post-Test scores and interview	Students' engagement and the development of students' inquiry skills were promoted.
	Mulder, Lazonder, Jong, Anjeweirden & Bollen (2012)	Validating and Optimizing the Effects of Model Progression in Simulation-Based Inquiry Learning	Pre-Test and students' final model	Model progression leads to more efficient and effective performance of students.
	Hwang, Wu, Zhuang & Huang (2013)	Effects of the inquiry-based mobile learning model on the cognitive load and learning achievement of students	Pre- and Post-Test scores and questionnaire	Students had better learning achievement and less cognitive load.
	Chiang, Yang & Hwang (2014)	An Augmented Reality-based Mobile Learning System to Improve Students' Learning Achievements and Motivations in Natural Science Inquiry Activities	Pre- and Post-Test scores, questionnaire	Improved students' learning performance in inquiry-based learning activities & students gained significant learning motivation

Sokolowski (2014)	Modelling rate for change of speed in calculus proposal of inductive inquiry	Pre- and Post-Test scores	Enriched students' perception of object rate of speed
Peffer, Beckler, Schunn, Renken & Revak (2015)	Science Classroom Inquiry (SCI) Simulations: A Novel Method to Scaffold Science Learning	Questionnaire (likert scale)	Positive impact on students' perception on authentic science practices and strengthened students' prior knowledge.

Embedding technology into inquiry-based learning is not an uncommon strategy used by science educators. Technology enhanced inquiry-based strategy has been tested by studies reviewed in the current study, and the methodology and results were shown in Table 1. (Kim, 2006; Lin, Hsu, & Yeh, 2012; Mulder, Lazonder, Jong, Anjewierden, & Bollen, 2012; Hwang, Wu, Zhuang, & Huang, 2013; Sokolowski, 2014; Chiang, Yang, & Hwang, 2014; Peffer, Beckler, Schunn, Renken, & Revak, 2015). The following three studies illustrate the integration of teachers' technological knowledge and pedagogical knowledge for improving students' achievement of various science concepts (content knowledge), fostering positive attitude, developing inquiry skills, and increased engagement.

Kim (2006) examined the effect of using 3D virtual reality simulations (technology) designed to support inquiry-based science curriculum (pedagogy) on students' achievement and attitude towards science on fifth-grade students (N = 41). The results showed that the 3D group scored significantly higher on the achievement test compared to the control group who were taught using the traditional 2D visuals. While a positive change of attitude towards science was found in both 3D and 2D groups, the difference was not statistically significant. However, for both groups, the researcher found that students' prior attitude had a significant determining effect on the later attitude.

Similarly, Lin, Hsu and Yeh (2012) analysis of students' pre- and post-test scores, and interview data about the effect of computer simulation (technology) in inquiry-based learning environment (pedagogy), showed a positive impact on the development of students' inquiry skills, and their engagement in learning. Hwang, Wu, Zhuang and Huang (2013) examined the effect of using mobile learning system (technology) in an inquiry setting (pedagogy) on 51 sixth grade students' learning achievement and cognitive load. Data analysed from pre- and post-tests and questionnaire showed that students in the experimental group with the inquiry-based mobile learning model had better learning achievement, and less cognitive load, than those in the control group with traditional learning method.

Whilst the previous studies showed significant effect on students' understanding, development of inquiry skills, and increased students' engagement, motivation, and attitudes towards science, the current study investigates the effect of TPACK-integrated lessons, designed by scaffolding knowledge from low level thinking (declarative and procedural knowledge) to higher order thinking (schematic and strategic knowledge), on students' conceptual understanding, and students' achievement in a different classroom setting, where the students' language of instruction (English language) is not their first language.

The current study involved 22 lower secondary students in a science classroom where their second language (English) is used as the language of instruction. This study examines the effect of TPACK-designed lessons with technology-enriched, inquiry-based learning environment on students' conception of measurement, and students' development of higher-order thinking in learning science.

