

**ASSESSMENT OF TECHNOLOGICAL
PEDAGOGICAL CONTENT KNOWLEDGE OF
BIOLOGY TEACHERS IN SENIOR SECONDARY
SCHOOLS IN KWARA STATE, NIGERIA**

Ph. D. Interim Report

By

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CERTIFICATION

This is to certify that this study was carried out by BELLO, Abdulrazak Agboola (13/680N004) in Department of Science Education, Faculty of Education, University of Ilorin, Ilorin, Nigeria. In partial fulfillment of the requirements for the award of Ph.D. Science Education (Biology).

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KNOWLEDGE OF BIOLOGY TEACHERS IN SENIOR
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DEDICATION

This research study is dedicated to the Almighty Allah.

ACKNOWLEDGEMENTS

I return all glory and adoration back to Allah, the Almighty, for His protection, blessings and favour which are highly valued and appreciated.

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ABSTRACT

The integration of Technological Pedagogical Content Knowledge (TPACK) into classroom instruction has been a challenge for the educational systems that aim to cope with the needs and demands of the 21st century. TPACK framework represents the knowledge needed by teachers bringing together content knowledge, technological knowledge and pedagogical knowledge with the aim of integrating Information and Communication Technology (ICT) into teaching-learning processes. There is growing concern on the method of teaching biology. Therefore, the study assessed the TPACK of biology teachers in senior schools. The objectives of the study were to: (i) examine biology teachers' knowledge about teaching biology topics at the senior school level; (ii) determine the extent to which biology teachers were knowledgeable about modern digital technologies for teaching biology; (iii) ascertain the availability of modern digital technologies for teaching by biology teachers; (iv) determine the form of training possessed by biology teachers with modern digital technologies; and (v) investigate the biology teachers' level of Technological Pedagogical Content Knowledge based on gender, teaching qualification and teaching experience.

The cross-sectional survey type of descriptive research method was adopted in the study. The total population of biology teachers in Nigeria consisted of 22,675. The target population were 1,122 biology teachers from senior secondary schools in Kwara State. Purposive sampling technique was used based on the teachers that have ICT gadgets in their schools to select 680 sampled biology teachers from the target population. The research instrument that was used in this study was adapted from Archambault and Crippen (2009) and Sahin (2011). Data were tested using Analysis of Variance (ANOVA) and t-test statistics at 0.05 level of significance.

The findings of the study were that:

- i. 65.0% of the Senior School biology teachers possessed adequate knowledge about biology topics;
- ii. 74.9% of the biology teachers did not possess adequate knowledge about modern digital technologies in teaching of biology topics;
- iii. 57.9% of the sampled schools did not possess modern digital technologies in the teaching of biology topics;
- iv. 53.5% of the Senior School biology teachers acquired self-training of ICT use in teaching;
- v. 74.2% of the biology teachers possessed adequate knowledge of TPACK;

- vi. there was a significant difference in the level of TPACK between male and female biology teachers in favour of the female teachers ($t=555$)-3.467 $p<0.05$);
- vii. there was a significant difference in the level of TPACK between qualified and less qualified biology teachers in favour of less qualified teachers ($t=555$)-6.288, $p<0.05$); and
- viii. there was significant difference in the level of TPACK of biology teachers' based on teaching experience in favour of the experienced biology teachers ($F=_{3,554}$) 66.587, $p=.003$)

The study concluded that biology teachers possessed low level of TPACK. This implies that although biology teachers had good mastery of their subject matter, they do not have ICT-integration in their instructional approach due to lack of ICT knowledge. The study recommended that biology teachers should integrate TPACK in their lessons and its application in teaching so as to solve problem of poor performance in biology.

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CHAPTER ONE

INTRODUCTION

Background to the Problem

Science has brought to education many valuable indentures of learning and instruction with considerable stress put on the relevance of the visual approach to instruction. All over the world, teachers are becoming more aware of new teaching strategies and classroom tools that integrate the inquiry-based learning. But most schools are filled up with teachers and pseudo-educators with lesson notes, methods and approaches that have lost relevance in a changing world. Science, which is the bedrock of national development, according to Abimbola (2013), is a body of knowledge, a way or method of investigating, and a way of thinking in the pursuit of understanding nature.

Biology is the branch of science that deals with living things and their crucial actions. The field deals with all the physicochemical features of life. The advance inclination about cross-disciplinary research and the merger of scientific knowledge and investigation from diverse fields have led to the relevant overlap of the field of biology with other scientific disciplines. Advanced principles of other fields such as Chemistry, Medicine, and

Physics, for instance are merged with those of Biology in areas such as biochemistry, biomedicine, and biophysics(Rogers, Joshi, &Green 2019).

Biology is the science of life, with its focus on the structure, function, distribution, and evolution of the organism (LiveScience, 2017). It is an autonomous natural science discipline composed of two major fields namely, functional biology and historical biology. Functional biology deals with life processes at both genome and cellular levels. It can be detailed with the natural laws of physical sciences such as chemistry and physics. Historical, otherwise known as Evolutionary biology, is concerned with the explanation of all aspects of the living world that have to do with the dimension of historical time (LiveScience, 2017).

Furthermore, biology is the branch of science that involves the study of life and that addresses societal problems such as population explosion, environmental pollution, global warming, drug addiction, food insecurity, and healthy living among others which are taught during biology lessons in secondary schools. Fish farming is also made possible through the teaching of Biology (Barbara, 2017). The importance of biology studies in the life of individuals cannot be underrated. In the past 10 years, in Nigeria, biology that was previously a compulsory subject for all senior secondary school students has been made non-compulsory especially for non-science students.

This evolution arises with some concerns for science educators, particularly as it relates to capacity building and application of the subject in the life of all (Akingbemisilu & Ayegbo,2019).

Four fundamental issues are advanced: (a) enhancement of the curriculum; (b) scheming of various instructional methods and strategies; (c) teaching materials; and (d) enhancing the status of the secondary school biology teachers. It would appear that there is an agreement among professionals in the field of teacher education that focuses on upgrading the quality of the teacher which has a higher benefit (Shulman, 1986). This is true because the best curriculum and the very effective teaching method can decline in the hand of a poorly prepared teacher. A highly competent teacher is more likely to produce good students through the effective use of appropriate instructional strategies and materials than an incompetent teacher.

The constant poor academic performance of Nigerian students at secondary schools level is becoming disturbing. A number of factors has been attributed to be liable for the ugly performance. Teachers' Pedagogical Content Knowledge (PCK) and Teachers' Technological Pedagogical Content Knowledge (TPACK) are the two prominent teacher-related factors responsible for the students' poor performance (Niess, 2013). The teacher

needs an articulation of knowledge to effectively deliver instruction in the classroom. This knowledge comprises content knowledge, pedagogical knowledge, and knowledge of students' conception.

The consolidation of these knowledge realms is framed as Pedagogical Content Knowledge (PCK). Loughranm, Mulhall, and Berry (2004) opined that PCK is a unique combination of content and pedagogy that is singularly constructed by teachers and thus, is a peculiar type of an educators' professional understanding. PCK is expressed as a separate category of knowledge with its solitary identifiers (Magnusson, Krajcik, & Borko, 1999). Studies have established that PCK significantly enhances teachers' effectiveness (Loughranm, Berry, & Mulhall, 2004). It is a unique type of content knowledge and pedagogical knowledge that is developed and based on experience over time.

This kind of professional knowledge was first identified by Shulman (1987). Astoundingly, studies in this field have constantly displayed no connection between subject matter knowledge and pedagogic content knowledge (Parker & Heywood, 2000). Consequently, irrespective of a secondary school biology teachers' subject content knowledge, teachers still need to upgrade their pedagogical content knowledge for effective teaching and meaningful learning to occur. The PCK evolved through the integration

of subject matter knowledge and general pedagogical knowledge and it is considered by most educators as the most important element in teaching.

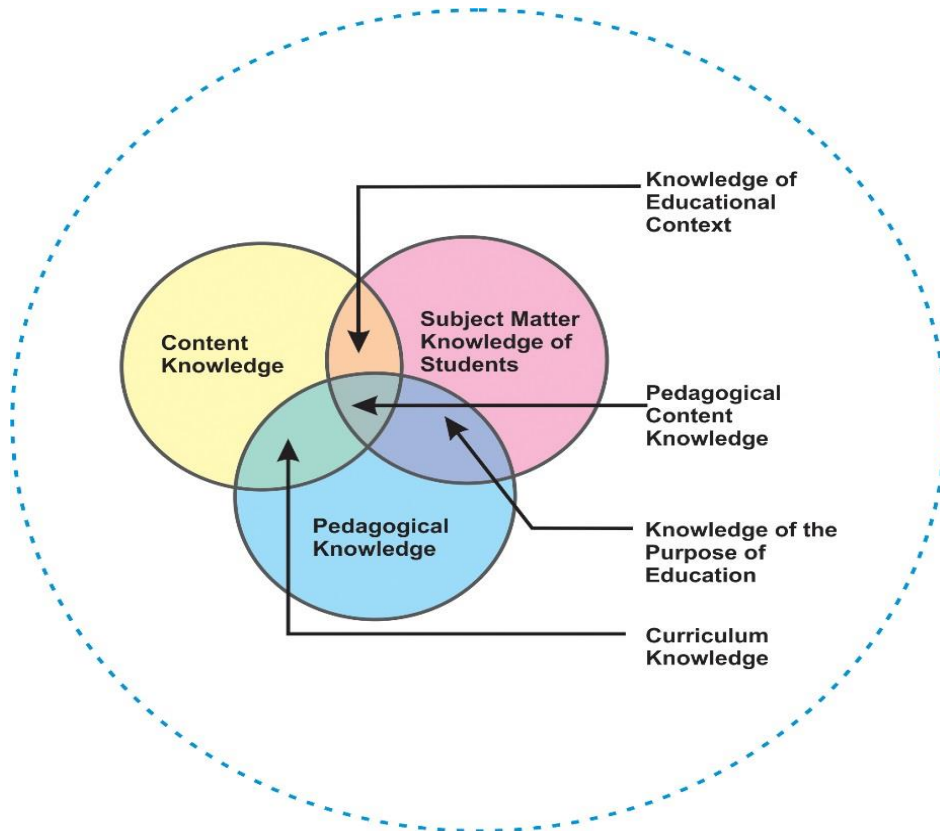


Figure1. Model of the Elements of Pedagogical Content Knowledge Source: Bello and Abimbola (2015).

Figure 1 shows the intermediation of the three fundamental knowledge components of PCK. The integration of teachers' content knowledge and teachers' pedagogical knowledge results to the knowledge of curriculum, while the combination of the teachers' content knowledge and the subject matter knowledge of the students leads to the knowledge of

educational context. More so, the teachers' understanding of student subject matter knowledge with the pedagogical knowledge leads to the knowledge of the purpose of education. A study is purposeful in establishing characteristics of Pedagogical Content Knowledge and studying the psychometric properties of the definition. While lack of agreement mostly considering the level of analysis that is appropriate for it.

According to Borowski, Neuhaus, Tepner, Wirth, Fischer, Leutner, (2010) in a theory of action, it was proposed that intervention, such as professional development, affects the teachers' knowledge bases. These knowledge bases comprise academic content knowledge (ACK), general pedagogical knowledge (GenPK) and content-specific Pedagogical Content Knowledge. The interaction of these six components will bring about teachers' knowledge of PCK (Bello & Abimbola, 2015).

The integration of modern digital Information and Communication Technology (ICT) into the classrooms to meet the needs of the 21st century has added a new dimension to teaching and learning process (Kyriakidou, Chrisostomou, & Banks, 1999; Yapici & Hevedanli, 2012). Teachers now need to acquire basic ICT knowledge and skills as part of the requirements to deliver educational services through ICT platforms. There is a trend toward many ICT applications becoming a general knowledge that has

become an open source to all and sundry, which in turn, has brought about the improvement of the standard of various ICT developers across the globe (Information Communication and Technology & Sustainable Development Goals, 2017). Keeping in mind the advantages of integrating ICT into instruction, teachers must be aware of the latest ICT resources for teaching.

According to the Benchmark for Science Literacy sets by American Association for the Advancement of Science, (2013), understanding the nature of technology is one of 12 standard-based areas that science teachers should help their students achieve in their science learning. Functioning as a tool that keeps civilisation advancing, technology is taken as the means and the goals for curriculum design. Besides making science teaching and learning less strenuous, teaching with technology can also get students acquainted with the latest technological tools and prepare them to solve problems with those tools. Though learning science with technology seems a win-win idea for both the development of science literacy and technological literacy, the ways in which teachers utilise technology to assist their science instruction are also critical to students' learning. (AAAS, 2013).

Teachers can apply technology in instruction in various ways depending on the attributes of the concept they are teaching and the ICT gadget they are using. Some teachers use technology to create worksheets or

assignments as well as ask students to use computers to complete assignments, thus, increasing the number of major activities in teaching that involve technology (American Association for the Advancement of Science, 2013). Modern digital ICT is an integral component of the 21st century. Its applications extend to every facet of human daily activities at every level of the society. For example, in the education sector, instructional technologies have brought about significant novelties to teachers and their classroom instruction. Karasavvidis and Kollias (2014) noted that the use of modern digital ICT in the class will transform teaching and learning practices, and the quality of students' learning experiences making them more, interesting and appealing to the students, thereby enhance meaningful learning.

Hicks (2006) observed that teachers with more experience in the use of modern digital ICT in education use to maintain higher prospects for students learning, while Angeli and Valanides (2005) stated that the use of modern ICT enhances students' performance and that, teachers should have knowledge in;

- identifying subjects to be learnt with educational technology in a manner that will express the value of educational technology applications,

- determining representation for displaying the context in an understandable manner which seems hard to teach using traditional methods;
- recognising teaching strategies which suit learners' needs;
- selecting suitable educational technology tools which are accompanied with veritable information transformation and teaching strategies, and
- integrating classroom practice with educational technology.

Although many teachers are now using modern digital technology in the class, they often do so purely as an extension of the traditional teaching and learning models. Some key factors tend to discourage teachers from integrating modern digital ICT into the teaching and learning process Richmond Public Schools (2018), noted that some of the factors include: low level of teaching experience, negative perceptions of technology, insufficient on-site time or financial support, insufficient time to fulfill the task of teaching with technology and increased requirements for students to operate technology in the classroom.

Some other barriers that inhibit teachers' incorporation of technology into their teaching include conflicting pedagogical beliefs from external sources and the lack of proper assessments reflecting students' learning from technology-supported curricula among others (Richmond Public Schools,

2018). Most of the aforementioned challenges would be solved if teachers are more open-minded to technology implementation in instruction and focus on developing ideas on how technology could assist their instruction in the classroom. Niess (2005) and Angeli and Valanides (2013), suggested that the terms “technology PCK” and “ICT-related PCK” respectively to describe the knowledge required by teachers to integrate modern ICT into the process of teaching and learning. This realm of knowledge is called Technological Pedagogical Content Knowledge (TPACK).

The basic components of TPACK include content knowledge (CK), pedagogical knowledge (PK), and technological knowledge (TK). The synergy between these three essential forms of knowledge lead to pedagogical content knowledge (PCK), technological content knowledge (TCK), technological content knowledge (TPK) and the TPACK. As a form of knowledge, TPACK is being portrayed as well-fixed, complicated, multifarious, integrative and transformative concept (Angeli & Valanides, 2009). TPACK is also seen as the set of knowledge that teacher develops from and for teaching with technology (Mishra & Koehler, 2006). The development of the concept of TPACK stacked upon the belief of Shulman’s 1986 on PCK, enhancing the level of comprehension of the active

interaction among the various forms of knowledge that support the practice of teachers.

The wide range of research that grew along with, and from the evolution of the TPACK construct has also supplied a deeper understanding of how teachers' knowledge is related to pedagogical integration of digital technologies in educational contexts. Literature in TPACK has presented several knowledge enhancement processes (Mishra, 2012), multiple standard of measurement tools Cavanaugh and Koehler, (2013); Chai, Koh, and Tsai, (2016) and many empirical approaches (Koehler, Shin, & Mishra, 2012; Archambault, 2016) for identifying and comprehending teacher's knowledge of TPACK.

Integrating technology into teaching and learning process does not mean achieving the desired result as noted by Koehler and Mishra (2009). Graham, Burgoyne, Cantrell, Smith, Clair, and Harris, (2009), stated that educators have come to share common view that a fundamental knowledge of how to utilise technological tools isn't enough; the most important thing is the ability to use those tools thoroughly in order to enhance meaningful learning by the students. Thus, research interest has concentrated on methods to unify and integrate technological tools in teaching and the learning process.

