ENRICHING THE TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE (TPACK) OF SCIENCE TEACHERS THROUGH AN ENHANCEMENT TRAINING PROGRAM

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ABSTRACT

The study was conducted to enhance the Technological Pedagogical Content Knowledge (TPACK) of selected public school science teachers in Quezon province through development of a training program. The mixed method of research design was utilized in the study wherein quantitative data and qualitative data were triangulated. The respondents were thirty (30) science teachers from Division of Lucena City, Division of Tayabas City and Division of Quezon. The weighted mean, t-test for significance and one-way ANOVA were used as statistical treatment of the data. Based on the findings, it was concluded that the respondents have sufficient knowledge in each domain of Technological Pedagogical Content Knowledge (TPACK). However, aiming to elevate higher the TPACK of science teachers, an enhancement training program was developed. Implemented to the respondents, it is valid for use and it can enhance the science teachers' TPACK level regardless of their age, sex, and teaching experience. It was recommended that science teachers may consider using the TPACK framework in order to develop their knowledge level and to enhance the teaching and learning processes. School administrators may also adapt the TPACK training program as part of their faculty development program.

Keywords: *enhancement training programs, science teachers technological pedagogical content knowledge*

INTRODUCTION

In the changing world of today, technologies play a significant role in the lives of people including in their learning processes and communication. To be able to succeed in the teaching career, teachers have to become successful in pedagogy, technology, and subject content areas. Realizing this need, one of the important agenda in research and development in learning science is the effective utilization of technology in the procedure of teaching and learning processes. To be able to accomplish such aim, teachers have to be educated and equipped with knowledge and skills on technology infusion into their teaching practice in the classroom. In that way, teachers can respond to the need of students of technology-enhanced learning (Srisawasdi, 2014).

It is significant that the preparation programs of teachers respond to the challenges brought upon by the integration of technology into the lives of educators and their students (Martin, 2015). In the public educational system in the Philippines, beginner science teachers are required both with dedication and skills that are essential to the needs of the 21st century learners. Thus, the teacher trainer program needs to embrace the paradigm shift that leads to technology infused pedagogy curriculum from courses that focused on technological skills (Mizell, 2010; Moeler & Reitzes, 2011). Such program should provide science educators with copious time to prepare in such changes in pedagogical approaches that are enriched with education technology innovations.

The Technological Pedagogical Content Knowledge (TPACK) framework plays an important role in achieving effective technology integration in the teaching and learning processes. It was created and emerged as a precise valuable tool that examines how technology integration can reinforce pedagogical approaches and strategies as well as the knowledge content in the curricula. TPACK describes and recognizes the goals in using technology. The framework explains the interconnections and overlying relationship between the three knowledge components

of technology, pedagogy and content. It emphasizes understanding of teachers on effective use of technology as a pedagogical tool and describes the overlay between pedagogy, content and technology knowledge bases (Koehler & Mishra, 2009).

In the field of teaching and learning, TPACK has already taken important effects. The problem however lies on the insufficient understanding of educators to TPACK. Remediating, Harris and Hofer (2009) and Niess (2011) found out that through a program of technology-enriched learning activity types, TPACK level of teachers can be developed. They claimed that when teachers appropriately utilized technology to achieve their learning goals, there is maximization on the learning of students.

The Section 10, Article XIV of the Philippine Constitution serves as a guide in science teaching in the Philippine Educational System. It states that Science and Technology are essential for the national development progress, invention, innovation and their utilization, and to science and technology education, training and services. Responding, the Enhanced Basic Education Act of 2013 (RA 10533) or the K to 12 law mandates the government to create a functional basic education system that will develop productive and responsible citizens equipped with essential competencies, skills and values for both life-long learning and employment.

As part of achieving these goals, the Department of Education implemented DepEd Computerization Program that allows Information Communication Technology be integrated in the formal school systems to increase ICT literacy among learners, teachers and school heads. They even created the Learning Resources Management and Development System (LRMDS) that made available online quality assured teaching and learning materials that could be used inside and outside the classroom. Despite these efforts, still, it was not utilized to its maximum potentials (Borbon, 2011).

Problems continue to arise in science classroom due to weak technology integration. Even if teachers are already decided to integrate technology in the science education, they still encountered barriers such as lack of competence and confidence, access to resources, and overloaded science curriculum (Annetta, 2010; Ball, 2011; Bingimlas, 2009; Larivee, 2009; Snowman, Dobozy, Scevak, Bryer, Bartlett & Biehler, 2009).