Methodology

This study embarked on a designed-based research, which has demonstrated its potential as a methodology for research and design of technology-enhanced learning environment (Wang & Hannafin, 2005). The design-based research will inform the effectiveness of TPACK-integrated designed lessons on students' achievement through a cycle of scientific processes of design, and implement interventions systematically to improve and refine the initial designs. The design-based research was focused on cycles that also allowed teachers to better understand their students so they could improve the quality of their instructional methods and effectiveness through a process of action cycles – plan, act and reflect (Mertler, 2014).

For the last step, we designed lessons consisting of four cycles of the knowledge dimensions of TPACK framework, each cycle consisting of actions: Plan, Act and Reflect (see Figure 1) and test administrations. The first cycle was addressed the declarative knowledge dimension of the TPACK framework, where the focus is on students' knowledge of 'what'. This included the definitions of basic measurements students need to know e.g. length, mass, time and temperature. Students were also required to identify the correct measuring tools and units for each measurement.

The second cycle was addressed the procedural knowledge dimension of the TPACK framework, where the focus is the students' knowledge of 'how'. At this stage, students learnt how to use the knowledge they acquired during cycle 1 to generate another knowledge on how to calculate area and volume.

The third cycle and fourth respectively addressed the schematic and strategic knowledge dimensions of the TPACK framework where the focus is on the students' knowledge of 'why' (schematic) , and "when" and "where" (strategic). Students learnt the method of evaluating the knowledge they gained during cycles 1 and 2 (involving low order thinking skills) to independently build the conception of density on their own (requiring higher order thinking skills), and provide accurate explanation of the concept.

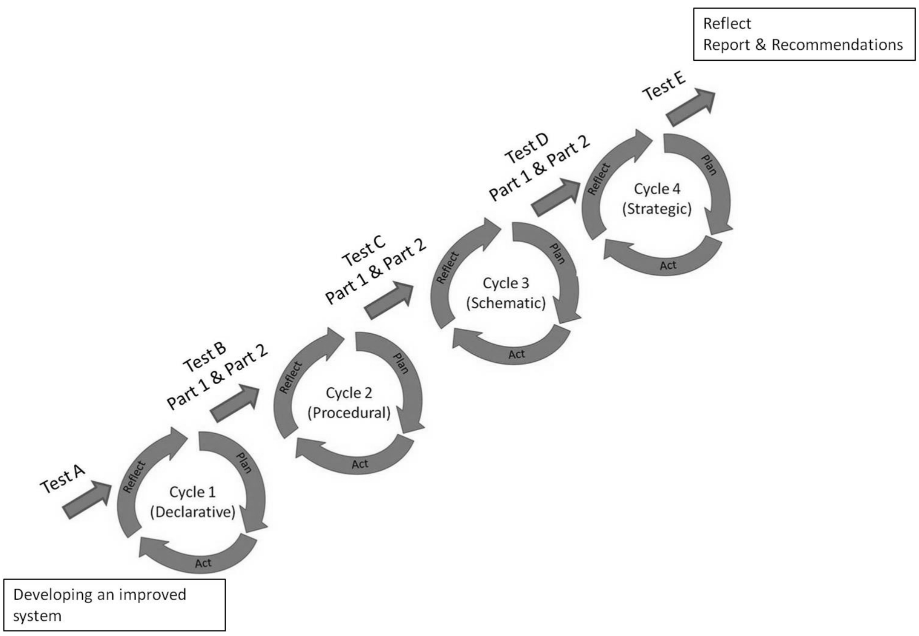

Figure 1. The TPACK framework and its knowledge components.

All the cycles were carried out in technology-enhanced, inquiry-based-learning environment. Online games and computer simulations from open sources from the Internet were used (see Table 2) at the beginning of each intervention before students were given the chance to experience the content through hands-on activities. Students were prompted to develop questions, sought answers, and made use of the real measuring tools to create knowledge. Students' knowledge were built up during each of the cycles until they reached the final cycle where they had the opportunity to utilise all the knowledge they had acquired in earlier cycles. The final cycle was focused on the students' ability to perform scientific investigations and where they organised their data using ICT (excel document).

Table 2
Table Showing The Technology Used in Each Cycle.