TPACK has been presented as a framework for teachers' knowledge needed for productive technology integration (Mishra & Koehler, 2006; American Association of Colleges of Teacher Education, 2008; Koehler & Mishra, 2008; 2008). A growing body of research according to Gess-Newsome (2002) shows that students' achievement is more strongly influenced by teachers' quality than by students' race, class, prior academic record, or the school a student attends. This is particularly significant among students from low-income families. The advantages of being taught by good teachers are quite cumulative. Therefore, a teacher must possess the following knowledge to be effective:

1. Technological Knowledge (TK): Is the knowledge about the distinct technologies, ranging from low-tech technology such as pencil and paper to digital technology such as the internet, digital video, interactive whiteboard, and others. It refers to the knowledge of all forms of technology and not just computers.
2. Content Knowledge (CK): The knowledge that a teacher has on biology or Science subjects which he or she teaches; it covers the knowledge linked to a subject matter.

3. Pedagogical Knowledge (PK): The knowledge of the teacher about the methods and customs of teaching and learning. It includes knowledge about the conduct and organisation of the classroom; curricular analysis and planning; and student's learning.
4. Technological Pedagogical Knowledge (TPK): Comprehending how various technology tools can be used in teaching, along with the belief that making use of technology can bring about change in the way teachers improve their practices and develop their professional operation.
5. Technological Content Knowledge (TCK): This is the knowledge of how technology can form new exhibitions and new learning models for specific contents
6. Pedagogical Content Knowledge (PCK): A form of knowledge that integrates both the content and pedagogy with the view of improving the instructional practices in the content area.
7. Technological Pedagogical Content Knowledge (TPACK): required by teachers for integrating technology into their instruction and content area. Teachers have to reach the knowledge of the intricate interrelations existing between the three basic components of

knowledge (CK, PK, and TK) which is revealed in their ability to teach using the suitable pedagogical methods and technologies.

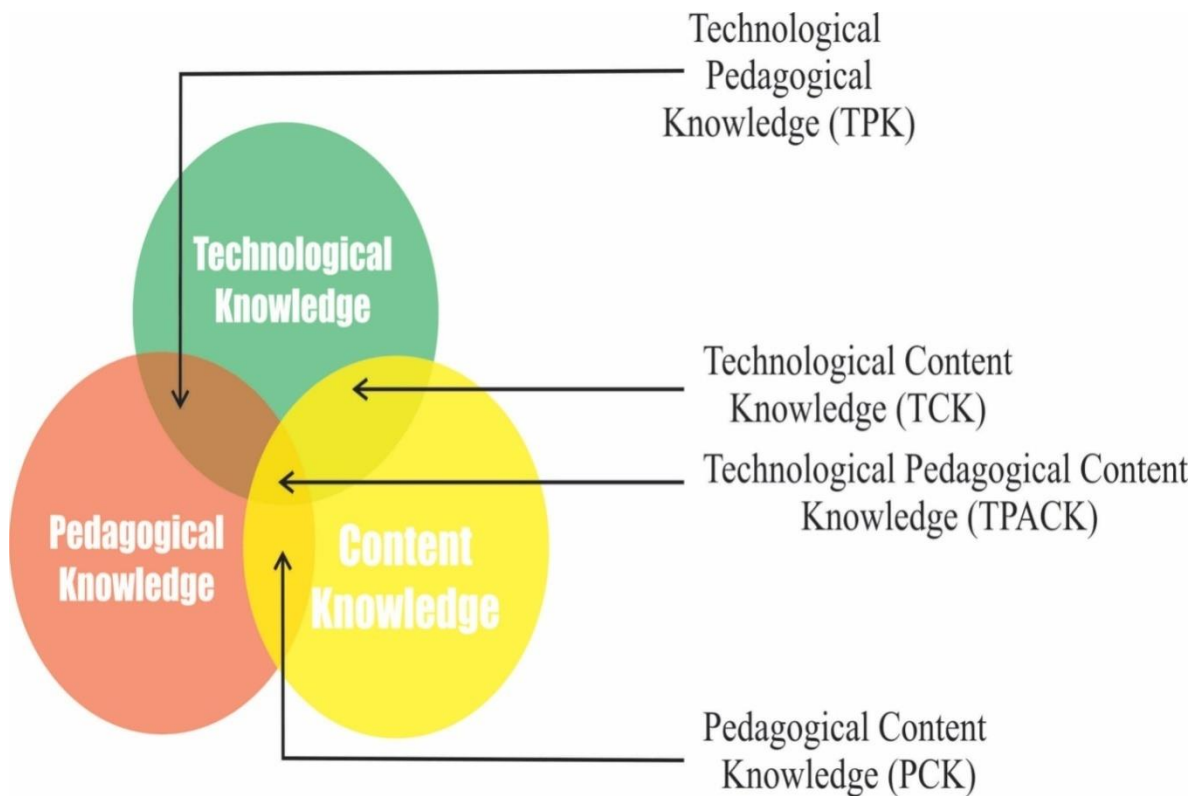


Figure2. Conceptual Model of the Elements of TPACK as Developed from Literature

The various components of TPACK and their descriptions as explained by Mishra & Koehler, (2006) is summarized in Table 1.

These knowledge components can be effective when they interplay with each other. The integration of TK, CK, PK, TPK, PCK, and TCK will give TPACK.

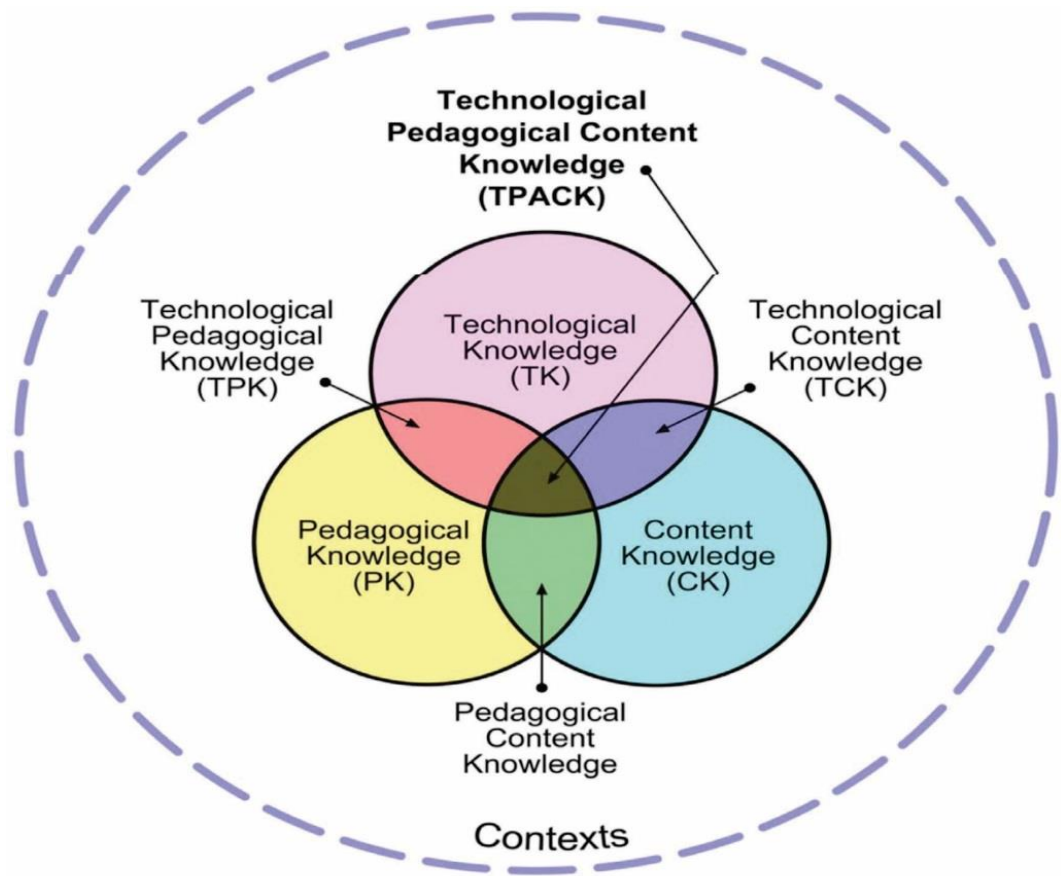


Figure 3. The TPACK framework

(Mishra & Koehler, 2006)

Table 1: The Various Components of TPACK and their descriptions as explained by Mishra and Koehler (2016)

TPACK Knowledge Types and Their Descriptions

Knowledge Type	Description
Technological Knowledge (TK)	Knowledge and skills of traditional, current and emerging technologies
Content Knowledge (CK)	Knowledge about the subject matter for teaching and learning.
Pedagogical Knowledge (PK)	Knowledge about methods and process of teaching, such as

		classroom management, assessment and student teaching
Pedagogical Knowledge (PCK)	Content	The tacit of blending content and pedagogy for developing better teaching practices
Technological Knowledge (TCK)	Content	The tacit of blending content and technology for developing better teaching practices.
Technological Knowledge (TPK)	Pedagogical	Knowledge of the affordances of technologies and what teaching strategies can be combined with those affordances to leverage learning outcomes
Technological Pedagogical Content Knowledge (TPACK)		Teachers' understanding of the interplay among content, pedagogy and technology as well as the procedural knowledge of integrating technologies into their teaching routines.

(Mishra & Koehler, 2006)

The integration of modern digital technology into the classroom could significantly bridge the gap in the performance of male and female students according to Koh, Chai, and Tsai (2015) since the newer generations are more technologically literate. Female teachers may be weak in TK but they acquire better Content Knowledge and Pedagogical Knowledge that complement the knowledge gap. Similarly, male teachers were discovered to possess lower Content Knowledge and Pedagogical Knowledge but their Technology Knowledge helps to alleviate the weaknesses (Shaharom & Faridah, 2010). A good mastery and integration of all the seven TPACK dimensions by the teacher could narrow the gap between male and female

students' performance. Similarly, the seven TPACK dimensions could also go a long way in reducing the difference in teachers' qualification.

Teacher qualification in the view of Alazam, Bakar, Hamzah, and Asmiran (2013) is a major determinant of learning. Teachers have to be creative, innovative and qualify in specific field to meet the requirements of the educational system. They also need to continuously improve upon their professional knowledge and skills after completing their teacher education programme. In addition to qualification, teachers' experience is also a crucial factor in the development of TPACK.

Typically, teacher preparation programmes require pre-service teachers to enroll in one course that focuses on learning about technology (Gronseth, Brush, Ottenbreit-Leftwich, Strycker, Abaci, Easterling, & Leusen, 2010), while others have attempted to introduce technology into other courses in education like educational psychology or methods of teaching (Wetzel, Foulger, Buss & Lindsey, 2014). So far, there is a great anticipation on the pre-service teachers convey naturally the knowledge of technology and proficiency they learnt from courses in their preparation programs to their future classrooms. However, just by having pre-service teachers undertake these courses may not necessarily resolve the problem of transfer of knowledge and its application of technology into their future

classrooms. Evidence suggests that pre-service teachers still do not feel adequately prepared to effectively use technology in teaching (Polly, McGee, & Martin, 2010).

Statement of the Problem

The availability of ICT gadgets in school does not imply technology integration into teaching and learning process. There is a trend toward many ICT applications as becoming generally applicable, this allows for benefits made by one developer to be picked up and improve upon by other developers. The differences in how technology is seen and utilised by every educational stakeholder are impeding the positive impacts that technology can make to students' learning outcome. Although the integration of technological, pedagogical, and content, is presently receiving lots of attention in the educational world, there is no evidence that teachers are adequately integrating these components into their teaching.

Information about effective methods for assessing teacher TPACK is also not sufficient in science or any other subject area. Most of the studies focus more on Science Teachers' TPACK-Practical: Standard-setting Using an Evidence-based Approach (Jen,Yeh, Hsu, Wu, & Chen, 2016). Mastery

of Content Representation (CoRes) Related TPACK High School Biology Teacher (Nasution, Sriyati, Riandi and Safitri,2017), The role of TPACK in physics classroom: case studies of pre-service physics teachers (Niwat,2012), Developing Technological Pedagogical Content Knowledge (TPACK) in Animal Physiology (Pusparini, Riandi, & Sriyati, 2017)

Due to limited available measures, survey research on TPACK has gained much attention. More so, these studies have either focused their attention on cross-validating ranks of teachers or see how teachers master their content specific to integrate technology. Some studied challenges teachers face teaching with technology or rather impact of TPACK on teaching and learning process. None has talked about assessing the teachers' knowledge of TPACK in teaching biology.

Teachers' views of their technological abilities and their perception concerning the advantages of ICT for classroom instruction have been shown to be strong predictors of a planned and determined usage of these tools. However, in searching for the best practices to improve teachers for effective learning to take place, the most significant factor of school variables to be considered are the teachers, researchers, and policymakers. Surprisingly, not much work has been done in the aspect of assessing and improving teachers' knowledge of ICT application to the teaching of science

content area. The poor performance of students on the consistent basis in biology in Nigerian schools is becoming disturbing (Pusparini, Riandi, & Sriyati, 2017).

However, several factors have been attributed to be the leading cause of students' failure in biology. Some of these factors are: they include the poor reading habit of students, the distraction of global information and technology, parental factors, teachers' PCK, and most recently, teachers' TPACK (Niwat, 2012). This study was set to underpin the major problems faced by teachers in teaching with technology. It is to be noted that, the society is technologically driving, hence, teachers' effort can best be appreciated with the integration of ICT into the process of instruction. More so, teachers who use technology will be better placed than teachers who do not (Niwat, 2012). There have been several attempts to study the effect of teachers' subject matter knowledge on students' achievement. The result is achieved by assessing differences in students' outcomes for teachers with various academic specifications. However, lots of potential gaps still need to be occupied by TPACK which could enhance greater transformation in education.

Few studies concentrated on the integration of teachers' knowledge of ICT into the teaching process in the classroom more importantly in the area

of biology which makes this study different from other studies. In concrete terms, technology won't replace teachers but teachers who use technology will probably replace teachers who do not. The need to strengthen the teaching of biology at the secondary school level appears to be well recognised. Hence, this study addressed the Technological Pedagogical Content Knowledge of biology teachers in senior secondary schools in Kwara State, Nigeria.

Purpose of the Study

The main purpose of this study was to assess the Technological Pedagogical Content Knowledge of biology teachers in Senior Secondary Schools in Kwara State, Nigeria.

Specifically, it:

1. examined biology teachers' knowledge about teaching biology topics at the senior school level.
2. determined the extent to which biology teachers are knowledgeable about modern digital technologies (ICT) for teaching biology.
3. ascertained the availability of modern digital technologies for teaching by biology teachers.

4. determined the form of training biology teachers possess in teaching with modern digital technologies (ICT)
5. Investigate the biology teachers' level of Technological Pedagogical Content Knowledge.
6. determine biology teachers' level of Technological Pedagogical Content Knowledge based on gender.
7. determine the level of biology teachers' Technological Pedagogical Content Knowledge based on teaching qualification.
8. Determine the level of biology teachers' Technological Pedagogical Content Knowledge based on teaching experience.

Research Questions

In this study, the following questions were raised and answered.

- I. What is the extent of biology teachers' knowledge of teaching biology topics at the senior school level?
- II. To what extent are biology teachers' knowledgeable about the use of modern digital technologies (ICT) for teaching biology?

- III. What are the available modern digital technologies for teaching biology in the school?
- IV. What types of training do biology teachers acquired for teaching with modern digital technologies (ICT)?
- V. To what level are biology teachers knowledgeable about TPACK?
- VI. What are biology teachers' level of knowledge of TPACK based on gender?
- VII. To what level are biology teachers knowledgeable about TPACK based on their qualifications?
- VIII. What is biology teachers' level of knowledge of TPACK based on their teaching experience?

Research Hypotheses

The following research hypotheses were generated from the research questions and tested at 0.05 level of significance.

H₀₁: There is no significant difference in the Technological Pedagogical Content Knowledge of male and female biology teachers.

H0₂: There is no significant difference in Technological Pedagogical Content Knowledge of qualified and unqualified biology teachers.

H0₃: There is no significant difference in Technological Pedagogical Content Knowledge based on the teaching experience (experienced, moderately experienced and less experienced) of biology teachers.

Scope of the Study

The study was carried out among biology teachers in selected public and private senior secondary schools in Kwara State, Nigeria. It focused primarily on the assessment of biology teachers' Technological Pedagogical Content Knowledge. Teachers' gender, teachers' qualifications, and teachers' teaching experience were the variables considered in the study.

Significance of the Study

This study could be of great benefit to students, teachers, teacher educators, curriculum planners, Science Teachers Association of Nigeria (STAN), Federal and State Ministries of Education, Educational

Consultants, Educational administrators, Researchers and Examination bodies.

The results of this study would stimulate biology teachers to upgrade their TPACK to enhance their teaching effectiveness and efficiency. This would impact positively on students' learning and performance in biology at the final external examinations such as the Senior School Certificate examinations organized by WAEC, NECO and NABTEB among others. hoped that the findings from this study would encourage school administrators and proprietors to provide essential modern digital ICT tools for teachers and students' use.

The findings of this study would provide biology teacher educators and teacher education institutions useful insights into the quality of teachers they are producing. This would stimulate them to review approaches adopted in equipping pre-service biology teachers with TPACK.