In the case of Quezon province, which is one of the recipients of changes in the technological approach in the teaching and learning processes, Science teachers also experience various constraints such as lack of time of preparation, equipment, pedagogical content knowledge, technological knowledge and pedagogical skills in implementing technological approaches in the teaching and learning processes. Most of them, either old or new find time insufficient whenever they prepare technology-based lessons. This could be attributed to lack of technological and pedagogical content knowledge which is highly needed in preparing lessons that are integrated to technology. Lack of proper equipment may also be a cited reason since only few teachers own a personal laptop or desktop. Though some have them, only few can use its full potential as regard to the integration with TPACK.

Thus, the researcher became motivated to determine the level of technological pedagogical content knowledge of science teachers and use the result as basis for development of TPACK enhancement program. Science teachers were chosen because the researcher believed that they should be well equipped with these knowledge and skills as they enter the teaching profession. Being truly knowledgeable, their students will gain more of the benefits from such learning.

With these discussions, this research study focused on the enhancement of the Technological Pedagogical Content Knowledge os Science teachers in Quezon province for SY 2017-2018.

Specifically, it sought to achieve the following objectives:

1. Determine the level of respondents' knowledge before the enhancement training program in terms of:
   - 1.1. Technological Pedagogical Content Knowledge (TPACK)
   - 1.2. Technological Pedagogical Knowledge (TPK)
   - 1.3. Technological Content Knowledge (TCK)
   - 1.4. Pedagogical Content Knowledge (PCK)
   - 1.5. Pedagogical Knowledge (PK)
   - 1.6. Content Knowledge (CK)
   - 1.7. Technological Knowledge (TK)
2. Develop training program that would enhance the technological pedagogical content knowledge of science teachers.
3. Determine if there is significant difference on the Technological Pedagogical Content Knowledge level of the respondents before and after the enhancement

training program.

4. Determine if there is significant difference on the TPACK level of the respondents when grouped as to the following:
   - 4.1. Age
   - 4.2. Sex
   - 4.3. Teaching Experience

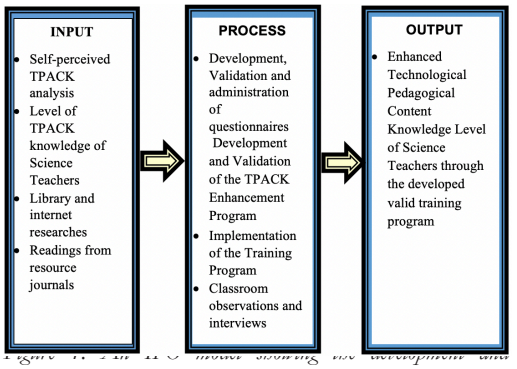
Conceptual Framework

The following discussions show the framework for the conduct of this research study. The Technological Pedagogical Content Knowledge (TPACK) framework describes the type of teacher knowledge necessary to teach effectively and efficiently with technology. It describes the kinds of knowledge that teachers need in order to teach with technology, and the complex ways in which these bodies of knowledge of pedagogy and content interact with one another (Koehler & Mishra, 2009; 2008). This builds on the approach used by Shulman's (2007) pedagogical content knowledge (PCK), explaining the reason why the knowledge of pedagogy and content of the teachers cannot be considered in isolation. Teachers, according to Shulman, need to master the interaction between pedagogy and content in order to implement strategies that help students to fully understand content. The TPACK framework extends Shulman's (2007) notion of PCK by including knowledge of technology. Teachers must understand how technology, pedagogy, and content are interconnected, and construct a form of knowledge that goes beyond the three domains or knowledge bases. A flexible framework is necessary in teaching with technology which elucidate how technologies are versatile and rapidly changing which can be utilized effectively with proper combination of pedagogical approaches to teach different subject content.

In the work of Guzey & Roehrig (2009), the development of TPACK among teachers who are already in service can be done through in-service professional development programs or training in which participants are expected to have a certain level of pedagogical content knowledge which later on aid in the development of TPACK. The development of TPACK can be done in several approaches. It could be from PCK to TPACK in which technology provide and improve teaching strategies currently implemented in the classroom. TPACK can also be developed through TPK. This can be done by giving activities on instructional technology in a form of courses or seminars conducted by an expert in technology. The third way is to develop PCK and TPACK simultaneously.

Koh and Divaran (2011) described in their TPACK-Developing Instructional Model how teachers improved their Information and Communication Technology (ICT) instruction. To develop the TPACK level of teachers through ICT instruction, they suggested three phases. These phases are: fostering teachers' acceptance and technical proficiency; pedagogical modelling; and pedagogical application.