Intervention cycle	Game / Simulation content	URL
Cycle 1: Length, Mass, Time & Temperature	Choosing stamps for parcels; practice length and mass measuring skills.	http://www.sciencekids.co.nz/gamesactivities/math/measurements.html
	Learn how to measure mass using beam balance simulation.	http://www2.smarttutor.com/player/swf/Math_measurement_tools_Weight_Lev3_vol_01_ss_t3_edact_n_y_3_1.swf
	Battleship number line; practice skills on using scales	https://www.brainpop.com/games/battleshipnumberline/
	Reading a thermometer	https://www.ixl.com/math/grade-3/read-a-thermometer
	Jack the builder; units of measurement, read mass, volume and length	http://www.bgfl.org/bgfl/custom/resources_ftp/client_ftp/ks2/maths/measures/index.htm
	Stop the clock; time measurement	http://resources.oswego.org/games/StopTheClock/sthec3.html
Cycle 2: Area & Volume	Area and perimeter interactive game	http://www.bgfl.org/bgfl/custom/resources_ftp/client_ftp/ks2/maths/perimeter_and_area/index.html
	Surface area and volume simulation	http://illuminations.nctm.org/Activity.aspx?id=4095
Cycle 3: Density	Density simulation	http://phet.colorado.edu/sims/density-and-buoyancy/density.swf
Cycle 4: Scientific method	Walk the plank game on scientific methods	http://www.solpass.org/5s/Games/ScientificMethodPlank.html

Findings and Discussions

The assumptions for parametric statistical analysis were carried out before the quantitative analysis of the test scores was done. Quantitative analysis of pre- and post-test data using the one-way repeated measures ANOVA, and the interpretation is supported by the qualitative students' interview data.

Assumptions for Parametric Statistical Analysis
In order to assess the suitability to use parametric statistical analysis (ANOVA) for this study, the general assumptions are tested to check for violation of assumptions (Tabachnick & Fidell, 2013). The following Table 3 shows the results of the tests for assessment of the assumptions where three out of the four levels of measurement provided support for the appropriateness to employ parametric statistical analysis.

Table 3
Results of General Assumptions for Parametric Statistical Analysis (ANOVA)

Level of measurement	Assumption requirement	Check for violation of assumption
Variables	Dependent variable is measured at continuous scale (at interval / ration).	Assumption is met as the dependent variable in this study is continuous scale (raw scores of the tests).
Random sampling	Scores are obtained using a random sample from the population.	Assumption is not met. This study engages purposeful sampling.
Normal distribution	The scores on the dependent variable are normally distributed.	Using skewness and kurtosis to assess the normal distribution, the results show that scores for post-tests for cycle 2 and cycle 3 are normal.
Homogeneity of variance	The samples are obtained from population of equal variances. In this study, the independent variable is gender.	From Levene's test for equality, the results show 7.36 at $p = .013$, which shows significance and therefore violating the assumption. However, after conducting the ANOVA which measures the robust to violation of the assumption, the results shown in the table for Robust Tests of Equality of Means for Welch and Brown-Forsythe show that the statistics were 1.551 at $p = .230$ which is not significant.

Result 1: Improvement of Students' Conceptual Understanding

The first research question was: How do Year 7 students' conceptions of measurement improved after each cycles of lessons designed with TPACK framework. Table 4 shows the results of the one-way between groups (male and female) analysis of variance (ANOVA) to explore the impact of gender on the pre-test scores for each cycle. Table 4 shows that there are no significant variances at $p < .05$. Therefore it can be assumed that the sample is homogeneous.

Table 4
Results of One-Way Between Groups (Male and Female) ANOVA

DV	IV	F	p
Pre-test cycle 1		1.173	.290
Pre-test cycle 2	Post –tests	.382	.543
Pre-test cycle 3		2.828	.108

Wilk's Lambda is a test statistic used in one-way repeated measure Analysis of Variance to test whether there are differences between the means of identified groups of subjects on more than two or more different conditions (the action cycles in the current study). In this study, the Wilk's Lambda is reported to test whether there are significant differences in students' conceptual understanding of measurement over the three cycles of knowledge, procedural and schematic knowledge respectively.