The findings could sensitize curriculum developers on the need to infuse all elements of TPACK into biology teacher education curricula at all levels. The Biology Panel of the Science Teachers Association of Nigeria (STAN) may be sensitised on the need to organise special workshops and

conferences on TPACK as part of biology teachers' professional development programme.

Science Teachers Association of Nigeria (STAN) may find this study very useful in bringing out areas where teachers training and re-training workshops and seminar could be organised. Federal and State Ministries of Education may find this research highly beneficial in identifying areas where an upgrade in the curriculum is needed. This will expose teachers in training and even in-service to the application of pedagogical content knowledge in teaching. It would also be a basis for educational researchers who will want to take on extended research in this area or related issues. Educational consultants will find this study beneficial in understanding the area to improve and develop their training programmes on and educational packages for teachers to include technology education and integration but not necessarily technology application.

The results of this study would propel researchers in the field of biology education to conduct more studies on biology teachers' TPACK and also, serve as useful literature material.

Clarification of Major Terms and Variables

The following terms and variables were operationally defined as used in this study:

Technological Knowledge (TK): the knowledge of the different forms of technologies, ranging from low-tech technology such as pencil and paper to digital technology such as the internet, digital video, and interactive whiteboard and many others that biology teachers use in the teaching process.

Content Knowledge (CK): the knowledge that a teacher has in biology concepts which he/she teaches. It covers the knowledge linked to a subject matter.

Pedagogical Knowledge (PK): is the knowledge biology teachers acquire to processes and practices of instruction, it comprises knowledge about the management of classroom and organisation; analysis of curriculum and planning; and overall learning of students in biology.

Technological Pedagogical Knowledge (TPK): the understanding of how various technology devices can be used in teaching biology, along with the assurance that using technology can change the way in which teachers improve their practices.

Technological Content Knowledge (TCK): the knowledge of how technology can create new representations and/or new learning scenarios for specific biology contents

Pedagogical Content Knowledge (PCK): the integration of both content and pedagogy with the goal of developing better teaching practices in the biology topics.

Technological Pedagogical Content Knowledge (TPACK): the knowledge needed by teachers for integrating technology into their teaching of biology concepts.

Assessment: an instance of making an observation on how teachers perform their teaching of biology through rating.

Curricular Knowledge: the accumulation of a step by step planned interaction of students and instructional content, material resources, and processes for evaluating the attainment of educational purpose.

Qualified Teacher: is a person who is certified with at least a bachelor degree in Biology and demonstrates competence in the teaching of biology concepts.

Less Qualified Teacher: This is a person who does not possess a minimum teaching requirement of B.Sc. Ed. to teach biology.

Experienced Teacher: a person who has skills or knowledge from the teaching of biology concepts for not less than ten years.

Moderately Experienced Teacher: a teacher who has skills or knowledge in the teaching of biology for not less than 5-10 years.

Less Experienced Teacher: a teacher who has experience in teaching biology for less than five years.

Teachers' Gender: this is an expression used to signify teachers' range of identities that not agrees to existing ideas of male and female.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

The review of related literature was discussed in this chapter under the following sub-headings:

- The Framework of the Study
- The Nature and Components of Technological Pedagogical Content Knowledge
- Models of Technological Pedagogical Content Knowledge and Teachers Instructional Applications of ICTs
- Empirical Studies on Measuring and Assessing Technological Pedagogical Content Knowledge
- Empirical Studies on Technological Pedagogical Content Knowledge and Gender
- Empirical Studies on Technological Pedagogical Content Knowledge and Teachers' Qualification
- Empirical Studies on Teachers Experience and Pedagogical Content Knowledge
- Appraisal of the Reviewed Literature

The Framework of the Study

Both the separate and combined use of TPACK inform the decisions of teachers during the choice and utilisation of curricular resources in addition to ICT-rich tools (Voogt, Fisser, ParejaRoblin, Tondeur, & van Braak, 2013). Specifically, the process of choosing and using resources requires the knowledge of relevant resources; knowledge of the features of relevant resources; and knowledge of how to use the resources effectively in practice.

Teachers require specific hardware and software knowledge that will enable them to make preference from which they may choose and utilise efficiently (technological knowledge) for peculiar domains in the curriculum (technological content knowledge). Understanding the characteristics of technology-rich learning resources is vital because it enables teachers to identify the qualities and produce special tools in respect of pedagogical (technological pedagogical) and domain-specific learning (technological content) goals.

It is very necessary for teachers to possess the knowledge of how to use technology-rich curricular resources to enable them to integrate ICT in pedagogically meaningful ways to accomplish learning in particular content

areas (technological pedagogical content knowledge). Jimoyiannis (2010) and Harris and Hofer (2011) justify clearly relating to the development of TPACK to subject domains. In their methodical review of literature on TPACK. Voogt, Fisser, Pareja Tondeur and Van Braak (2013) found a severe lack of research related to TPACK that makes close connections to specific subject domains.

Currently, in the literature, there are two dominant theoretical models of TPACK: the integrative model and the transformative model. The integrative model was projected by Mishra and Koehler (2006). It conceptualises TPACK as an integrative form of knowledge determined by the connections between content and pedagogy, content and technology, and pedagogy and technology. Angeli and Valanides (2009, 2015) proposed the transformative model (known as ICT-TPCK) which contains technology, pedagogy, and content as a unique form of knowledge.

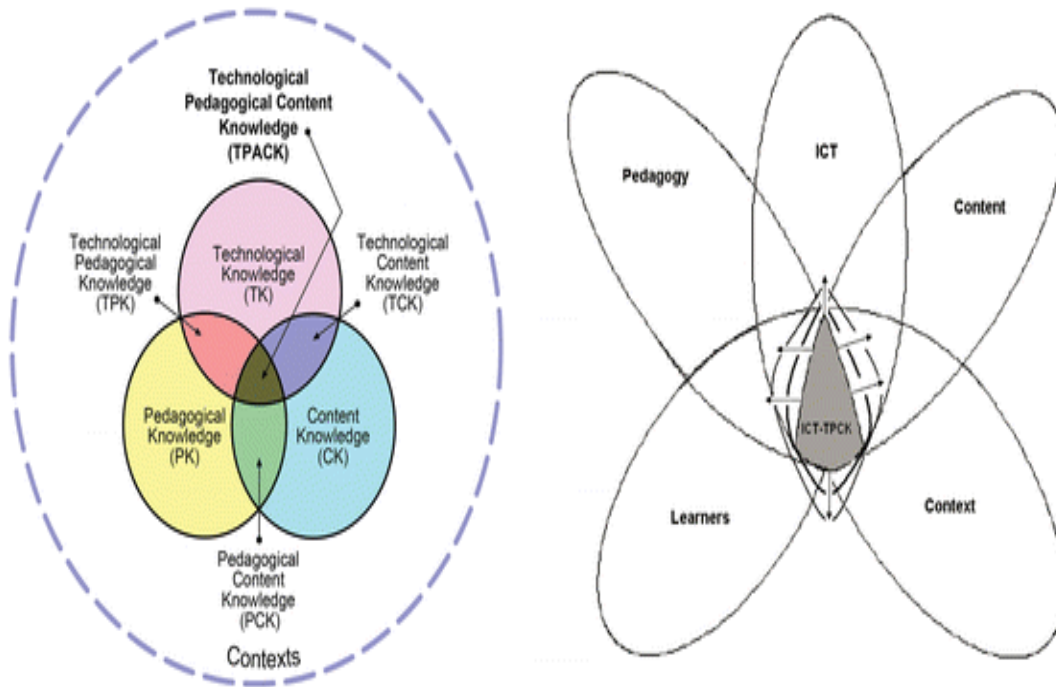


Figure 4. The TPACK framework

Angeli and Valanides (2009)

Studies have revealed that teachers still resist the integration of new technology into the classroom. There are many factors affecting the teachers' usage of new technology, Kathryn MacCallum, Lynn Jeffrey, and Kinshuk (2014) proposed the factors as the following:

1. Teachers' beliefs about the value of the new technology "usefulness" and the perceived effort required to learn to use the new technology "ease of use".
2. Teachers' skills to use and integrate digital technology into their instruction "digital literacy".

3. Self-efficacy of the teachers concerning their individual competent level and the attitude they portray in adopting technology.
4. ICT anxiety is considered as the tendency of a teacher to experience a level of uneasiness over his/her impending use of ICT.

These elements are vital in encouraging a teacher to make use of technology in classroom instruction. The success of any initiative to integrate ICT into classroom life depends strongly upon teachers' perceptions of technology use and its affection in their use of technology in instruction; guide teachers' decisions and actions they undertake in the classroom. For several decades, educational technology as a field has strived to search its theoretical base (Graham, 2011); developing theory for educational technology is hard because it demands a full understanding of complex relationships that are contextually confined. Likewise, cause and effect become difficult to study when teachers, classrooms, politics, and curriculum aims vary from one case to another (Mishra & Koehler, 2006).

According to Khaddage and Knezek (2013), educational technology researchers around the globe have developed an interest in technology integration related issues, Therefore, they are increasing the use of the technological pedagogical content knowledge (TPACK) framework in the

recent studies (Graham, 2011). It is important to understand that teaching is a highly complicated exercise that brings on several forms of knowledge. Tracing to history, teacher education has centered mainly on the content knowledge of the teacher. In recent times, however, teacher education has shifted its focus to general pedagogical classroom practices independent of subject matter and this is mostly at the expense of content knowledge.

This lead teacher education to stress one or the other forms of knowledge, concentrating on knowledge of content (C) or knowledge of pedagogy (P) (Mishra & Koehler, 2006). Shulman's (1986, 1987) conception of pedagogical content knowledge (PCK) was the TPACK framework originated from by clearly integrating the component of technological knowledge into the model (Graham, 2011). A venn diagram with three overlapping circles is mostly used to represent the TPACK framework with each representing individual form of knowledge of the teacher. Previously, TPACK framework has become a familiar lens for studying teachers' knowledge and has been used in several recent studies on teachers (for example: Ozgun-Koca, Meagher, & Todd, (2010); Syh-Jong and Kuan-Chung (2010); Han, Eom, & Shin, (2013).

Both frameworks are brought to light by a venn diagram to draw attention to how the TPACK can be disjointed, then, how the intersections

connect the different knowledge areas. The core of the venn diagram where the three knowledge components meet is TPACK and ICT-TPCK, respectively, it presents TPACK as a cohesive whole, working and intermediating together (Fig. 4). Imperatively, the teacher is able to understand and negotiate the complex relationships between the three knowledge areas. The TPACK framework clarifies the complexity of teaching with ICT (Hasniza, 2014). Wang, Jin and Schmidt (2018). Submitted that TPACK is a vital framework for thinking, analysing and evaluating what teacher ought to understand to be able to integrate technology into his process of instruction and how this knowledge can be developed.

They further argued that measuring teaching knowledge could potentially have an impact on the type of training and professional development experiences that are designed for pre-service and in-service teachers. TPACK is a very exceptional kind of knowledge that agrees with integration of content-based technology into the teaching process. It comprises multiple intersections of teachers' knowledge of curriculum content, general pedagogies, technologies, and contextually based on learning (Harris & Hofer, 2011). Many researchers recognise the broad appeal and potential of the TPACK model (Graham, 2011). Pedagogical

content knowledge is of special interest because it shows the distinctive bodies of knowledge for teaching. It shows how content and pedagogy are married together favourably to the knowledge of how specific concepts, problems, or issues are arranged, represented, and adapted to learners' abilities and diverse interests and presented for instruction.

The framework for TPACK produces active and whippy approaches for teachers to grow and therefore, enhance the process of instruction (Junnaina & Hazri, 2014). According to Hasniza (2014), using the TPACK framework can constitute an added value since the structure of this particular model can be used to:

- simplify topics that are not easy for teachers to understand.
- help teachers to increase their competencies by being able to create good educational materials and useful instructional material designs that can utilize both pedagogical knowledge and ICT.
- allow teachers to develop strategies that will be effective for students' learning.
- enable teachers to effectively integrate the use of ICT in designing content.
- increase teachers' skills not only in the use of effective technology when designing course-related content and pedagogy

- help teachers to design and implement useful content-based lectures using a wide-range of ICT (such as design tools in Web 2. 0).
- enable teachers to shift their focus from the use of social networking tools to re-designing the main uses of social networking tools.

Several quantitative studies have been attributed to enhancing various instruments to examine teachers' TPACK, having established the significance of the TPACK framework. More so, it is imperative for a great deal of work to be done in improving the validity of the TPACK instruments for many reasons. First, more research is required to address some methodological issues harmful to the validity of the TPACK instruments, such as lack of subject-specificity in TPACK, ambiguity of words of items, indecipherable definitions and examples of the TPACK components, small number of items per construct (example, fewer than three items) and small sample size (for example, Cox & Graham, 2009; Chai, Koh, & Tsai, 2016). One of the major barriers to effective technology integration has been identified as teachers' knowledge (Mishra & Koehler, 2006; Hew & Brush, 2007). The issue of what teachers required to know about technology for effective teaching has been the core of strained debate recently (ISTE, 2002; Zhao, 2003).

It is obvious that the mere introduction of technology to the classrooms will not bring desirable results as it is what people do with the machine, not the machine itself that makes a difference (Mehan, 1989). Similarly, Koehler and Mishra (2005) observed that the adoption of new technologies does not assure successful teaching and learning experiences. They stress the relevance of focusing on describing what teachers need to know about the role of technology to be productive in the classroom (Mishra & Koehler, 2006). In other words, the construction of a knowledge base for teachers is crucial for effective integration of technology into their teaching and for expecting teachers to add technology education to the learning areas that they are required to teach.

One of the key aspects of the TPACK frame is the teacher education (Maor & Roberts, 2011). Hofer and Grandgenett (2012) mentioned that in teacher education programmes, various courses and field experiences assist pre-service teachers (PTs) and develop their TPACK. Several studies have been carried out among the PTs of different subject matters such as science, mathematics or social studies to examine how their various course affects their development of TPACK. Cavin (2007) examined the development of TPACK in six PTs from mathematics and science education majors as they participated in a microteaching lesson study (MLS) process. During the

MLS, the instructor modeled technology-enhanced instruction with PTs as students; PTs kept written reflections on each modeled instruction; and PTs developed and micro taught a content area lesson plan by integrating technology.

The results of the data coming from audio recordings of group meetings, video recordings of microteaching, interviews and PTs' written reflections showed that they began to consider the connection between content, pedagogy, and technology, showing a change in their TPACK and modify their plans in teaching so that the effectiveness of the lesson can be increased (Cavirn, 2007). In a more recent study, Mahdum (2015) worked with PTs to assist them to develop their TPACK through a designed project which involved using interactive whiteboards (IWBs). There were 74 participants enrolled in an educational technology course.

The researchers built TPACK-Developing Instructional Model that depend on the following three phases: (1) faculty modeling of a new ICT tool; (2) building technical proficiency and pedagogical modeling; (3) and pedagogical application. Data came from pre- and post-surveys to examine PTs' confidence level and attitudes towards IWB and PTs' end-of-class reflections use. It was revealed from the data analysis that PTs improved their firmness in integrating IWBs into their instruction and their attitude

towards IWBs was highly positive throughout the study. The reflections of PTs revealed no significant focus on TPACK throughout the study, but while PTs stressed TK at the outset of the study, TPK became their focus when the study ended.

The outcome of the survey revealed significant growth in the TPACK of PTs throughout the study. PTs' lesson plans demonstrated adequate TPACK though the scores on the plans showed a slight decrease during the student teaching semester from the fall semester. Finally, PTs' reflections displayed that PTs mostly focused on their TPK for technology integration. The study sought to contribute to the literature on how the TPACK framework can guide the development of PTs' effective technology integration skills. Specifically, the aim of the present mixed methods study was twofold: firstly, to examine the TPACK development of Turkish PTs of English as they took part in a study explicitly focusing on the framework of TPACK and designed following Learning Technology by Design approach; and secondly, to examine how this knowledge was reflected and presented in PTs' lesson plans.

Technology changes and develops rapidly. This situation demands the determination of its effect on education and the beliefs of the teacher (Margerum-Leys & Marx, 2002). In their knowledge of teacher conceptual

framework, Mishra and Koehler (2006) extended Shulman's (1986) pedagogical content knowledge model by joining technology knowledge. As shown in figure 5, the final framework comprises three areas of knowledge (technology, pedagogy, and content) and their intersections.