Research Paradigm



implementation of TPACK enhancement training program

Methodology

The mixed method research design was used in the study. This method of research focuses in the collection, analysis and combination both of quantitative and qualitative data in a single study (Creswell & Plano Clark, 2011). Quantitative data came from the answered questionnaires on TPACK level of the respondents (Babbie, E. 2010) while the qualitative data were gathered from classroom observations and interviews (Yin, R. 2015). It is also triangulation since mixing of data types and methodologies was done to further get accurate information and data which are necessary in the conduct of the study. This design aims to obtain different but complementary data on the same sources to best understand the research problem or the topic of the research. The intent of this design is to bring together the different strengths and non-overlapping weaknesses of quantitative data with those of qualitative data (Johnson & Onwuegbuzie, 2013).

This was conducted in the selected public schools in Quezon province namely Lucena Dalahican National High School, Lucena City National High School, Gulang-Gulang National High School, Luis

Palad Integrated High School and Sariaya National High School. They were from the Division of Lucena City, Division of Tayabas City and Division of Quezon. These schools were chosen due to their closer location in order to monitor the selected respondents during the classroom observations which was part of gathering for the qualitative data of the research.

The respondents of this research were the selected thirty (30) public school science teachers who came from the three school's division in the province of Quezon. Purposive sampling technique was used in selecting the respondents since there were specific characteristics of science teachers needed in the conduct of the study. These were age, sex and years of teaching experience. Meanwhile, there were seven (7) selected respondents who became the subjects for classroom observations and interviews. They were purposively selected and became representative of the demographic profile variables I terms of age, sex and teaching experiences which were necessary on the qualitative part of the study. These repondents were labelled as Teacher A to Teacher G. Teacher A was male with the highest TPACK self-assessment. Teacher B was female with the lowest TPACK self-assessment. Teacher C was female with the second highest TPACK self-assessment. Teacher D was female and had the longest teaching experience which was categorized as expert. Teacher E was female and had one of the shortest teaching experiences which was categorized as novice. Teacher F was female and categorized as one of the oldest among the respondents. Teacher G was female and categorized as the youngest among the respondents.

The instruments were developed by the researcher in order to gather the needed data. First was the TPACK assessment questionnaire that was constructed based on the work of Forssell (2011), Uwusu (2014) and Schmidt, et.al (2009). The questionnaire was a Likert-Scale type with four choices and equivalent values. The questionnaire was divided into seven domains of TPACK. Each domain was composed of ten (10) questions. Pilot testing of the questionnaire was done to fifteen (15) science teachers who were not part of the study. After which, some statements were rephrased to better comprehend and some grammar were also corrected for clarity. Likewise, other statements were reclassified to other domains of TPACK. The second instrument was the TPACK enhancement training program. This was developed based on the result of the TPACK assessment questionnaire. These were the parts of the enhancement training program which includes (a) Introduction – science teachers were properly oriented as to the rationale of the TPACK and the flow of the enhancement training program; (b) Seminars and Workshops – this includes seminars and workshops on teaching pedagogy, ICT and educational technology and the TPACK Framework; (c) Classroom observations – selected respondents were subjected to classroom observations in order to see the actual TPACK integration; and (d) Interviews – those who were observed in their actual classroom teaching were also subjected for interviews. Experts suggested that the enhancement training program should be supported with legal basis such as those of DepEd Orders and Memorandum and the matrix of trainings should be clear in such a way that objectives, expected outcomes and activities are parallel to each other, and explanations as to the processes of the training should be given emphasis. These suggestions were incorporated in the enhancement training program and the final revised enhancement training program.

In gathering the data, a letter of request for permission to conduct the study was given to the three school's division superintendents in the province of Quezon. Upon approval, another letter for the conduct of the study was given to the principals of the target schools. These schools were Lucena Dalahican National High School, Lucena City National High School, Gulang-Gulang National High School, Luis Palad Integrated High School and Sariaya National High School. Once approved, an orientation about the research was conducted and the assessment of the respondents' TPACK was then administered. The collected answers were checked and analyzed by the researcher.

Based on the result of the analysis, a TPACK training program was then constructed, validated and implemented. The program included a series of seminar and workshop where the respondents learned those that are essential in enhancing their TPACK level. Classroom observations and interviews were conducted among representative respondents who were purposively selected. Interviews were also used to triangulate the result of the TPACK assessment and the performance in the classroom observation. After all the series of getting the quantitative and qualitative data, these were treated, tabulated and analyzed by the researcher. At the end of it, a valid TPACK enhancement training program was developed.