The one-way repeated measures ANOVA was performed to compare the tests scores on the conception of measurements with statistic test at cycle 1 (prior to the intervention), cycle 2 (following the intervention), and cycle 3 (three weeks follow-up). In can be inferred that there were significant changes in the mean scores after each cycles (Wilk's Lambda = .107, $F(2, 20) = 83.73$, $p < .001$, multivariate partial eta squared = .893). Based on Wilk's Lambda, it can be concluded that there was significant improvement in students' conception of measurement over the three cycles of teaching as observed by the changes in mean scores from the first cycle ($M = 2.86$, s.d. = 2.68) to the second cycle ($M = 8.86$, s.d. = 1.67) and to the third cycle ($M= 10.27$, s.d. = 4.22). The effect size of this study was eta = 0.89, which suggests a very large effect size based on Cohen (1988, pp. 284-7) (.01 = small effect, .06 = moderate effect, .14 = large effect).

Result 2 : Effect on students' order of thinking.

The second research question was: How do the TPACK-integrated lessons develop students' higher order thinking skills in the science classroom? To investigate the effect of the interventions on students' order of low and high level of thinking, the test scores were sectioned into two parts. Students' scores from questions involving low order thinking (understanding and explaining) were separated from the scores from questions involving high order thinking (analyzing and applying) based on Bloom's taxonomy.

The one-way repeated measures ANOVA was again performed separately to compare scores on the conception of measurement with each test scores on questions pertaining low order thinking, and the scores on questions pertaining high order thinking at cycle 1 (prior to the intervention), cycle 2 (following the intervention), and cycle 3 (three weeks follow-up). The means and standard deviations for each case are presented in Table 5.

Table 5

Means and Standard Deviations of Test Scores on Questions Pertaining To High Order Thinking and Questions Pertaining To High Order Thinking (N=22)

Order of thinking	Cycle	Mean	Std. Deviation
Low Order	1	2.8636	2.67787
	2	5.5909	.95912
	3	5.6364	2.05971
High Order	1	.0000	.00000
	2	3.2727	1.57908
	3	4.6364	2.57359

From the results shown in Table 6, the effect of interventions on students' low order thinking was significant, as proven by Wilk's Lambda = .405, F (2, 20) = 14.69, p < .001, multivariate partial eta squared = .595. Students showed improvement in their scores as observed by the changes in mean scores on questions pertaining to low order thinking from the first cycle (M = 2.86, s.d. = 2.67) to the second cycle (M = 5.59, s.d. = .95) and to the third cycle (M = 5.63, s.d. = 2.05). The effect size of this study on students' low order thinking was eta= 0.59, which suggests a large effect size.

Table 6

The Effect of the Intervention Using the TPACK Framework on Student's Low and High Order Thinking

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Wilks' Lambda	Low Order	.405	14.699	2.000	20.000	.000	.595
	High Order	.171	48.533	2.000	20.000	.000	.829

Significant effect of the interventions was also observed on students' high order thinking, as proven by Wilk's Lambda = .171, F (2, 20) = 48.53, p < .001, multivariate partial eta squared = .829 (see Table 6). The changes in students' mean scores on test questions pertaining to high order thinking from first cycle (M = .00, s.d. = .00) to the second cycle (M = 3.27, s.d. = 1.57) and to the third cycle (M = 4.63, s.d. = 2.57) suggested significant improvement. The effect size on students' high order thinking was eta= 0.82. The larger effect size was shown for higher order thinking compared to the effect size on students' low order thinking.

Students' Confidence With Their Correct Conceptions.

While the quantitative analyses provide evidence of significant improvement in developing students' low to higher order thinking skills, which also indicated a positive impact of the TPACK-integrated lessons, on their correct conceptions of measurement, the qualitative data reveal that students were not confident in oral expression of their correct understanding. The students' lack of confidence in expressing their correct conceptions orally, are illustrated in the following excerpts from the interview data.

The following excepts illustrate how student S07 (who scored lowest in the post test at cycle 2). The interview question probed student's higher order thinking (application of knowledge).