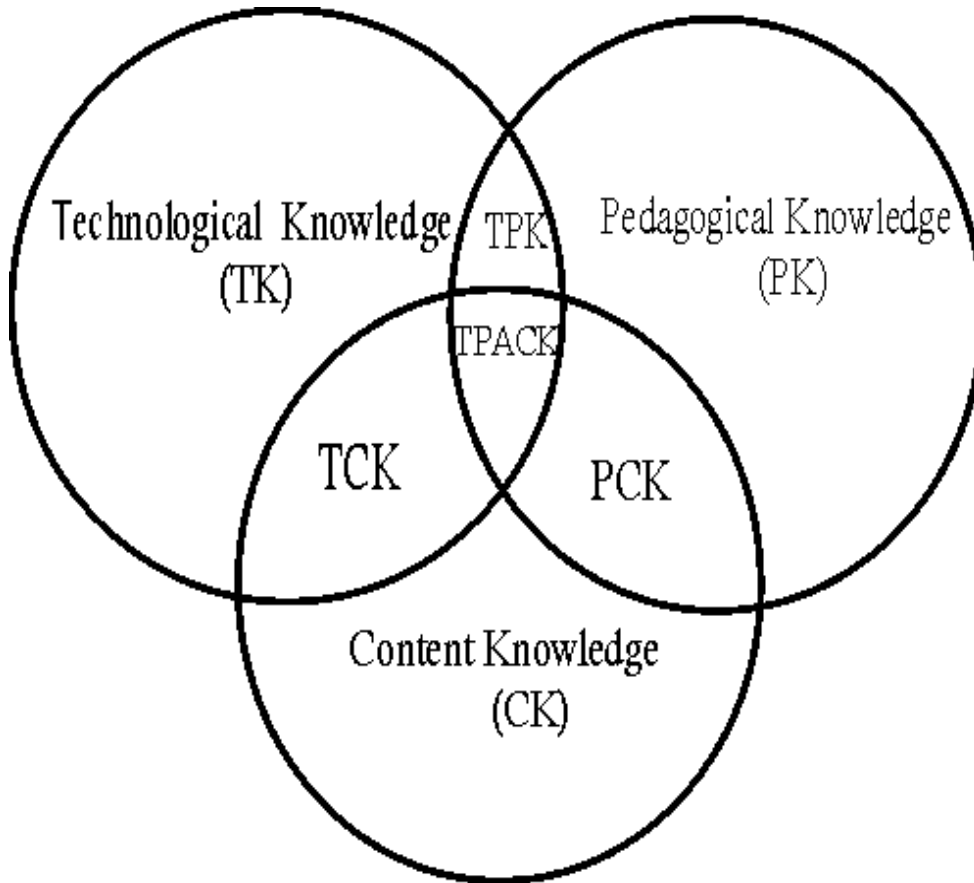


Figure 5: Relationships among Technology, Pedagogy, and Content Knowledge Mishra and Koehler (2006)

In the model, the three major forms of knowledge are technology knowledge (TK), pedagogy knowledge (PK), and content knowledge (CK). The three knowledge constructs are explained below.

Technology Knowledge (TK): includes knowledge of all instructional materials ranging from blackboard to advanced technologies (Koehler, Mishra, & Yahya 2007). Generally, it refers to a variety of technologies used in learning environments (Margerum-Leys & Marx, 2002).

Pedagogy Knowledge (PK): includes teaching strategies for addressing individual learning requirement and mode of presenting the subject matter (Kanuka, 2006). This is otherwise, known as practice, procedure, or methods necessary for teaching and learning (Koehler et al., 2007). For instance, this knowledge comprises general classroom management strategies, course planning, and student assessment.

Content Knowledge (CK): a form of knowledge a teacher acquires about a particular concept that he teaches (Koehler et al., 2007). Therefore, the question what will be taught is answered (Margerum-Leys & Marx, 2002). It includes terms, theories, ideas, constructs, and applications peculiar to a content area such as mathematics, biology and history (Shulman, 1986). Lack of this knowledge by an individual may lead to misconceptions or misleading facts towards the area (Koehler & Mishra, 2009). More so, the mode comprises three forms of knowledge: technological pedagogical knowledge (TPK), technological content knowledge (TCK), and pedagogical content knowledge (PCK).

Technological Pedagogical Knowledge (TPK): an understanding of general pedagogical strategies employed in the use of technology (Margerum-Leys & Marx, 2002). It involves the knowledge of how the application of certain technologies can change the process of teaching and learning. It consists of the integration of technological tools and equipment with relevant methods of instruction and strategies by realizing their forces and restrictions. Most common computer software materials are educationally inclined (Koehler & Mishra, 2009). Instead, they are business, entertainment, communication, and social interaction oriented.

Thus, it is imperative for teachers to go beyond the general uses of these technologies and integrate them into classroom instruction. Koehler and Mishra (2008) projected the attributes of teachers' ICT skills in teaching and learning across various dimensions. In designing a model that will explain the effectiveness of adopting educational technology, the need to integrate three basic types of teachers' knowledge, specifically, technological knowledge, content knowledge, and pedagogical knowledge is called for by the teacher. The outcome generated among these three elements is said to produce different areas each representing precise skills. Sitting at the centre of all these intersections, the concept of TPCK appears at the utmost level of skill deployment

Technological Content Knowledge (TCK): helps teachers imagine situations where technology can be effectively integrated into their teaching (Margerum-Leys & Marx, 2002). For example, significant developments can be achieved by computer simulations in physics and math areas (Koehler & Mishra, 2009). This form of knowledge indicates that technology and content affect and support each other. Hence, teachers must have an idea about their content areas as well as the use of certain technologies that enhance students' learning.

Pedagogical Content Knowledge (PCK): describes the knowledge of teaching relevant to a certain subject area (Harris et al., 2007). It is necessary to convert content into teaching, such that a subject is being presented in different ways or adapting instructional materials, based on student needs and alternative ideas. This sustains the relationship between curriculum, assessment, and pedagogy. Nevertheless, being the focal point of the model, TPACK intersects the three knowledge bases.

Technological Pedagogical Content Knowledge (TPACK): a content-based educational technologies which must be pedagogically sound (Ferdig, 2006). Mishra and Koehler (2006) specially stressed the interactions between the three elements. Teaching successfully with technology involves many stages that need understanding the representation and formulation of

concepts when technology is applied; the teaching methods that utilise technologies in constructively to teach content; knowledge of what makes concepts tasking or easy to learn and how technology can be used to tackle these issues; knowledge of what student already knew; and a typical knowledge of how the use of technologies can enhance existing knowledge and to develop new or enhance old epistemologies (Koehler et al., 2007).

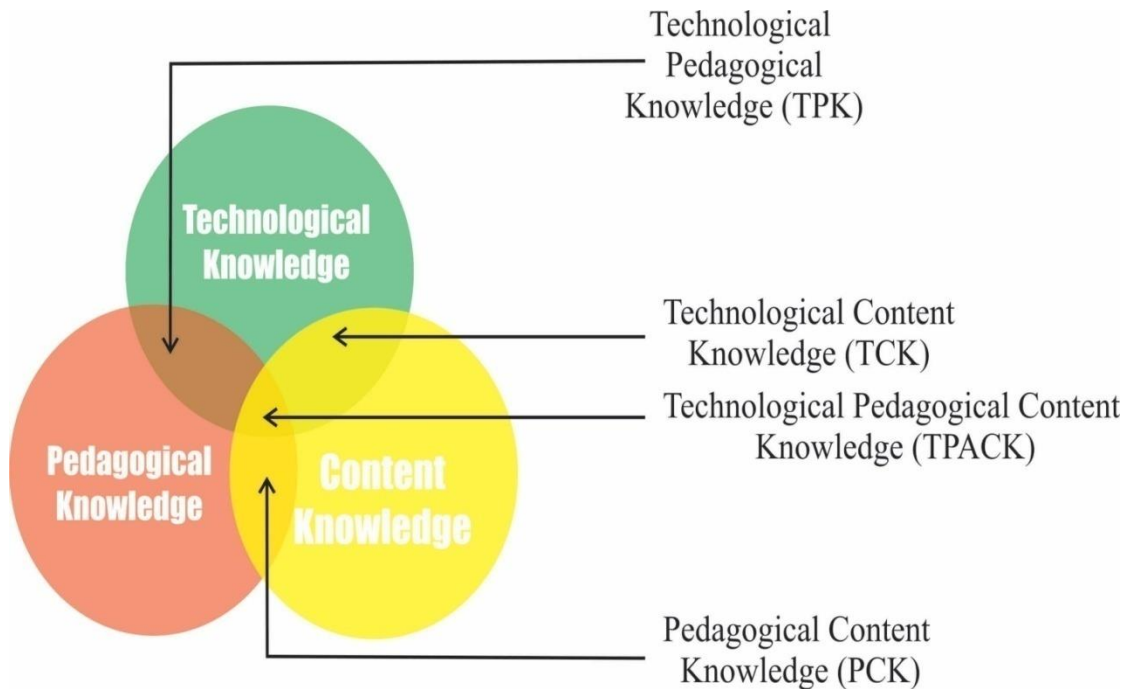


Figure 6. Conceptual Model of the Elements of TPACK Developed from Literature Read

TPACK is suggested as effective teaching with technology. Angeli and Valanides (2009) submitted that TPACK has been portrayed as well-fixed, complicated, multifarious, integrative and transformative. Enhancing

and implementing successful teaching demands an understanding of how technology is related to pedagogy and content (Koehler et al., 2007). Unless a teacher sees the use of technology as an essential part of the learning process, it will remain a peripheral auxiliary to his or her teaching. True integration can only be understood as the intersection of several types of teacher knowledge (Pierson, 2001).

The key components of TPACK are content knowledge (CK), pedagogical knowledge (PK), and technological knowledge (TK). The interrelationship among these three knowledge categories leads to pedagogical content knowledge (PCK), technological content knowledge (TCK), technological content knowledge (TPK) and the TPACK. As a form of knowledge, TPACK has been described as well-fixed, complex, multifaceted, integrative and/or transformative (Manfra & Hammond, 2008; Angeli & Valanides, 2009; Harris et al., 2009; Koehler & Mishra, 2009). As a framework, it has been applied to separate ICT-integrated lessons, teachers work with ICT, to design teacher education curriculum, to design use of ICT in the classroom and to structure literature review relating to ICT or educational technology (Polly, McGee & Martin 2010). In essence, this is a strong framework which has many potentials to bring about the application in the research and development related to the use of ICT in education.

Figure 7: Shows the diagrammatic depiction of the relations among the seven constructs.

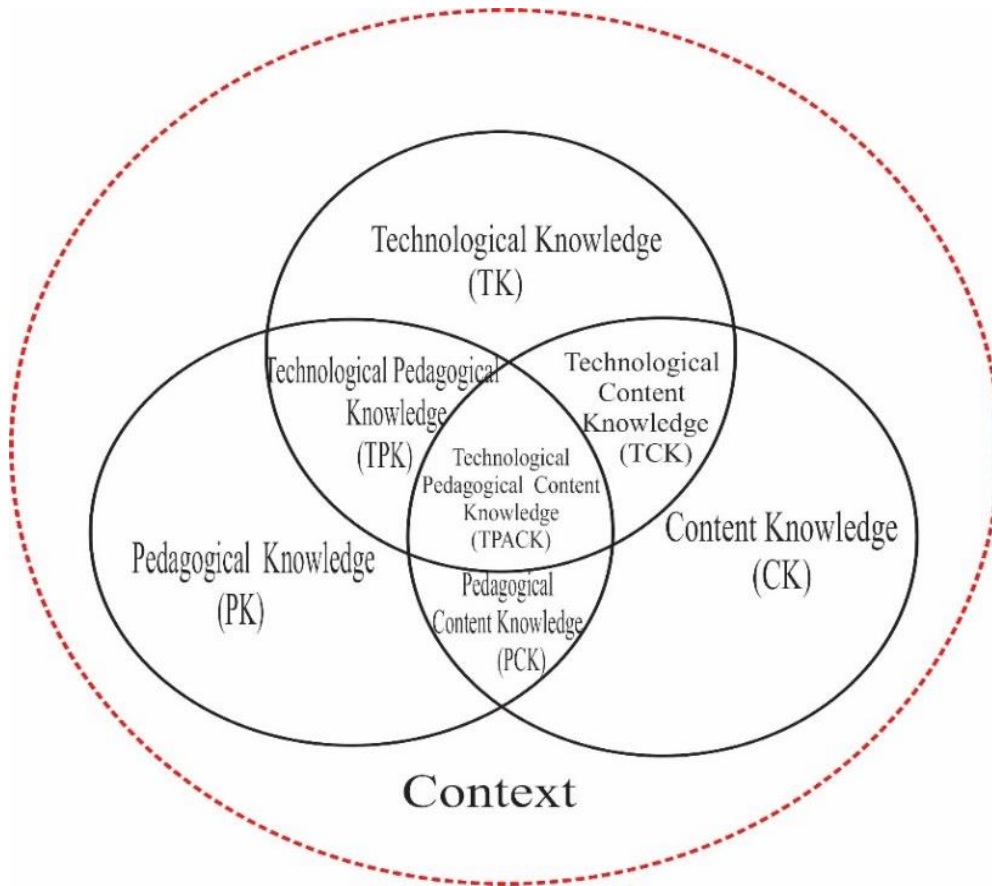


Figure 7. TPACK Framework

(Koehler & Mishra 2009)

Confusion about TPACK constructs

Due to the overlapping nature of the framework, the growing concerns about the confusion among the constructs have been enlisted by researchers such as Cox and Graham (2009) and researchers interested in measuring

teachers' self-assessment perception of TPACK (Archambault & Barnett, 2010; Lee & Tsai, 2010). Cox and Graham (2009) identified the idea of independence when the forms of knowledge are placed into categories. When considering issues regarding TPK such as the principles of the application of an online forum for discussion, matter subject (CK) should not be discussed. Their suggestion seems very adequate in enhancing researchers to specify the constructs. Upon their suggestions, some free use of terms in the literature can be identified.

Other components that need to be illuminated include TK and TCK. Since it is important to identify some basic techniques in operating some of the traditional devices as technological knowledge such as knowledge of operating overhead projectors and many others (Schmidt et al., 2009), in the context of TPACK research, it would only serve to distract the focus. Restricting the discussion of TK to skills and knowledge in using technologies associated with computers would be more appropriate and meaningful (Cox & Graham, 2009). Synthesizing from the literature reviewed, (Cox & Graham, 2009; Koehler & Mishra, 2009; Mishra & Koehler, 2006), Table 2 below attempts to provide the concise definition of each construct cohabiting with some examples.

Table 2

Definition and Examples of TPACK Dimensions

TPACK Constructs	Definition	Example
TK	Knowledge about how to use ICT hardware and software and associated peripherals	Knowledge about how to use Web 2.0 tools (example, Wiki, Blogs, Facebook)
PK	Knowledge about the students' learning, instructional methods, different educational theories, and learning assessment to teach a subject matter without references towards content	Knowledge about how to use problem based learning (PBL) in teaching
CK	Knowledge of the subject matter without consideration about teaching the subject matter	Knowledge about Science or Mathematics subjects
PCK	Knowledge of representing content knowledge and adopting pedagogical strategies to make the specific content/topic more understandable for the learners	Knowledge of using analogies to teach electricity (see Shulman, 1986)
TPK	Knowledge of the existence and specifications of various technologies to enable teaching approaches without reference towards subject matter	The notion of Webquest, KBC, using ICT as cognitive tools, computer supported collaborative learning
TCK	Knowledge about how to use technology to represent/research and create the content in different ways without consideration about teaching	Knowledge about online dictionary, SPSS, subject specific ICT tools example. Geometer's Sketchpad, topic specific Simulation
TPACK	Knowledge of using various technologies to teach and/represent and/ facilitate knowledge creation of specific subject content	Knowledge about how to use Wiki as an communication tool to enhance collaborative learning in social science

Nature and Components of Technological Pedagogical Content Knowledge

While ICT is gaining more ground in schools, and children are increasingly growing up with ICT, teachers' attitude to ICT utilisation in instruction has been a major concern for the stakeholders (Jimoyiannis, 2010; Polly, et al, 2010). One of the most challenging task for many teachers

in teaching and learning process is the integration of ICT into their practice (Shafer, 2008; So& Kim, 2009). Teachers feel ill-prepared for subject-specific use of ICT and lack a robust theoretical framework (Brush & Saye, 2009; Kramarski & Michalsky, 2010). A framework has been designed to guide studies relating to teachers' use of ICT as the technological pedagogical content knowledge (TPACK) in solving problem.

According to Kramarski and Michalsky (2010), TPACK reflects better the interdependence of the three contributing knowledge domains (example, content knowledge, pedagogical knowledge, and technology knowledge), and it was easier to communicate than TPCK (Mishra, personal communication). In the study, the researcher used both acronyms interchangeably because the change in terminology was not adopted by everyone. Since the introduction in 2005, the notion of TPACK has been greatly extended across the fields of professional development and technology integration. The increasing number of studies that refers to TPACK calls for a logical combination of both the evolution of TPACK as a concept and its practical applications.

These representational and metaphorical connections are not superficial. Most of the times they are responsible for the fundamental changes experience in the field of study. Having realised the importance of

technology in teaching and learning, it is imperative to developing appropriate technological tools for the purpose of education. It may then be appropriate to introduce the choice of technological affordance and constrains the types of content ideas that can be put to perspective. Likewise, certain content decisions can limit the types of technologies that can be used. Technology can limit the types of possible representations, but also can afford the construction of newer and more varied representations. Furthermore, technological tools can provide more fluidity in navigating across these representations (Alazam, et. al, 2013).