RESULTS AND DISCUSSION

1. Level of Respondent's Knowledge

Table I. Weighted Mean Summary of the Respondents' Technological Pedagogical Content Knowledge (TPACK) before The Conduct of the Enhancement Training Program

Domain	WM	DR	TPACK Equivalent Level
Technological Knowledge (TK)	3.00	A	High
Content Knowledge (CK)	3.12	A	High
Pedagogical Knowledge (PK)	3.21	A	High
Pedagogical Content Knowledge (PCK)	3.11	A	High
Technological Content Knowledge (TCK)	3.15	A	High
Technological Pedagogical Knowledge (TPK)	3.14	A	High
Technological Pedagogical Content Knowledge (TPACK)	3.11	A	High
Average Weighted Mean	**3.12**	**A**	High

Table 1 shows the summary of weighted mean of the respondent's TPACK before the conduct of the enhancement training program. The data shows that respondents are low in Technological Knowledge (TK) with a weighted mean of 3.00 and Pedagogical Content Knowledge (PCK) and Technological Pedagogical Content Knowledge (TPACK) both got 3.11. Meanwhile, Technological Content Knowledge (TCK) and Pedagogical Knowledge (PK) obtained the highest with weighted mean of 3.15 and 3.21 respectively.

This data shows that the respondents already possessed high TPACK equivalent level which may be associated with the teaching experiences and the pre-service education of the respondents.

2. Development of the TPACK Enhancement Training Program

The Technological Pedagogical Content Knowledge (TPACK) enhancement training program was developed based on the results of the self-assessment questionnaire. The focused of the development was based on the items on the questionnaire that was least answered by the respondents. Even if all scores had shown high TPACK level, it was the goal of the enhancement training program to improve this to very high TPACK level.

The respondents showed least scores on the sufficiency of opportunities to work with technologies and solving problems and issues of certain technology. Likewise, they scored least on the way they communicate scientifically and matching their teaching style with the learning style of the students. Further, least scores were also seen on the development of activities outside the school and evaluation of the content of the science curriculum. Meanwhile, respondents scored the least on the technologies that they can use in teaching science and how they can design teaching approaches that utilized those technologies. Moreover, they appeared most problematic in guiding their colleagues in the combination of content, pedagogy and technology in science teaching.

The latter points were the focused in the development of the Technological Pedagogical Content Knowledge enhancement training program. The topics included were the TPACK Framework in which the respondents would not only be familiarized with all the domains but would be able to comprehend how pedagogy, content and technology can be integrated during the teaching and learning processes. Likewise, another topic was Pedagogical Approaches in Science for the 21st century learners. In this regard, different pedagogical approaches and strategies appropriate in the modern learners were identified and discussed. Technological tools in science teaching was the third topic of the enhancement training program in which the respondents were updated on the current trends in technological tools, their uses and problem solving issues. Lastly, TPACK framework in science teaching context was the last topic. This became the process of integrating the content, pedagogy and technology into the science education perspective.

After identifying the topics and their objectives, suitable resource speakers were selected. For the topic Pedagogical Approaches in Science for the 21st century learners, the resource speaker came from an Autonomous University in which she works as a college professor in the College of Teacher Education. She handles science education majors and hones them into science teachers. Importantly, she is a certified regional trainer of science teachers for the K-12 Enhanced basic curriculum. For the topic Technological tools in science teaching, the resource speaker came from a Tertiary Education Institution in which he works as a Marketing Assistant and a part-time instructor in the college department. Not only he teaches technology in teaching in that institution, he likewise trains teachers on how to use technology in their respective fields. The TPACK Framework and TPACK Framework in Science Teaching Context were discussed and explained by the researcher.

After identifying the topics and the resource speakers, the TPACK enhancement training program was developed. It was validated by five (5) experts composed of principals, research director and dean of graduate school, Senior Education Program Specialist on Research and an Education Program Supervisor in

Science. Validated, the TPACK enhancement training program was implemented.

3. Significant difference on the Technological Pedagogical Content Knowledge level of the respondents before and after the enhancement training program.