T: *How about the volume of a rock with the irregular shape? How do we find its volume?*
S07: *I know this. Use this one. (*points to the measuring cylinder*)*
T: *Okay. How? Tell me step by step.*
S07: *Fill with water, then put rock in it, and I don't know. That's difficult teacher.*

From the interview excerpt, it can be seen that this student (S07) was on the right track with the method of finding the volume of irregularly shaped objects even though his post-test score marked the lowest in the class. His lack of confidence with his own understanding of the concept, however, hindered him from proceeding with the description of the rest of the method.

From the qualitative analysis of the student interview data, lack of confidence is a common theme found throughout the current study. The majority of the students were not confident with their academic performance and ability, and this was especially observed during the five practical sessions of cycle 1. Students were doubtful about their own understanding, which made knowledge construction to higher order thinking (analysis and application) a difficult task to express orally. The interview excerpt inserted below illustrate the lack of confidence in expressing their correct understanding by two of the highest scoring students (S15 and S21) in the post-test of cycle 1, even for a low order thinking question (definition of units). The students' voice intonation when answering the questions indicated a lack of confidence, and implied that they were seeking confirmation from the teacher.

T: *Tell me what instrument you would use to measure the distance from here to here (gesturing to the sides of adjacent lab tables).*
S21: *This? (holding a measuring tape).*
T: *What is that?*
S21: *Measuring tape teacher.*
T: *And what is the unit of the distance?*
S21: ... (no answer)
T: *Let's say you measure the distance between the two tables, and you get 100. 100 what? Degrees? Seconds?*
S21: *Cen..ti..metre?*

Their lack of confidence in their understanding could be further illustrated for the higher order thinking question in cycle 1. Even though they had the correct answer, and they showed understanding on the content matter, slight probing for explanation from the teacher made them question their own understanding, and assumed that their answer was incorrect. Inserted below is the interview excerpt of the same students answering questions pertaining to high order thinking.

T: *Alright. Here I have 50 cm³ of water. The mass of this beaker before I put water in it is 50 g. We have an electronic balance right here. Use it and tell me the mass of the water. Water*

only.
S21: *(took the measurement) it is 100.2 teacher.. eh no?.*
S15: *What is the mass of the beaker again?*
T: *50 g.*
S21: *Then... (calculating) 50.2.*
T: *50.2...? What's the unit?*
S15: *g.*
S21: *Or grams.*
T: *Okay, I see you minus 50 g from the 100.2 g. Tell me why 100.2 is not the right answer.*
S21: *(flustered) Is it wrong, teacher?*
T: *No, it's correct. But tell me why you minus the 50 g.*
S15: *Because... this (pointing to the electronic balance reading) is for water and beaker. You want water only.*
S21: *Yes. So we remove the beaker.*

The results of the current study showed that although students gained significant improvement in their conceptual understanding, further improvement on their confidence level would be desired so they coulf further benefit their learning process. As documented by House and Telese (2014), students who initially reported that they are confident with their ability scored higher in their academic achievement compared to those who do not think that they are able to complete the given task. This is echoed by Miscevic-Kadijevic (2015) who reported that students' academic achievement was mainly linked to self-confidence in each of the three cognitive domains (knowing, applying, and reasoning).

Limitations

While this study focuses on the benefits of the efficacy of the developed curriculum in engaging students in science, and increasing their understanding of the concept of measurement, the findings are limited only for that particular concept under study. The findings cannot be generalised to other conception and other classroom situations. However, the usefulness for teacher's preparation for developing curriculum designs through TPACK framework was illustrated.

Conclusions and Recommendation

The current study concluded that TPACK-integrated lessons caused significant improvement on students' conceptual understanding on measurement; and the lessons designed for each cycles of the TPACK framework were successful in scaffolding students understanding from low order of thinking to higher order thinking. However, the qualitative analysis showed that both low-ability and high-ability students, who showed gain improvement in understanding, were lacking in confidence about their correct conceptions. The current study also concluded that the TPACK-integrated lessons are useful in helping ESL students, who study science in the English language as the mode of instruction, showed significant improvement in their conceptual understanding of the concept of measurement.