TCK is an understanding of the way in which technology and content influence and ravish each other. Teachers are expected to be well furnished with information about than the subject matter they intend to teach; including knowledge of logical presentation of the subject matter that is likely to change when some technologies are applied. There is a need for the teachers to understand which specific technologies are best suited for addressing subject-matter learning in their domains and how the content determines or perhaps even alters the technology or vice versa (Alazam, et. al, 2013).

Technological Pedagogical Knowledge is the knowledge of adopting different methods of teaching using technology (Koehler & Mishra, 2008;

Mishra & Koehler, 2008; Harris, Mishra & Koehler, 2009). It is an understanding of how the teaching and learning process can change when specific technologies are used in specific ways. It involves understanding of the various challenges associated with different technological tools relating to developing adequate pedagogical models. To build TPK, a deeper understanding of the constraints and affordances of technologies and the disciplinary contexts within which they function is needed (Wetzel, Buss, Foulger, & Lindsey, 2014). For example, understanding how whiteboards may be used in classrooms by teachers is a factor to be considered.

Because a whiteboard is typically immobile, noticeable to many, and easily editable, its uses in classrooms are presupposed. Thus, the whiteboard is ordinarily positioned at the front of the classroom and is controlled by the teacher (Wetzel, et.al, 2014). This location determines a particular physical arrangement in the classroom by deciding the placement of tables and chairs and framing the nature of student-teacher interaction since students can often make use of it only when called upon by the teacher. However, it would be wrong to say that there is just a way in which whiteboards can be utilised. One has only to compare the use of a whiteboard in a brainstorming meeting in an advertising agency setting or in capturing and saving notes written on a graphics tablet connected to the whiteboard to see a rather different use of

this technology. Not a single person will have access to the whiteboard in such a situation, any other person in the group can adopt it and it can become a major point of discussion and meanings are giving to it. The most important part of the understanding of TPK is getting to realise the affordances of technology and how they can be categorised differently based on the changes in purposes and context.

Since majority of the common software packages are not suited for educational purpose, TPK becomes more crucial. The application packages such as the Microsoft Office (Word, PowerPoint, Excel, Entourage, and MSN Messenger) are designed specifically for business oriented environments. Web-based technologies such as blogs or podcasts are for entertainment, communication, and social networking. TPK requires a prospective, creative, and ready to entertain new ideas in seeking technology use, not for its own sake but for the sake of developing students' learning and understanding (Wetzel, et.al, 2014).

Polly, et al., (2010) reiterated that TPACK is a rising form of knowledge that extends beyond all three “core” components (content, pedagogy, and technology). The knowledge of how to apply technology in different subjects and instructional approaches is called TPACK.

It is a form of knowledge that evolve with the synergy of content, pedagogy, and technology knowledge. Identifying meaningful skillful teaching with technology, understanding the three component is quite different from the knowledge of TPACK. Instead, TPACK forms the basis for teaching effectively using technology, requesting to know how concept with the use of technologies are represented; the constructive methods of teaching content with technologies using pedagogical techniques; how technology can address some problems students face; knowledge of what the students are already aware of and theories of epistemology; and knowledge of how existing knowledge can be built to enhance new knowledge or sustain the old ones with the use of technologies (Polly et.al, 2010).

By constantly integrating the knowledge of technology, pedagogy, and content, professional teachers apply TPACK any time they teach. Each situation presents to the teachers a peculiar combination of these three components, and accordingly, there is no single technological solution that applies to every teacher, every course, or every view of teaching. Rather, the ability of the teacher to be able to navigate flexibly between the confines of the three elements (content, pedagogy, and technology) in specific terms and the logical synergy among the three. Not considering the logicity

embedded in each of the components but as a unit component or as the complexity of the relationship among the components can lead to failure.

Thus, teachers need to develop volubility and cognitive flexibility not just in each of the specific domains (T, P, and C), but also in a way in which these domains and contextual parameters connect to one another so that they can construct efficient solutions. This is the kind of deep, flexible, skilled, and nuanced understanding of teaching with technology, engaged in considering TPACK as a professional knowledge construct (Polly et.al, 2010). It is rather complicated to see the three components (technology, pedagogy, and content) as knowledge that is interconnected. As mentioned earlier, separating the three is a very logical process and may not be easy to do in instruction. Applying technology in teaching and learning process can be viewed in different transactional relationship between the three components in the model; changing any of the factors will affect the other two if not compensated. (Mishra & Koehler, 2006).

The compensation to be made if any of the three components is changed is clearer whenever using a new educational technology suddenly pushes teachers to confront basic educational issues and reconstruct the dynamic equilibrium among all the three elements. This approach changes the conventional perspective that pedagogical goals and technologies are

derived from content area curricula. Things are seldom that simple, especially when newer technologies are employed. The introduction of the Internet, for example, specifically, the rise of online learning is an example of the arrival of a technology that compelled educators to think about core pedagogical issues, ranging from how to represent content on the Web to ways of connecting students with subject matter and with one another (Peruski & Mishra, 2004).

Integrating technology in the teaching process requires some logic to be able to do well. The TPACK framework proposes that content, pedagogy, technology, and teaching/learning contexts have impacts to play individually and collectively. Successful teaching with technology demands unceasingly creating, maintaining, and re-establishing a dynamic equilibrium among all components. It is deserving to observe that a range of factors influences how this equilibrium is attained (Mishra & Koehler, 2006).

Models of Technological Pedagogical Content Knowledge and Teachers Instructional Applications of ICTs

To blend with the 21st-century teaching, teachers are saddled with the responsibility of keeping themselves abreast of the changes associated with their respective discipline. With the advancement in technology, changes in the learning environment, content, and integrating ICT into classroom teaching and learning continue to pose challenges teachers (So & Kim, 2009). Along with digital technologies, technical competencies have also surfaced. These require having the understanding and skills in using technologies which will provide comprehensive learning. The teachers are not well furnished with the necessary resources to teach with their respective concept using, and has no framework (Kramarski & Michalsky, 2010). The TPACK framework solves the problem of placing too much relevance on the knowledge of technology in several ICT courses that are offered separately from teachers' subject matter, the nature of knowledge and inquiry in different fields becomes absolutely important for teachers to understand (Papanikolaou, 2014).

Technological Pedagogical Content Knowledge (TPACK) most recently is recognised among many educational technologists as pedagogical uses of technology which are strongly influenced by the content domains in which they are placed. For instance, the teachers' knowledge required to effectively integrate technology in a science classroom may differ from that

which is required for a social studies teacher. TPACK framework synergises the three basic forms of knowledge: Content (CK), Pedagogy (PK), and Technology (TK) (Koehler & Mishra, 2005). Based on the findings of Papanikolaou (2014) who opined that blended programmes can help teachers understand better and apply technology into their classrooms and, to a lesser extent, adapt exemplary materials to their own settings, also Kazua (2014) asserted that teachers possess high levels of content, pedagogical and technological knowledge perceptions and also, they have a high level of perceptions for that they realize the interaction of this knowledge in the best way.

It is also known that teachers know the type of knowledge they should have together with technology use in education and they can develop this knowledge. Lee (2010) suggested that a multidisciplinary team with braille knowledge, educational technology knowledge, as well as systems development knowledge contributed to the different aspects of content, pedagogy, and technology that framed the system, Alazzam et. al, (2012) observed that the major source of concern for many teachers remain the ability to integrate ICT into classroom teaching and learning. Furthermore, inferred that Jimoyiannis (2010) the development of teachers' TPACK requires continuous and genuine learning experiences that open

opportunities for teaching in classroom situations, and then reflection and feedback. Teachers' TPACK development should extend beyond training programmes and should be an essential part of in-service teacher professional development. All the studies have yielded positive outcomes in developing teachers' ability to integrate ICT into instruction and be informed of ways in which TPACK could pilot the effort of educators in managing the challenges of teaching and learning that are encountered in a constantly dynamic technology.

However, TPACK can still be used to fill many gaps which can enhance a greater change in education. Specifically, the studies of Lee (2010) and Jimoyiannis (2010) assessed the teachers' basic ICT knowledge and skills with the assumption that any teacher of any subject will need to acquire it. Earlier studies have indicated the relevance of ICT knowledge as a critical factor among teachers' ICT readiness to integrate ICT into classroom teaching in their conceptual framework for teacher knowledge. Integrating ICT into teaching and learning can appear in several folds such as information and computer networks, digital content, internet sites, multimedia, mobile technologies, multi-touch collaborative software, multi-users virtual environment and several others.

To integrate ICT means to teach with ICT in classroom. To successfully execute this, it is required that the knowledge of representation and formulation of concepts with the use of technologies pedagogical skills that adequately use technologies in teaching subject are important accordance with the intersection of the three basic knowledge (Mishra & Koehler, 2006). The framework for TPACK suggested seven separate classes of teachers' knowledge. Technological Pedagogical Content Knowledge (TPACK) is at the core of the model, and it is the basis of effective teaching with technology, representing the use of technology to support content-specific pedagogical strategies (for example the use of technology to support science inquiry in the classroom).

Technological Pedagogical Content Knowledge (TPACK)

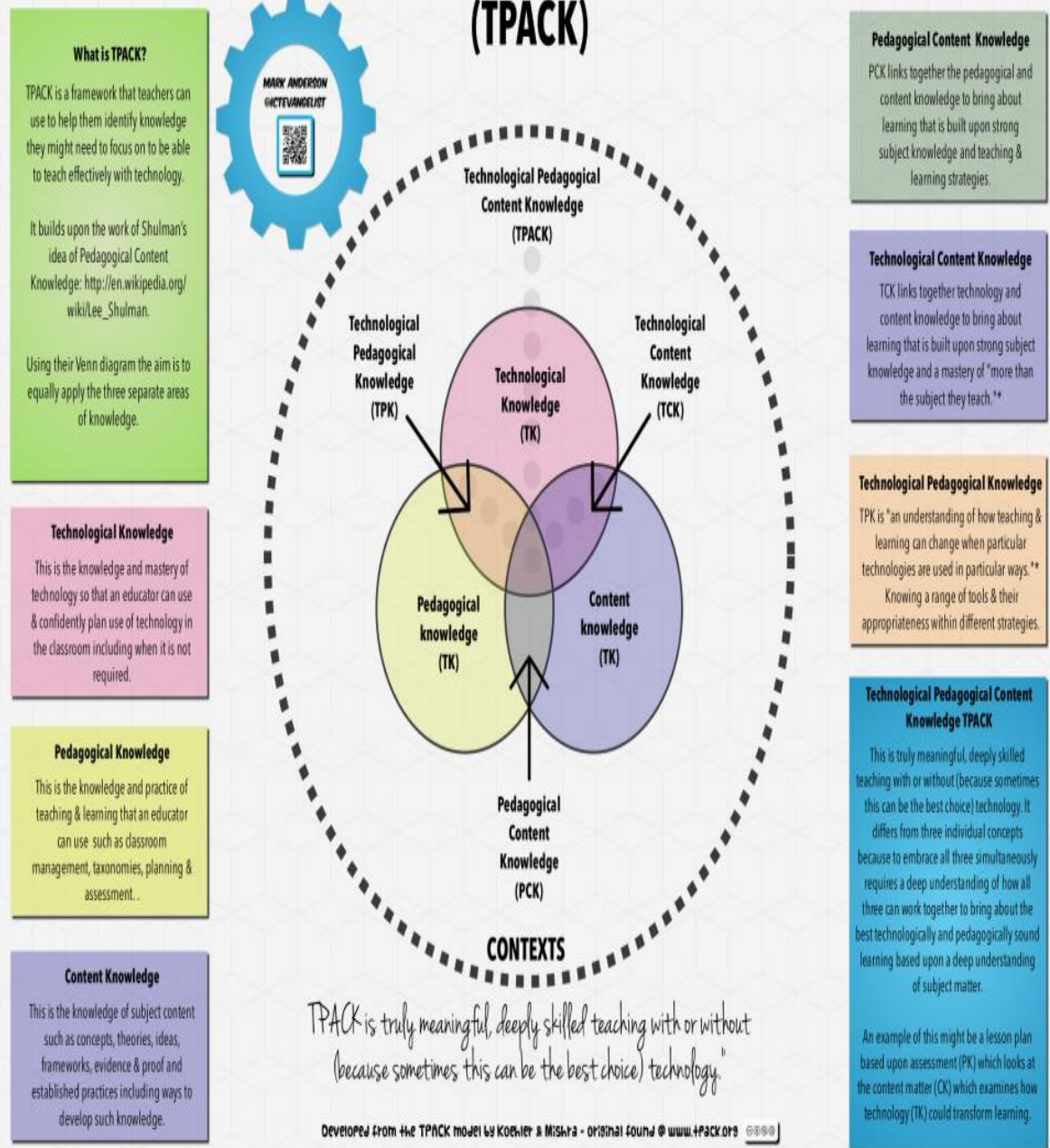


Figure 8: TPACK Model

Mishra and Koehler (2009)

Within the TPACK model, there are 7 different divisions, each of which is represented in this diagram. Thinking about the first three elements of Technology, Pedagogy, and Content as separate elements will give one the framework for thinking about how the different elements can be merged.

Technology Knowledge is the Knowledge about particular ways of reasoning and working with technological, devices, and resources and working with technology. Technology can suit all technology tools and resources. This includes understanding information technology generally enough to apply it productively at work and in everyday life, being able to recognize when information technology can help or obstruct the achievement of a goal, and being able to adapt continually to changes in information technology (Koehler & Mishra, 2009).

Pedagogical Knowledge. Pedagogical Knowledge is, according to Koehler and Mishra, (2009). Teachers' intense knowledge about the processes and practices or methods of teaching and learning. It comprises several factors among them are general educational purposes, values, and aims. This form of general knowledge is put upon the understanding of how students learn, general classroom management skills, lesson planning, and student assessment. (Koehler & Mishra, 2009).

Content Knowledge. Koehler and Mishra (2009) observed that it is the Teachers' knowledge about the subject matter to be learnt or taught. The content to be taught in middle school science or history differs from the content to be covered in an undergraduate course of art appreciation or a graduate seminar on astrophysics. Shulman (1986) observed that, it is a form of knowledge that represents the knowledge of concepts, theories, ideas, organisational frameworks, knowledge of evidence and proof, as well as establish practices and approaches toward developing such knowledge. (Koehler & Mishra, 2009). The TPACK model then is one which takes these three elements of Technological, Pedagogical and Content Knowledge and combine them to create PCK, TPK, TCK and finally, the holy grail of TPACK.

According to Mandinach and Cline, educators go through 4 stages of development with their use of technology (2012):

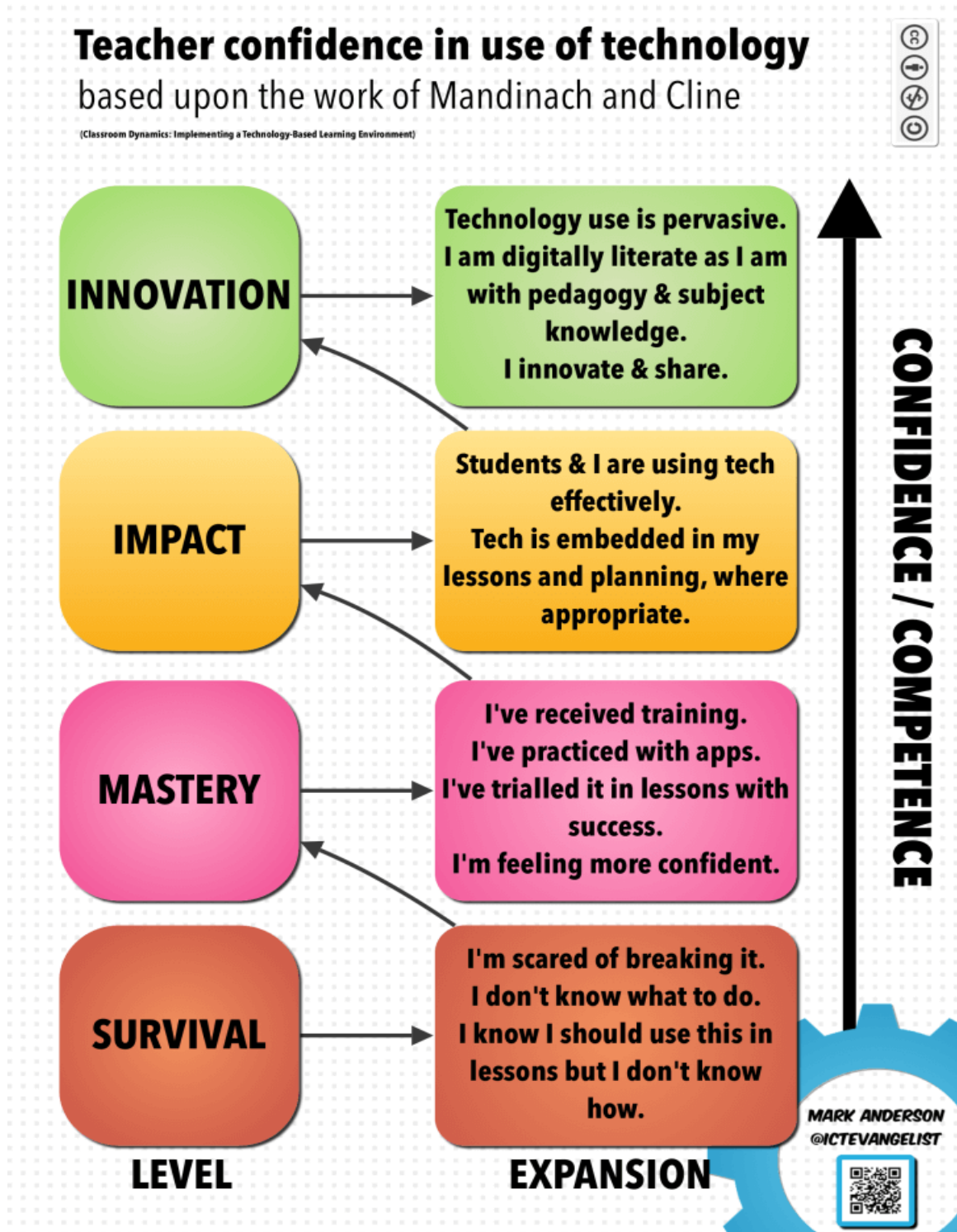


Figure 9. Teacher Confidence in the Use of Technology

Mandinach and Cline (2012)

When it comes to the use of technology as stakeholders in the technology world one needs to be very mindful of the responsibility to students and staff. Strategic planning and building in training for staff are critical if one wants transformational learning happening. Several forms of technology can be applied to sustain and improve learning. This Ranges from digital moviemaking, video content to laptop computing and handheld technologies which have all been utilised in classrooms. Likewise, there is an emergence of new use of technology such as podcasting (Clare, Dharamshi & Menna, 2019). The range of technologies available in present day classrooms are from simple tool-based applications (such as word processors) to online repositories of scientific data. Others include primary historical documents, handheld computers, closed-circuit television channels, and two-way distance learning classrooms.