Table II. Comparison of TPACK before and after the Use Enhancement Training Program

Domain	Mean						t-value	p-value	significance
	Before	DR	VD	After	DR	VD			
Technological Knowledge (TK)	3.00	A	High	3.63	SA	Very High	-8.271	0.000	Significant
Content Knowledge (CK)	3.12	A	High	3.70	SA	Very High	-9.545	0.000	Significant
Pedagogical Knowledge (PK)	3.21	A	High	3.72	SA	Very High	-7.396	0.000	Significant
Pedagogical Content Knowledge (PCK)	3.11	A	High	3.65	SA	Very High	-10.544	0.000	Significant
Technological Content Knowledge (TCK)	3.15	A	High	3.73	SA	Very High	-9.607	0.000	Significant
Technological Pedagogical Knowledge (TPK)	3.14	A	High	3.69	SA	Very High	-10.030	0.000	Significant
Technological Pedagogical Content Knowledge (TPACK)	3.11	A	High	3.69	SA	Very High	-6.248	0.000	Significant
Summary	**3.12**	**A**	High	**3.69**	**SA**	**Very High**	**-11.406**	**0.000**	**Significant**

Table 2 shows the test for significance between each domain of Technological Pedagogical Content Knowledge or TPACK before and after the training program.

The data reveal the t-value of Technological Pedagogical Content Knowledge or TPACK (-6.248), Technological Pedagogical Knowledge or TPK (-10.030), Technological Content Knowledge or TCK (-9.607), Pedagogical Content Knowledge or PCK (-10.544), Pedagogical Knowledge or PK (-7.396), Content Knowledge or CK (-9.545) and Technological Knowledge or TK (-8.271).

These values reveal that there is a significant difference on each domain of the TPACK of the respondents before and after the training program as seen on the verbal description of High to Very High, respectively. Moreover, the summary of the test for significance between each domain has a t-value of -11.406 implying a significant difference on the Technological Pedagogical Content Knowledge or TPACK of the respondents before and after the training program. Thus, the null hypothesis that there is no significant difference on the Technological Pedagogical Content Knowledge level of the respondents before and after the enhancement training program is rejected.

Such data claim that there is a change in the Technological Pedagogical Content Knowledge (TPACK) level as observed on the data before and after the enhancement training program. Each domain increases which can be associated to the contribution of the enhancement training program to each science teacher participant.

4. Significant difference on the TPACK level of the respondents based on demographic groupings

Table III. Significant Difference on the TPACT Level of the Respondents when grouped according to Age

Domain	Age Group	Mean	F-value	p-value	Significance
Summary	21-30	3.72	.471	.630	**Not Significant**
	31-40	3.62			
	41-50+	3.67			

Table 3 on presents the test for significant difference on the Technological Pedagogical Content Knowledge or TPACK between age group of 21-30, 31-40, and 41-50+ years old.

The null hypothesis that there is no significant difference on the Technological Pedagogical Content Knowledge level of the respondents when grouped according to age is accepted. Moreover, the summary of values shows an F-value of 4.71 suggesting that the TPACK of the respondents among the age groups are the same.

Table IV. Significant Difference on the TPACT Level of the Respondents when grouped according to Sex

Domain	Sex	Mean	t-value	p-value	Significance
Summary	Male	3.75	.839	.409	**Not Significant**
	Female	3.66			

implying that the TPACK of the respondents between sexes are the same. Thus, the null hypothesis that there is no significant difference on the TPACK level of the respondents when grouped according to sex is accepted.

Table V. Significant Difference on the TPACT Level of the Respondents when grouped according to Teaching Experiences

Domain	Category	Mean	t-value	p-value	Significance
Summary	Novice	3.64	-1.223	.230	**Not Significant**
	Expert	3.74			

on the Technological Pedagogical Content Knowledge or TPACK based on teaching experience (novice and expert).

The summary of values shows a t-value of -1.223 indicating that the TPACK of the respondents between years of experience is the same. Thus, the null hypothesis that there is no significant difference on the Technological Pedagogical Content Knowledge level when grouped according to teaching experience is accepted.

CONCLUSIONS

Based on the gathered findings of the study, the following conclusions were drawn:

1. The respondents have sufficient knowledge in each domain of Technological Pedagogical Content Knowledge (TPACK).
2. The enhancement training program is valid for use by science teachers.
3. The training program can enhance the Technological Pedagogical Content Knowledge level of science teachers.
4. The training program enhances the TPACK level of science teachers regardless of their age, sex and teaching experience.