The current study recommends future TPACK-integrated lessons should assigned students to produce video-recorded presentations to reinforce their understanding orally to improve their confidence. The current study also did not measure the measure students' confidence quantitatively. Therefore, quantitative justification would provide empirical evidence on the impact of the TPACK framework on students' confidence in their correct conceptions could be explored for further research.

REFERENCES

Calik, M., Ozsevgec, T., Ebenezer, J., Artun, H., & Kucuk, Z. (2014). Effects of 'Environmental Chemistry' Elective Course Via Technology-Embedded Scientific Inquiry Model on Some Variables. *Journal of Science Education and Technology*, 23, 412-430.

Chai,C.-S., Koh. J. H.-L., &Tsai, C.-C. (2013). A review of Technological Pedagogical Content Knowledge. *Educational Technology & Society, 16 (2).* 31-51.

Chiang, T. H., Yang, S. J., & Hwang, G.-J. (2014). An Augmented Reality-based Mobile Learning System to Improve Students' Learning Achievements and Motivations in Natural Science Inquiry Activities. *Educational Technology & Society,* 17(4), 352-365.

Chiu, M. H., & Wu, H. K. (2009). The Roles of Multimedia in the Teaching and Learning of the Triplet Relationship in Chemistry. In *Multiple Representations in Chemical Education* (pp. 251-283). Springer Netherlands.

Demirbag, M., & Gunel, M. (2014). Integrating Argument-Based Science Inquiry with Modal Representations: Impact on Science Achievement, Argumentation, and Writing Skills. *Educational Sciences: Theory & Practice*, 14(1): 386-391.

Demircioglu, T., & Ucar, S. (2015). Investigating the Effect of Argument-Driven Inquiry in Laboratory Instruction. *Educational Sciences: Theory & Practice*, 15(1): 267-283.

Doering, A., & Veletsianos, G. (2008). An investigation of the use of real-time, authentic geospatial data in the K-12 Classroom. *Journal of Geography*, 106(6), 217-225.

Gerber, C., Mans-Kemp, N., & Schlechter, A. (2013). Investigating the moderating effect of student engagement on academic performance. *Acta Academica, 45 (4)*, 256-274.

Graham, C. R., Burgoyne, N., Cantrell, P., Smith, L., Clair St., L., & Harris, R. (2009). TPACK development in science teaching: Measuring the TPACK confidence of inservice science teachers. *TechTrends*, *53*(5), 70–79. http://doi.org/10.1007/s11528-009-0328-0

House, J. D., & Telese, J. A. (2014). Confidence in Mathematics and Algebra Achievement of Eight-Grade Students in Japan: Findings from the TIMSS 2011 Assessment. *Education, 135*(2), 252-256.

House, J. D., & Telese, J. A. (2015). Engagement in Science Lessons and Achievement Test Scores of Eight-Grade Students in Korea: Findings from the Timss 2011 Assessment. *Education, 135 (4)*, 435-438(4).

Hwang, G. J., Wu, P. H., Zhuang, Y. Y., & Huang, Y. M. (2013). Effects of the inquiry-based mobile learning model on the cognitive load and learning achievement of students. *Interactive Learning Environments*, 21(4): 338-354.

Khan, M. S., Hussain, S., Ali, R., Majoka, M. I., & Ramzan, M. (2011). Effect of Inquiry Method on Achievement of Students in Chemistry at Secondary Level. *International Journal of Academic Research*, 3(1): 955.

Khan, S. (2011). New Pedagogies on Teaching Science with Computer Simulations. *Journal of Science Education and Technology*, 20:215-232.

Kim, P. (2006). Effects of 3D Virtual Reality of Plate Tectonics on Fifth Grade Students' Achievement and Attitude Toward Science. *Interactive Learning Environments*, 14(1): 25-34.

Koehler, M. J., & Mishra, P. (2009). What is technological pedagogical content knowledge? *Contemporary Issues in Technology and Teacher Education*, 9(1), 60-70.

Koehler, M. J., & Mishra, P. (2005). What happens when teachers design educational technology? The development of technological pedagogical content knowledge. *Journal of Educational Computer,* 32(2), 131-152.

Kogan, M., & Laursen, S. L. (2014). Assessing Long-Term Effects of Inquiry-Based Learning: A Case Study from College Mathematics. *Innovative Higher Education*, 39: 183-199.