Prensky (2013) was of the view that learning can be achieved even on the cell phones that many now carry with them. Based on the findings of Lei and Zhao (2006), different technologies play different role in the learning of students. This jettison the idea of generalising the impact of technologies as if they were the same. It is important for researchers to know the kind of technologies that are being used in the classroom and their purposes. Two common differences could then be observed. Students can learn from

computers where technology is used basically as tutors and serve to increase their basic skills and knowledge. Moreover, they can be used to achieve various educational goals and could be a resource to enhance higher order thinking, creativity and research skills (Ringstaff & Kelley, 2002).

According to Murphy, Penuel, Means, Korbak, Whaley, (2001). TPACK is described as Discrete Educational Software (DES), Integrated Learning System (ILS), Computer-assisted Instruction (CAI), and Computer-based instruction (CBI) as a fundamental form of student learning. These software applications are also the most widely available applications of educational technology in schools today, along with word-processing software, and they enhance classroom teaching for more than 20 years (Becker, Ravity & Wong, 1999). Murphy et al., (2001) explains that teachers use DES not only to supplement instruction, as in the past, but to introduce topics, provide the means for self-study, and offer opportunities to learn concepts otherwise inaccessible to students.

This shift in a pattern which has been driven by the glut of new information and communication devices now increasingly available to students in schools and at homes. These individual devices provide new affordances to teachers and students alike for improving student performance and for meeting the 21st-century skills demand (Zhang, 2005).

It should be noted at this juncture that there appears to be three main approaches to ICT taken by teachers according to (UNESCO, 2004). These are Integrated approach in planning ICT use within the subject to develop special concepts and improve students' achievement. This involves a careful and critical review of the curriculum area, selecting adequate ICT resource which will add to the aims and objectives of the curriculum and scheme of work, and then integrating that use in relevant lessons.

Another approach is enhancement approach: This is the improvement of the existing topic through some aspect of the lessons and tasks which is based on planning the use of an ICT resource. For example, connecting a computer system to a projector for presenting a theory about a topic. In this approach, the teacher plans to complement the lesson with an innovative method of presentation to enhance class discussion and the visualisation of problems. Complementary approach is another approach: It is using an ICT resource to enhance students' learning. For example, by allowing them to improve their class work by taking notes on the computer, or by sending homework by email to the teacher from home, or by word processing their homework. All the three procedures can enhance accomplishment. In the integrated approach, students' learning is enhanced because they are faced with challenges to their existing knowledge and given a deeper

understanding of the subject being studied. The enhancement approach could improve students' learning through presenting knowledge in new ways, promoting debates among students, and inciting them to devise their own explanations.

The complementary approach draws on the concept that learning can be aggravated by reducing the routine and insistent aspects of project such as writing essays and homework by hand, demising the learner to emphasis on more contending and subject-focused tasks (UNESCO, 2004). These different types of use require the teacher to have extensive knowledge of ICT and to be able to fit its use either into their existing pedagogy or to stretch their pedagogical knowledge so they can accommodate ICT effectively in their teaching.

Empirical Studies on Measuring and Assessing Technological Pedagogical Content Knowledge

TPACK being an unconscious knowledge that the teacher possesses has generated a lot of questions on how to assess this knowledge in teachers, putting all the seven components into position. Shulman (2009) noted that Pedagogical Content Knowledge (PCK) and that TPCK consists of

Technological Knowledge (TK), Pedagogical Knowledge (PK), Content Knowledge (CK) and the overlapping domains, Pedagogical Content Knowledge (PCK), Technological Pedagogical Knowledge (TPK), Technological Content Knowledge (TCK), and Technological Pedagogical Content Knowledge (TPCK) were built upon by Matt Koehler and Punya Mishra. In 2007, TPCK shifted paradigm to TPACK to better express the connection between the three conspiring knowledge domains, and in 2008 context was added to the framework because it was evident that integrating technology into teaching cannot be done in isolation but must be placed in a definite educational context each time (Mishra, et. al, 2012).

Since then, the only concept that has been used to describe knowledge and skills that are needed for the effective integration of information and communication technologies (ICT) in teaching is the TPACK framework. This also led to the demand to measure whether teachers have sufficient TPACK and growth in TPACK can be measured. This entry first discusses researchers' and teacher educators' views on TPACK, then, describes the instruments used to measure it. The entry explains the methods of using the instruments and the potential enhancement of a common understanding of TPACK (Mishra, et. al, 2012).

There are many instruments used to measure TPACK. Several researches have shown different instruments of measuring teachers' TPACK. Literature show two main classes of instruments which can be distinguished as self-assessment surveys and performance-based assessments with emphasis on lesson plan, performance of teachers in the classroom, and performance on specific tasks. One common instrument that is used to assess self-perception of teachers on the TPACK is referred to as TPACK Survey, which was designed by Denise Schmidt and colleagues, where both pre-service and in-service teachers objectively rate their perceptions of confidence in TPACK using 5-point Likert scale with items that indicates the seven domains of the TPACK framework (Petra, Joke, Johan & Jo, 2015).

For example, items in the TPACK Survey that can be used in the context of mathematics are “I keep up with important new technologies” (TK), “I can adapt my teaching style to different learners” (PK), “I have adequate knowledge about mathematics” (CK), “I can identify adequate method of instruction to direct the thinking and learning of the students in mathematics” (PCK), “I am aware of technologies that I can apply to bring about understanding and doing mathematics” (TCK), “I can select technologies that enhance students' learning for a lesson” (TPK), and “I can

teach lessons that suitably combine mathematics, technologies, and teaching approaches” (TPCK). Many researchers have adopted the TPACK Survey because most studies show reliable outcomes when this survey is used. One can concentrate on specific form of technology or pedagogy or on the T-related knowledge domains only when adapting the survey. (Petra, et al., 2015).

Many controversies have generated over the possibility of measuring the seven knowledge domains from the TPACK framework using a self-assessment survey. Few studies reported a very positive duplication of the knowledge domains with factor analysis. Other studies, however, reveal duplication of the knowledge domain of the TPACK framework is not possible. Some of the most recent studies indicate that a factor analysis shows a high level of relationship between the T-related domains TK, TPK, TCK, and TPCK. There is every possibility that the three basic knowledge domains and the overlapping areas go beyond mere integration. The second category of instruments to assess TPACK is based on performance.

Measuring Teachers’ TPACK can be done using a different instrument, could be via questionnaire by self-assessment or clinical interview. It can be found out through performance-based test and teachers’ voluntary assessments which are adequate enough to assess a teachers’ level

of integrating technological skills. From studies relating to technology integration in education, it is known that knowledge and skills are important factors and that teachers' attitude towards technology and their pedagogical beliefs play a vital role in the success of technology integration. Teachers can for instance possess what is referred to as adopted-TPACK. This means that teachers can talk about pedagogically sound technology integration in a particular concept. But this does not mean that it will lead to what is referred to as in-use TPACK. In-use TPACK is said to be possessed by teachers when they are able to transform their ideology into the pattern and application of an effective pedagogical technology-enhanced lesson for their content within a specific concept. This demands the connection of skills, attitude and knowledge to think professionally (Petra, et al., 2015).

This means that a professional development programme should be considered. But also, knowledge and skills, beliefs, attitudes, and the ability to reason professionally should be considered when measuring teachers' technology integration exercise. A self-assessment design may be detailed with scale from other pre-existing instruments to assess the attitude of teachers toward the use of technology and their pedagogical beliefs. Likewise, there could be expansion of rubrics and other assessment forms with categories that are connected to beliefs and attitudes, but because these

are mostly tedious to realise, it would then be restored by the observation of professional argument. The self-assessment survey might also be set to measure the gender influence of the teacher on their TPACK.

Empirical Studies on Technological Pedagogical Content Knowledge and Gender

Investigating the role that gender may play in the measurement of Technological Pedagogical Content Knowledge (TPACK) is important. Given that research around gender and educational computing per se have shown that there are significant gender differences in relation to attitudes towards information and telecommunication technology (ICT), ICT skills and ICT use (Kay, 1992; 2006). The literature connecting to skills and use is particularly relevant given their synergies with technology knowledge, defined as knowledge of technologies and how to apply this knowledge productively (Harris, Mishra & Koehler, 2009). There is a flow-on effect on how teachers assess their knowledge of technology on the interrelated knowledge base of Pedagogical Knowledge TPK, TCK and finally Technological Pedagogical Content Knowledge. In relation to computer

use, Kay (2006) conducted a study on 42 students and concluded that 51% showed higher use by males.

In relation to computer ability, Kay (2006) reported that males have higher ability in eight students, females in one, and no difference reported in seven students. Markauskaite (2010) posited that gender has significant differences in ICT use, with males scoring higher than their female counterparts. In a similar vein, the earlier study by Albion, Jamieson-Proctor, and Finger, (2010) indicated that female teachers show less confident in the usage of ICT for teaching and learning. Being more likely to denote very little or some confidence (on a four-point scale) relating to listed ICT applications compared to male teachers. According to Koh, et al. (2010), the knowledge gap between gender will decrease eventually since the newer generation is more technologically literate. Female teachers may be weak in TK but they acquire better CK and PK that complement the knowledge gap. Similarly, male instructors were reported to have lower CK and PK but their TK assists and facilitate them to overcome the weaknesses (Low, 1999; Shaharom & Faridah, 2010). A well-balanced mastery of all the seven TPACK dimensions reduces the gap existed between gender.

The combination of all the knowledge dimensions produces a strong professional knowledge as a whole (Covey, 2011). It is to be noted that, in

the 21st century, the literature suggests that these gender gaps may be lessened. Mahdum (2015) for example, argue that, as more and more computers become prevalent in schools, this may have the effect of equalizing the difference in use between males and females. This sentiment is supported by Koh, et al. (2010). Some studies (Oz, 2015; Lin, Tsai, Chai, & Lee, 2013) suggest that teachers' gender contribute to the development of pedagogical knowledge. It was established that female teachers display high level of self-confidence in pedagogical knowledge, but this self-confidence tends to be low in technological knowledge when compared to their male counterparts. Notwithstanding, the study of (Oz et.al, 2013) did not include gender as the investigated variable so that it might be the direction for further studies. More so, while looking at gender as a very significant variable to be considered in measuring teachers' TPACK, the level of their qualification is also a variable to be investigated as it is considered a major determinant of students' academic performance.

Empirical Studies on Technological Pedagogical Content Knowledge and Teachers' Qualification

In the teaching and learning process, one important thing is the teachers' qualification. Teachers have to be creative, innovative, conscious, and qualified in their special fields to meet the requirements of the educational system. The most frequent subjects of the studies on TPACK are pre-service teachers for example, Chai, et al., 2010 who opined that most teacher education focused on taking preservice teachers through one specific technology skills based oriented course; Lux (2011) observed that for the successful integration of technology into classroom, teachers should be able to blend technology effectively with pedagogy and content. This is also supported by Graham, Borup, and Smith, (2012) who also observed that it is pertinent that the knowledge behind the teachers use of technology is fully explored during teaching in the classroom but are not given adequate attention as the study involved pre and in-service teachers.

TPACK studies have been carried out in places such as the USA and subsequently in Mediterranean and Asian countries such as Vietnam, Singapore, China, Turkey, and Malaysia. Several studies of teachers outside the USA are still needed in order to stabilise the possibility of cultural differences in the perceptions of teachers' TPACK (Koh, et al., 2010). An

important study of teachers' TPACK was done by Niess (2013). The study was carried out for three years and involved Mathematics teachers, Niess applied five stages of the developmental process to describe Mathematics teachers' TPACK. The five stages contained recognising, accepting, adapting, exploring, and advancing stages.

Niess (2013) found that in the first (recognizing) stage, teachers were found to possess ability in using the spreadsheet and recognised the potential of spreadsheets as a tool to do Mathematics. In the accepting stage, teachers started to recognise the capabilities of the spreadsheet as a tool for problem-solving and for teaching some topics in Mathematics. When teachers were in the adapting stage, they already engaged students to work with a spreadsheet but more as an additional tool to enrich students' understanding after learning mathematics. Teachers achieve investigating stage when they already had spreadsheet to take learning and acting consistent exploration to merge spreadsheet in instruction Mathematics (Niess, 2013).

At the advanced stage, teachers translated the concept of mathematics using a spreadsheet in the form of learning activities which support students' thinking and understanding. Teachers also underwent continuous motivation and exploration of the use of spreadsheet in planning, implementing, and evaluating teaching and learning process. Within the aforementioned studies,

it can be deduced that TPACK as a framework has been developed rigorously. It has been implemented as a research framework and as a framework for teaching practices. The most widely scrutinised content is Mathematics and Science. This tendency might happen since those content contain more abstract knowledge so that teachers require the articulation of Information and Communication Technology (ICT) to exhibit learning. Studies on TPACK in English as foreign language (EFL) context has been rarely approached (Lux, et al., 2011).

Considering the study of TPACK in EFL context is also striking because English as a foreign language gives similar test as Mathematics and Science. Based on the restricted number of studies, single study was carried out by Wu and Wang (2015). It used TPACK with 22 in-service EFL teachers at basic schools in Taiwan. Baser, Kopcha, and Ozden (2015) designed a TPACK instrument for training EFL teachers, while Tseng (2014) designed an instrument for assessing EFL teachers' TPACK as perceived by EFL students. It was found that the TPACK of the teachers was of good quality. A research study on TPACK was conducted in Indonesia by Mahdum (2015) who conducted the use of TPACK among Senior High School EFL teachers in Pekanbaru by using self-assess questionnaire. Moreover, there has never been any study conducted on EFL professional

development within the TPACK framework to the best of the present researchers' knowledge.

Empirical Studies on Teachers Experience and Technological Pedagogical Content Knowledge

In analysing the factors that could hinder the integration of ICT into classroom teaching and learning, another crucial element to be considered is the teachers' teaching experience which constitute the knowledge base of TPACK. Prensky (2005) investigated the Pedagogical Content Knowledge (PCK) of nine experienced chemistry teachers. The teachers took were trained on the kind of difficulties students encounter and the integration of models in teaching acid-base chemistry, electrochemistry, and redox reactions. The teachers were interviewed about their Pedagogical Content Knowledge of (1) difficulties students encountered in understanding acid-base chemistry and (2) concepts of acids and bases in their teaching practice. Teachers were made to pass comment on authenticity of the response of students regarding the earlier study that incorporated students' interviews about their understanding of acids and bases. Furthermore, the teachers drew

storylines representing their level of satisfaction with their teaching of acid-base (Prensky, 2005).

The outcome shows that, while all teachers are familiar with some of the students' difficulties as confusion between models, very few chose to accentuate the different concepts of acids and bases. Majority of the teachers thought it was adequate to differentiate obviously between the phenomenological stage and the particle stage. The manners the teachers reflected on their teaching, in order to recover it, also differed. Some teachers reflected more on students' difficulties, while others were more concerned about their individual performance (Prensky, 2005).