RECOMMENDATIONS

Based on the conclusions drawn from the study, the following were recommended:

1. Science teachers may consider using the TPACK framework in developing their knowledge level in order to enhance their teaching and learning processes.
2. The school administrators may adapt the TPACK training program as part of their faculty development program.
3. Seminars and trainings on the use technological tools, appropriate pedagogical approaches and content development may be conducted in order to develop the TPACK of science teachers.
4. This study may be replicated by conducting a longer training program or a wider area of coverage.

REFERENCES

Annetta, L.A. (2010). The "I's" Have It: A Framework for Serious Educational Game Design. Review of General Psychology, Vol. 14, No. 2, pp 105-112

Babbie, E. (2015). The Practice of Social Research 12th edition. CA: Wadsworth Cengage Learning

Ball, D. (2011). Building a Common Core for Learning to Teach. American Educator. Bingimlas, K. (2009). Barriers to the Successful Integration of ICT in Teaching and Learning Environments: A Review of the Literature. Eurasia Journal of Mathematics, Science and technology education, 2009, 5(3), 235-245

Borbon, M. (2011). Variables Affecting the Utilization of Computer Technology in Science Instruction: Basis for Computer Technology Integration Program. Unpublished Masteral Thesis. Sacred Heart College.

Creswell, J.W. and Plano Clark, V.L. (2011). Designing and conducting mixed methods research (2nd edition). Thousand Oaks, CA: Cengage Publications, Inc.

Forssell, K. (2011). Technological Pedagogical Content Knowledge: Relationships To Learning Ecologies and Social Learning Networks. Published Dissertation, Stanford University.

Guzey, S. S., & Roehrig, G. H. (2012). Integrating educational technology into the secondary science teaching. Contemporary Issues in Technology and Teacher Education, 12(2), 162–183

Harris, J., & Hofer, M. (2009). Instructional planning activity types as vehicles for curriculum based TPACK development. In Maddux, C. D. (Ed), Research highlights in technology and teacher education. pp. 99-108

Johnson, B. et.al. (2013). Mixed Method Research: A Research Paradigm Whose Time Has Come. Educational Researcher, Vol. 33 No. 7

Koh, J. and Divaharan, S. (2011). Developing Pre-Service Teachers' Technology Integration Expertise Through The TPACK-Developing Instructional Model. J. Educational Computing Research, Vol. 4491, 35-58

Larrivee, B. (2009). Authentic classroom management: Creating a learning community and building reflective practice (3rd ed.). Upper Saddle River,NJ: Pearson Education, Inc.

Marino, M.T. (2009). Enhancing TPACK with assistive technology: Promoting inclusive practices in preservice teacher education. Contemporary Issues in Technology and Teacher Education, 9(2), 186-207

Mishra, P. et.al. (2010). Technological Pedagogical Content Knowledge: A Framework for Teacher Knowledge. Retrieved 10 May 2017 from http//mkoehlereducmsu.edu/

Mizell, H. (2010). Why Professional Development Matters. Oxford, OHL Learning Forward.
Moeller, B., & Reitzes, T. (2011). Integrating technology with student-centered learning. Quincy, MA: Education Development Center, Inc. Nellie Mae Education Foundation.

Niess, M. (2011). Investigating TPACK: Knowledge Growth in Teaching with Technology. J. Educational Computing Research, Vol. 44(3) 299-317

Schmidt et.al. (2009). Technological Pedagogical Content Knowledge (TPACK): The Development and Validation of an Assessment Instrument for Pre-service Teachers. JRTE, 42(2), 123-149

Schmidt, D. A., Baran, E., Thompson A. D., Koehler, M.J., Mishra, P. & Shin, T. (2010). Technological pedagogical content knowledge (TPACK): The development and validation of an assessment instrument for pre-service teachers. Journal of Research on Technology in Education, 42(2), 123–149.

Shulman, L. (2007). Those who understand: Knowledge growth in teaching. Educational Researcher, 15(2), 4-14

Snowman, J., Dobozy, E., Scevak, J., Bryer, F., Bartlett, B., & Biehler, R. (2009). Psychology: Applied to teaching. Milton, Qld: John Wiley & Sons

Srisawasdi, N. (2014). Developing technological pedagogical and content knowledge in using computerized science laboratory environment: an arrangement for science teacher education. Research and Practice in Technology Enhanced Learning. 9(1), 123-143.

Uwusu, K. (2014). Assessing New Zealand High School Science Teachers' Technological Pedagogical Content Knowledge. Published Dissertation, University of Canterbury, New Zealand.

Yin, R.K. (2015). Qualitative Research from Start to Finish 2nd Edition. New York: Guilford