Lee, J. S. (2014). The Relationship Between Student Engagement and Academic Performance: Is It a Myth or Reality? *The Journal of Educational Research*, 107:177-185.

Lin, L.-F., Hsu, Y.-S., & Yeh, Y.-F. (2012). The Role of Computer Simulation in an Inquiry-Based Learning Environment: Reconstructing Geological Events as Geologists. *Journal of Science Education and Technology*, 21: 370-383.

MaKinster, J., & Trautmann, N. (2014). Understanding the Use of Geospatial Technologies to Teach Science: TPACK as a Lens for Effective Teaching. In *Teaching Science and Investigating Environmental Issues with Geospatial Technology* (pp.269-286). Springer Netherlands.

Marchand, G. C., & Furrer, C. J. (2014). Formative, Informative, and Summative Assessment: The relationship among curriculum-based measurement of reading, classroom engagement, and reading performance. *Psychology in the Schools, 51 (7)*, 659-676.

Mertler, C. A. (2014). *Action Research: Improving Schools and Empowering Educators.* London: Sage Publication.

Miscevic-Kadijevic, G. (2015). TIMSS 2011: Relationship between self-Confidence and Cognitive Achievement for Serbia and Slovenia. *Revista Electrónica de Investigación Educativa, 17*(3), 109-115.

Mulder, Y. G., Lazonder, A. W., Jong, T. d., Anjewierden, A., & Bollen, L. (2012). Validating and Optimizing the Effects of Model Progression in Simulation-Based Inquiry Learning. *Journal of Science Education and Technology*, 21:722-729.

Peffer, M. E., Beckler, M. L., Schunn, C., Renken, M., & Revak, A. (2015). Science Classroom Inquiry (SCI) Simulations: A Novel Method to Scaffold Science Learning. *PLoS ONE 10(3)*, e0120638. doi:10.1371/journal.pone.0120638.

Salehizadeh, M. R., & Behin-Aein, N. (2014). Effects of cooperative learning plus inquiry method on student learning and attitudes: a comparative study for engineering economic classrooms. *European Journal of Engineering Education*, 39(2): 188-200.

Sancar-Tokmak, H., Surmeli, H., & Ozgelen, S. (2014). Preservice science teachers' perceptions of their TPACK development after creating digital stories. *International Journal of Environmental and Science Education*, *9*(3), 247–264.

Sever, D., & Guven, M. (2014). Effect of Inquiry-based Learning Approach on Student Resistance in a Science and Technology Course. *Educational Sciences: Theory & Practice*, 14(4); 1601-1605.

Smith, S. (2013). Through the Teacher's Eyes: Unpacking the TPACK of Digital Fabrication Integration in Middle School Language Arts. *Journal of Research on Technology in Education*, 46(2):207-227.

Sokolowski, A. (2014). Modelling rate for change of speed in calculus proposal of inductive inquiry. *International Journal of Mathematical Education in Science and Technology*, 45(2): 174-189.

Soltis, R., Verlinden, N., Kruger, N., Carroll, A., & Trumbo, T. (2015). Process-Oriented Guided Inquiry Learning Strategy Enhances Students' Higher Level Thinking Skills in a Pharmaceutical Sciences Course. *American Journal of Pharmaceutical Education*, 79 (1)

Tabachnick, B. G., & Fidell, L. S. (2013). *Using Multivariate Statistics* (6th ed.). Boston: Pearson.

Walan, S., & Chang, R. S. (2015). Student responses to a context- and inquiry-based three-step teaching model. *Teaching Science*, 61(2), 33-39.

Wang, F., & Hannafin, M. J. (2005). Design-based research and technology-enhanced learning environments.*Educational Technology Research and Development. 53* (4). P5-23.

Wiggins, G. & McTighe, J. (2006). *Understanding by design*. Upper Saddle River, NJ: Pearson Education, Inc.

Zucker, A. A., & Hug, S. T. (2008). Teaching and Learning Physics in a 1:1 Laptop School. *Journal of Science Education and Technology*, 17. 586-594.