Appraisal of the Reviewed Literature

Technological Pedagogical Content Knowledge (TPACK) framework has been promulgated to solve the lack of a unifying concept in the quest to teach with technology (Archambault & Barnett, 2010). The framework as theorised by (Koehler & Mishra, 2005; Mishra & Koehler, 2006) is an extension of Shulman's (1986) concept of pedagogical content knowledge, which identified the distinctive features of knowledge for teaching. Within the contexts of education, the TPACK framework has seven constructs set:

technological knowledge (TK), pedagogical knowledge (PK), content knowledge (CK), pedagogical content knowledge (PCK), technological content knowledge (TCK), technological pedagogical knowledge (TPK) and technological pedagogical content knowledge (TPCK). All the constructs were well defined.

Teachers Pedagogical Knowledge (PK) was theorized to include their understanding of the underlying philosophy and approaches to classroom management and organisation (Shulman, 1987). It included the knowledge of the nature of teaching and learning (Abbitt, 2011) as well as the skills, beliefs, and conceptions about teaching (Grossman, 1990). The ability to comprehend the concepts, frameworks and processes in a given field constituted teachers' Content Knowledge (CK). The TPACK framework as proposed by (Koehler & Mishra, 2005; Mishra & Koehler, 2006) laid emphasis on the intersecting constructs between TK, PK, and CK which led to the formation of PCK, TCK, TPK and TPCK.

Teachers' pedagogical and content knowledge are arguably connected and merged to form Pedagogical Content Knowledge (PCK) in the TPACK framework. PCK goes pass just pedagogy and content. It looks at how these two relate and interact for effective teaching. PCK depicts the approach in which the content can be represented and formulated to make it

comprehensible to others (Shulman, 1986). Technological Content Knowledge (TCK) is the ability to determine how the content a teacher wants to teach is affected by the affordances of technology and vice versa. It is the knowledge of how to utilize an emerging technology to represent specific concepts in a given content domain (Cox & Graham, 2009). Technological Pedagogical Knowledge (TPK) deals with the ability to realise how technology affects the processes and strategies of instruction and how efficient teaching and learning can be accomplish with technology.

The final construct of the framework, TPCK, is the understanding that surfaces from the interactions and interplays between and among technology, content and pedagogical knowledge that underlies meaningful teaching with technology (Koehler & Mishra, 2009). The TPACK framework advocates the treatment of the various constructs in unison rather than in isolation. The constructs are intertwined and interwoven and therefore it is not sufficient for biology teachers to just learn about technology, content or pedagogy alone as being independent of each other. Although a lot of research has been conducted with TPACK as the framework (Voogt, Fisser, Pereja, Tondeur, & Van Braak, 2013), a critique of the theoretical underpinnings of the framework was conducted by Graham (2011).

Graham (2011) noted that TPACK looks clear and simple on the surface but hides a deep level of complexity. This has led to some researchers questioning the uniqueness of the various constructs of the framework (Archambault & Barnett, 2010; Graham, 2011). Although, some of the constructs within the TPACK framework lack clarity as far as their definitions are concerned (Graham, 2011), TPACK has still been able to explain the knowledge required by teachers and educators to effectively use technology in their teaching and has evolved as the knowledge required for teaching with technology effectively (Cox & Graham, 2009; Niess, 2012; Chai et al., 2013). The literature on TPACK seems to suggest a transformative model as opposed to an integrative one (Angeli & Valanides, 2009) which therefore supported the view that TPACK is a special body of knowledge which should be developed for effective teaching.

The advancement, use, and application of TPACK have been seen to be in levels as predicted by (Niess et al., 2009; Niess et al., 2010; Niess, 2012). They revealed that the levels are recognising, accepting, adapting, exploring and advancing levels of TPACK. Each level has certain characteristics that teachers operating at that level depict and demonstrate when it comes to the use of technology in teaching. Due to the dynamic nature and the influence of contextual factors on TPACK, teachers' levels of

TPACK may shift and change depending on the circumstances within which they find themselves as far as teaching with technology is concerned (Niess et al., 2010). The literature review has brought to fore the burgeoning interest in TPACK since its inception. There has been a range of research on TPACK that uses different methodological approaches.

Koehler et al., (2012) and Voogt et al. (2013) counted over 200 research studies that mentioned, measured or used TPACK as the framework. Some of these research sought to measure preservice teachers' TPACK (Chai, 2010; Chai et al., 2011; Horzum, 2013) whilst others used in-service teachers (Graham et al., 2009). The studies that sought to predict TPACK found out that of all the constructs it was TPK and TCK that made a significant contribution to the development of TPACK (Chai et al., 2011; Horzum, 2013; Pamuk, Marino, 2013). The researchers noted that the development of TPACK should be considered as a blend whereby emphasis is placed on the relationships among the various constructs rather than treating the basic constructs of TK, PK, and CK in isolation. Although a burgeoning interest in TPACK was noted, only two studies, Olatoye and Nieya (2014) and Ayoub (2015) were found to have been conducted on TPACK in Nigeria.

The former study was conducted on students learning in mathematics, whilst the latter was on pre-service teachers. Thus, the need for research on investigating biology teachers' TPACK in Nigeria was identified. In addition, the researcher identified a gap research on the contextual factors that affect the integration of teachers' TPACK in practice even though researchers have assumed that TPACK is influenced by contextual factors. This study, therefore, sought to fill that gap in the literature as far as TPACK for biology teachers is concerned.

CHAPTER THREE

METHODOLOGY

This chapter presents the methodology employed to conduct the study. It has been discussed under the following sub-headings; Research Type, Population, Sample, and Sampling Techniques, Research Instruments, Validation of the Research Instruments, Procedure for Data Collection and Data Analysis Techniques.

Research Type

This study was a descriptive research of the survey type. According to Devin (2018), a descriptive research design is a type of study designed to portray the participants in an accurate way. It is used to find meaning and obtain understanding of the present condition. Teachers' TPACK was the independent variable, while the teachers' gender (male and female), qualification (qualified and not qualified), and teaching experience (experience, moderately experienced, and less experience) were the moderating variables. Hence, the choice of survey method was to assess the technological pedagogical content knowledge of biology teachers in senior secondary schools in Kwara State, Nigeria.

Population, Sample, and Sampling Techniques

The population consisted of all senior secondary school biology teachers in Kwara State, Nigeria. The target population consisted of all Senior Secondary One to Three biology teachers (SS1-SS3). There were 1,283 Senior Secondary Schools in Kwara State, consisting of 753 public and 530 private schools. There were 1,122 biology teachers in the schools (Kwara State Ministry of Education, 2018), as at the time this study was conducted. The purposive sampling procedure was used to select 680 biology teachers, schools with basic ICT tools for teaching and learning. This was done by using 42% of the population. The schools were selected on the basis of availability of ICT gadgets.

Research Instrument

Instruments are tools used to collect data in a study. For the survey of this study, the questionnaire item is deemed appropriate for data gathering. The instrument employed in the study was adapted from Archambault and Crippen (2009) and Sahin (2011) referred to as Items for TPACK Survey (ITS). As part of the trial test, the questionnaire contained four sections that were administered to teachers in the sampled schools.

Section A requested for the personal information of each respondent, teaching qualification, teaching experience, gender and name of the school. Section B of the questionnaire requested for information about teachers' level of awareness and utilisation of ICT gadgets, Section C requested for information on the level of expertise in teaching biology concepts, while Section D assessed the teachers' level of TPACK.

Validation of Research Instrument

The research instrument was validated by three lecturers in the Department of Science Education, University of Ilorin, Ilorin, Nigeria, one experienced secondary school biology teacher and two experts in ICT in the Educational of Technology Department of University of Ilorin to ensure face and content validity. The instrument was taken through test-retest reliability procedure of three weeks interval, to establish that the collection process was consistent, stable and repeatable. The reliability coefficient was determined using Cronbach Alpha. Cronbach Alpha was also used to achieve consistency on the individual teachers that took part in the test-retest process for the Assessment of Technological Pedagogical Content Knowledge of biology teachers in senior secondary schools in Kwara. A

reliability index of 0.81 was obtained for the ITS which is high enough to make the instrument reliable for the study.

Procedure for Data Collection

Firstly, the researcher collected letter of introduction from the researcher's department to the principals of the sampled schools. The researcher then visited the schools where the study was carried out, on the need to engage the Biology teachers in the research study. Copies of an Informed Consent Form were distributed to teachers in the school. The researcher made it clear to the participating teachers that their efforts, contributions, and opinions would be treated with the utmost confidentiality and basically for the purpose of the study alone.

The selected teachers were allowed to participate voluntarily in the study in conformity with the ethical practice of research. Informed consent forms were made available to the school authority and the teachers indicated their willingness to participate in the study. The questionnaire was administered during the time given by the school authority to avoid disrupting their lessons. The researcher with help of the research assistants administered and retrieved the questionnaire from the biology teachers. The

teacher could decide to withdraw from the research at any time, such individual could do so without any hindrance. The names of the participating schools, likewise the identity of the respondents were not disclosed at any point in the study. All other related data were treated with the utmost confidentiality and was used exclusively for the purpose of the research. All reviewed work was paraphrased, summarised to reflect the authors' ideas and referenced appropriately. Also, at the end of the research work, the completed work was subjected to plagiarism and grammar check.

Data Analysis Techniques

Frequency, mean and the percentage were used to answer all the research questions. Hypothesis 3 was tested with the One-way Analysis of Variance (ANOVA); hypotheses 1 and 2 were tested using the t-test at 0.05 level of significance. The analysis was done using Statistical Package for Social Sciences (SPSS) software version 24.0.

CHAPTER FOUR

DATA ANALYSIS AND RESULTS

This chapter presents the analysis of the data gathered in the study and the results of the findings. Percentage computation, mean, t-test and Analysis of Variance (ANOVA) were the statistical tools employed for data analysis in the study. The data were analyzed with the aid of the Statistical Package for Social Science SPSS version 24.0. All the hypotheses were tested at 0.05 alpha level of significance

Research Question 1: *What is biology teachers' knowledge of teaching biology topics at the senior school level?*

To provide answers to the research question 1, Biology teachers were asked to honestly and objectively evaluate their knowledge in teaching biology topics. The evaluation scale was raised from 1 to 6, corresponding to those that need improvement in their knowledge level to those with excellent knowledge level, respectively. Table 3 summarizes the Biology teachers' assessment of their knowledge of teaching biology topics. The table indicates that some of the Biology teachers claimed to have either very good (53.8%) or good (20.4 %) knowledge of teaching biology topics. Some of the biology teachers (6.3%) and (8.9%) audaciously claimed to have average

or needed improvement in the knowledge of teaching biology topics. In view of the foregoing responses, it can be inferred that most of the biology teachers possessed a good knowledge of teaching the subject. This result provides an answer to research question 1.

Table 3:

Analysis of Biology Teachers' Level of Knowledge of Teaching Biology.

Knowledge of Teaching	Frequency	Percentage(%)
Excellent	70	10.4
Very Good	366	53.8
Good	140	20.4
Average	43	6.3
Needs Improvement	113	8.9
Total	680	100

Research Question 2: What is the extent of biology teachers' knowledge about the use of modern digital technologies (ICT) for teaching biology?

To provide answers to research question 2, biology teachers were asked to indicate their level of knowledge about modern digital technologies for teaching. The evaluation was ranged from 1-6, corresponding to those that need improvement to those that possess excellent knowledge about

modern digital technologies for teaching, respectively. Table 4 summarizes the level of teachers' knowledge of modern digital technologies.

The table indicates that 14.6% need improvement, 18.2% fair knowledge or had average knowledge of 42.1% about modern digital technologies for teaching. However, some of the biology teachers claimed that they had good (19.6%), very good (3.4%), and excellent (2.1%) knowledge about modern digital technologies for teaching of the subject. In view of the sequential responses, it can be deduced that most of the biology teachers did not possess knowledge about modern digital technologies in teaching. This result provides the answer to research question 2

Table 4:

Analysis of Biology Teachers' Knowledge about Modern Digital Technologies for Teaching

Level of Knowledge	Frequency	Percentage (%)
Excellent	14	2.1
Very Good	23	3.4
Good	133	19.6
Average	286	42.1
Fair	124	18.2
Need Improvement	100	14.6
Total	680	100.0

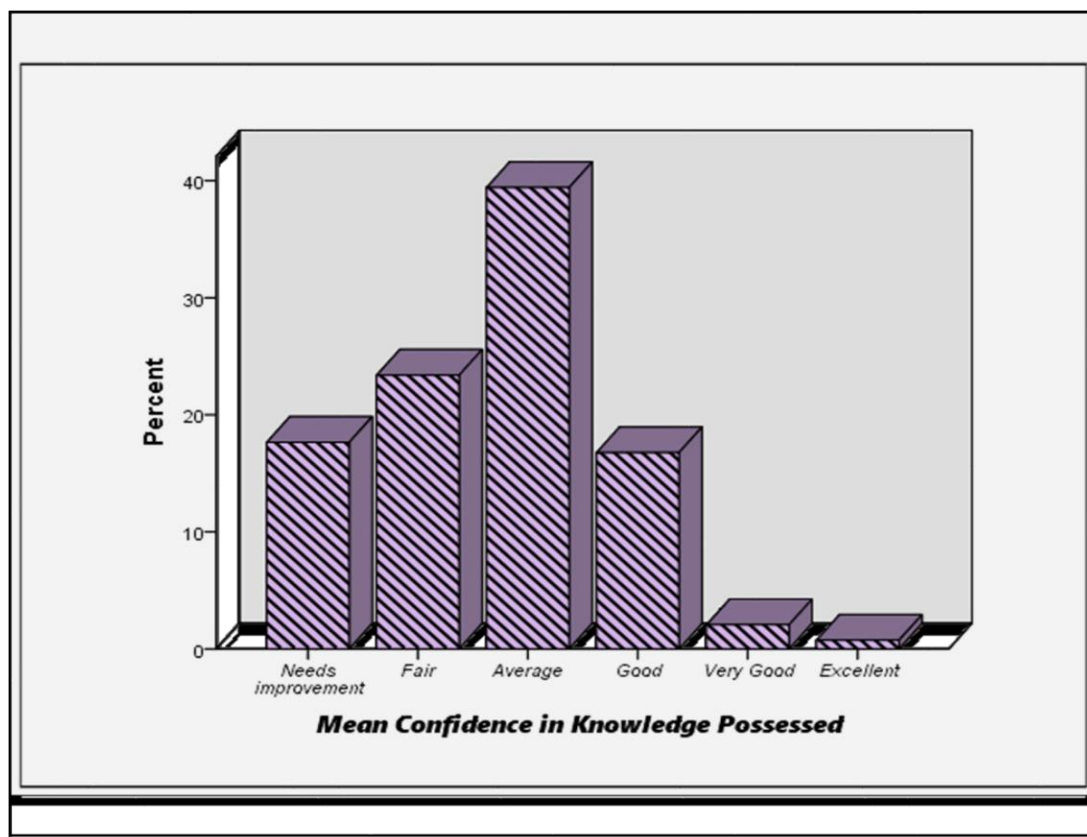


Figure 10: *The level of biology teachers' knowledge about modern digital technologies for teaching*

Research Question 3: what are the available modern digital technologies for teaching biology in the school?

To provide answers to research question 3, biology teachers were asked to indicate the availability of modern digital technologies (ICT) in the teaching of biology concepts. The response mode was between 0 and 1 corresponding to available and not available of modern digital technologies,

respectively. Table 5 summarises the availability of modern digital technologies (ICT) in the teaching of biology concept in the school.

The table indicates that 57.1% of the teachers claimed not to have most of the modern digital technologies, while 42.9% of the teachers claimed to possess modern digital technologies in the teaching of biology. It can thus be deduced that the majority of the schools did not have modern digital technologies to teach biology concept. This result provides an answer to research question 3.

Table 5a.

Analysis of Availability of Modern Digital Technologies (ICT) in the Teaching of Biology Concepts

Availability	Frequency	Percentage%
Available	292	42.9
Not Available	388	57.1
Total	680	100

Table 5b

Analysis of Availability of Modern Digital Technologies (ICT) in the Teaching of Biology Concepts

Modern Digital Technologies	Available	Not Available
SOFTWARE		

MS Word	Yes	
Power Point	Yes	
MS Excel	Yes	
Paint Editor	Yes	
Corel Draw	Yes	
Animations in biology		Yes
Computer Based Test		Yes
HARDWARE		
Computer in the classroom	Yes	
CD ROM	Yes	
RAM	Yes	
Media Player	Yes	
DVD	Yes	
Printer	Yes	
Projector		Yes
Scanner		Yes
Digital Camera		Yes
Interactive white board		Yes
Mobile device	Yes	
Podcast		Yes
Digital Camera		Yes
Digital video		Yes
Wireless Classroom Microphone		Yes
SOCIAL MEDIA		
Email	Yes	
Facebook		Yes
WhatsApp	Yes	

MSN messenger	Yes
Class blog	Yes
Wikipedia	Yes
Class website	Yes
Online media	Yes
Online Study tools (example flashcard, Study Group, classnote)	Yes
Qzone	Yes
WeChat	Yes
LinkedIn	Yes
Skype	Yes
Google+	Yes
Twitter	Yes
Viber	Yes
Snapshot	Yes
Myspace	Yes
Badoo	Yes
Flicks	Yes
Classmate	Yes
Weeworld	Yes
Livejournal	Yes
Netlog	Yes
Studiv	Yes
Friendster	Yes
Cyworld	Yes
51.com	Yes

Research Question 4: What types of training do biology teachers acquire for teaching with modern digital technologies (ICT)?

Table 6 revealed the forms of training acquired by biology teachers' in teaching with modern digital technologies (ICT). The response mode ranged from 0 to 2 corresponding to formal training to self-training, respectively.

The table revealed that majority (87.3%) of the biology teachers claimed to possess informal training (33.8%) and self-training (53.5%), while some (12.6%) agreed that they possessed formal training.

Table 6.

Analysis of the Form of Training Received by Biology Teachers in Teaching with Modern Digital Technologies (ICT)

Forms of Training	Frequency	Percentage%
Formal Training	86	12.6
Informal Training	230	33.8
Self-Training	364	53.5
Total	680	100.0

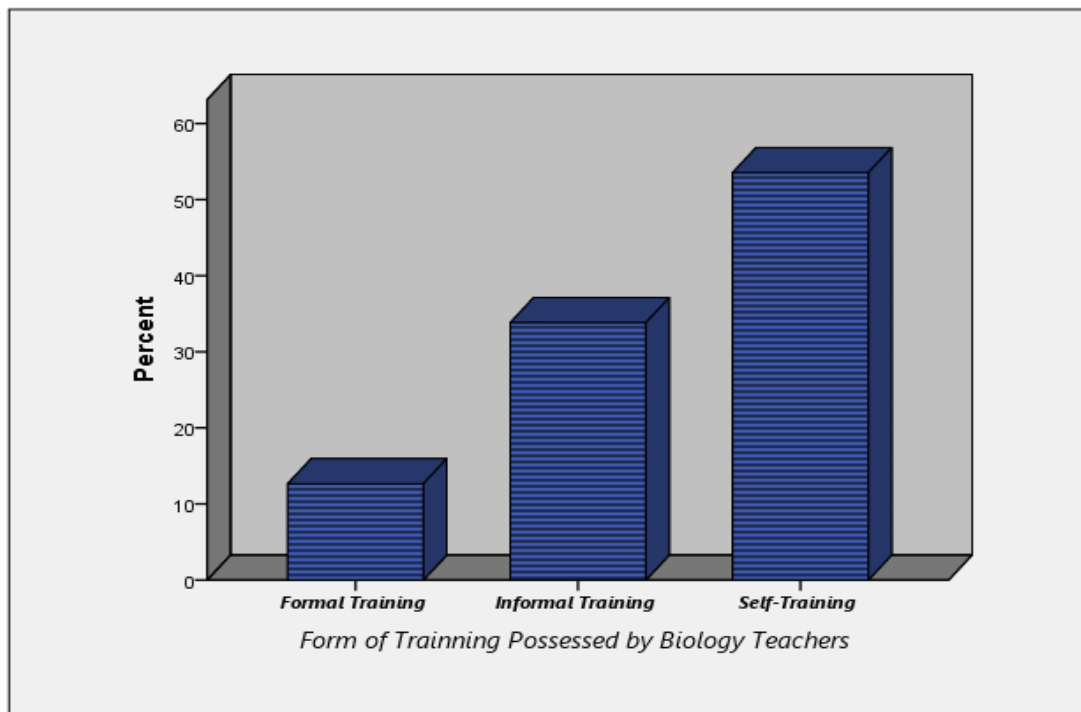


Figure 11: *The forms of training received by biology teachers in teaching with modern digital technologies (ICT)*

Research Question 5: what is the level of biology teachers' knowledge about TPACK?

Biology teachers were asked to indicate their level of Technological Pedagogical Content Knowledge. The assessment ran from 1-6 corresponding to those that need improvement to those that possess excellent knowledge of Technological Pedagogical Content Knowledge, respectively. Table 7 summarises the level of biology teachers' knowledge of Technological Pedagogical Content Knowledge.

The table indicated that majority of the biology teachers (64.2%) claimed to need improvement (53.8%) or possessed average (10.4%) knowledge of Technological Pedagogical Content Knowledge, while few of them (25.6%) claimed to possess excellent knowledge (6.3%), very good (8.9%) or average knowledge (10.4%). In view of the aforementioned responses, it can be deduced that most of the biology teachers do not have low level of Technological Pedagogical Content Knowledge.

Table 7

Analysis of Biology Teachers' Level of Technological Pedagogical Content Knowledge

Teachers' TPACK	Frequency	Percentage%
Excellent	43	6.3
Very Good	61	8.9
Good	140	20.4
Average	70	10.4
Needs Improvement	366	53.8
Total	680	100.00

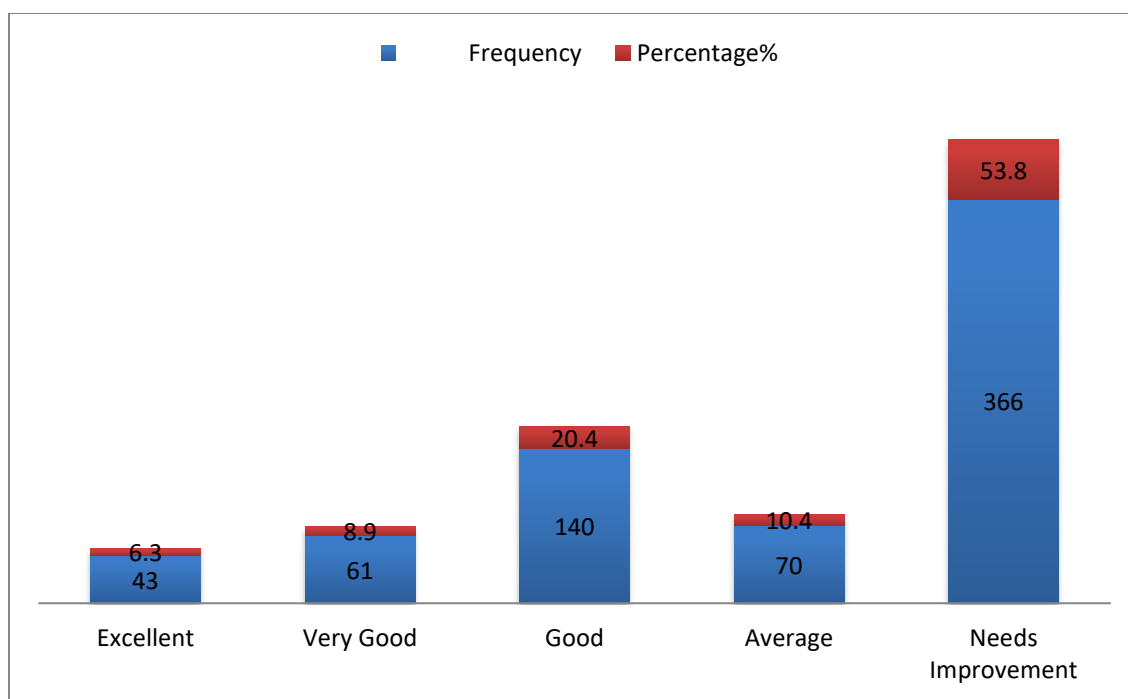


Figure 12: *Teachers' Level of Technological Pedagogical Content Knowledge*

Research Question 6: What are biology teachers' level of knowledge of TPACK based on gender?

Table 8 summarizes the biology teachers' knowledge of TPACK based on their gender. The table reveals that the Technological Pedagogical Content Knowledge of biology teachers is lower in male biology teachers (4.40 ± 1.382), which represents 59.1% compared to their female counterparts ($4.74 \pm .583$), which represents 40.9%.

Table 8

Analysis of Teachers' Technological Pedagogical Content Knowledge Based on Gender

Teachers' Gender	Frequency	Mean	STD	Percentage(%)
Male	402	4.40	1.382	59.1
Female	278	4.74	.583	40.9
Total	680	4.54	1.129	100.0

Research Question 7: To what level are biology teachers knowledgeable about TPACK based on their qualifications?

Table 9 summarises the biology teachers' Technological Pedagogical Content Knowledge based on qualifications. The table reveals that the knowledge of Technological Pedagogical Content of biology teacher is lower in qualified teachers (4.36 ± 1.294), which represents 73.5% of the teachers compared to unqualified teachers ($5.00 \pm .000$), which represents 26.5% of biology teachers.

Table 9

Analysis of Biology Teachers' Level of Technological Pedagogical Content

Knowledge based on Qualifications

Teachers' Qualification	Frequency	Mean	STD	Percentage(%)
Qualified Teachers	500	4.36	1.294	73.5
Unqualified Teachers	180	5.00	.000	26.5
Total	680	4.54	1.129	100.0

Research Question 8: what are biology teachers' level of knowledge of TPACK based on their teaching experience?

Table 10 summarizes the biology teachers' self-evaluation of their Technological Pedagogical knowledge based on teaching experience. The table depicted that there are differences in their mean based on teaching experience. The experienced biology teachers had statistically higher mean score followed by less experienced biology teachers, and, lastly, moderately experienced biology teachers with $(5.13 \pm .715)$, 36.8% $(5.00 \pm .000)$, 15.9% and (4.09 ± 1.271) 47.4%.

Table 10

Analysis of Biology Teachers' Level of Technological Pedagogical Content

Knowledge based on Teaching Experience

Teachers' Teaching Experience	Frequency	Mean	STD	Percentage(%)
Less Experienced	108	5.00	.000	15.9
Moderately Experienced	322	4.09	1.271	47.4
Experienced	250	5.13	.715	36.8
Total	680	4.54	1.129	100.0

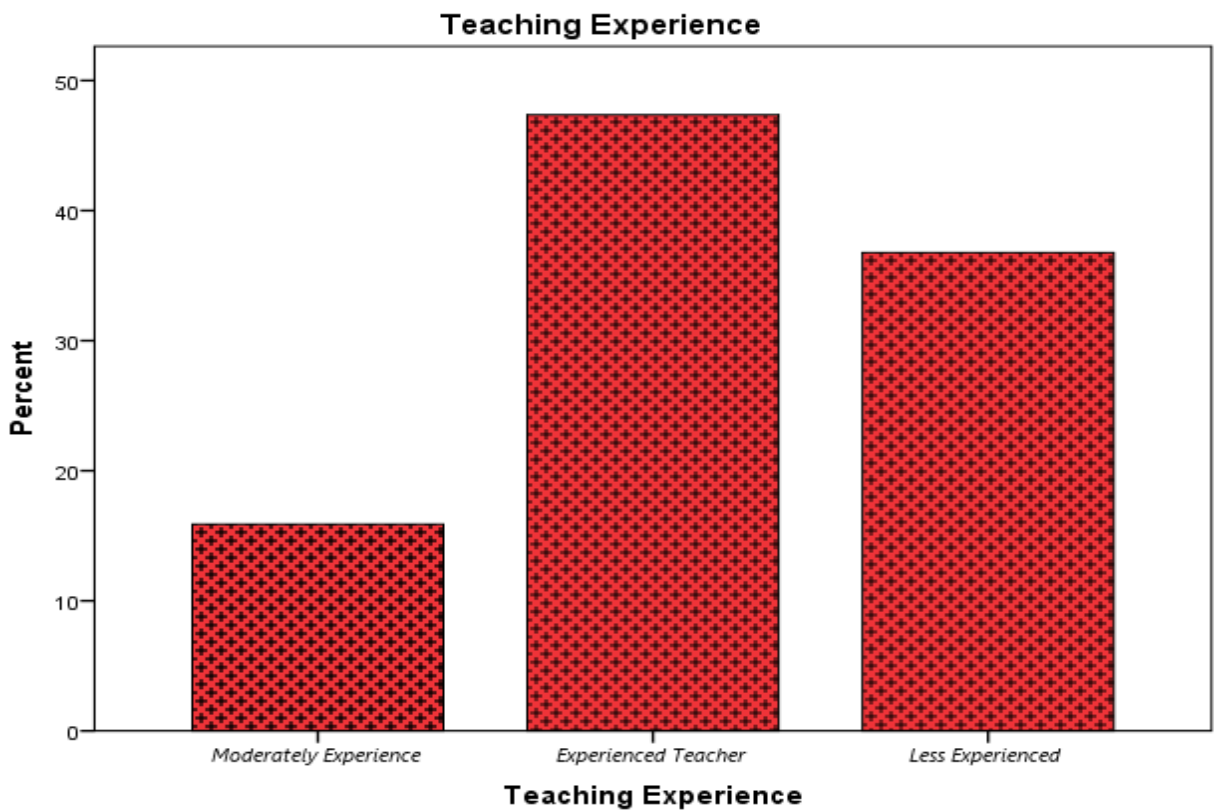


Figure 13: *Biology teachers' level of Technological Pedagogical Content Knowledge based on their teaching experience.*

Testing of Hypotheses:

H₀: There is no significant difference in the Technological Pedagogical Content Knowledge of male and female biology teachers

Table 11 shows that there was a statistically significant difference in the level of Technological Pedagogical Content Knowledge between male and female biology teachers in favour of female teachers. $t(555) = -3.467$, $p < 0.05$. Since the p-value is lower than the level of significance 0.05, therefore, the null hypothesis is rejected.

Table 11

t-test Table to Showing the Analysis of the Mean Score of the Level of Technological Pedagogical Content Knowledge of Biology Teachers Based on Gender

Teachers' Gender	N	Mean	SD	Df	t	Sig
Male	322	4.40	1.382	555	-3.467	.000
Female	235	4.47	0.583			

H02: There is no significant difference in the Technological Pedagogical Content Knowledge of qualified and less qualified biology teachers.

Table 12 shows that there was a statistically significant difference in the level of Technological Pedagogical Content Knowledge of qualified and unqualified biology teachers, in favour of unqualified teachers, $t=555.197.149$, $p < 0.05$. Since the p-value level is lower than the level of significance, this shows that there was a significant difference in the Technological Pedagogical Content Knowledge of biology teachers based on qualification. Thus, the null hypothesis is rejected.

Table 12

t-test Table to Analyze the Mean Score of the Level of Technological Pedagogical Content Knowledge of Biology Teachers Based on qualification

Teachers' Qualification	N	Mean	SD	Df	t	Sig
Qualified Teachers	396	4.36	1.294			
				555	197.149	0.000
Less qualified Teachers	161	5.000	0.000			

H03: There is no significant difference in the Technological Pedagogical Content Knowledge based on teaching experience (experienced, moderately experienced and less experienced).

Tables 13 and 14 show that there was a statistically significant difference in the Technological Pedagogical Content Knowledge of biology teachers' based on teaching experience ($F=3,554$) 66.587, $p=.003$), since the $P<0.05$. Hence, the null hypothesis rejected. However, a Tukey post-hoc test revealed that there was a statistically significant difference between the less experienced biology teachers and experienced biology teachers ($p=.001$) in favour of the less experienced biology teachers.

Table 13

Table of One-Way ANOVA to Analyze the Mean Score of Technological Pedagogical Content Knowledge of Biology Teachers Based on Experience.

Source	sum of square	df	Mean Square	<i>f</i>	sig
Between Group	137.243	2	68.621	66.587	.003
Within Group	570.929	554	1.031		
Total	708.172	556			

Table 12

Post-hoc Test to Analyze the Mean Score of Technological Pedagogical Content Knowledge of Experienced and Less Experienced Biology Teachers.

(I)Teaching Exp	(j) Teaching Exp.	mean difference (I-J)	Std. Error	Sig
Less Exp.	Moderate Experience	.911	.122	.610
	Experience	-.127	.133	.001
Moderate Exp.	Less Experience	-.911	.122	.006
	Experience	-1.037	.098	.610
Exp.	Less Experience	.127	.133	.001
	Moderate Experience	1.037	.098	.006

Summary of Major Findings

- I. Biology teachers in Kwara State, Nigeria had very good knowledge of biology topics.
- II. Majority of the biology teachers in Kwara State did not possess adequate knowledge about modern digital technologies in the teaching of biology topics.
- III. Majority of the Schools in Kwara did not have modern digital technologies for the teaching of biology concept.

- IV. Most biology teachers in Kwara State acquired self-training on ICT use in teaching.
- V. Biology Teachers in Kwara State, Nigeria possessed a low level of Technological Pedagogical Content Knowledge.
- VI. Technological Pedagogical Content Knowledge of biology teachers in Kwara State, Nigeria was lower in male biology teachers when compared with their female counterparts.
- VII. Technological Pedagogical Content Knowledge of biology teachers in Kwara State, Nigeria was higher in less qualified biology teachers than in the qualified teachers.
- VIII. Experienced biology teachers in Kwara State, Nigeria displayed a higher level of Technological Pedagogical Content Knowledge followed closely by less experienced biology teachers and lastly, moderately experienced biology teachers.
- IX. There was a significant difference in the level of Technological Pedagogical Content Knowledge between male and female biology teachers in favour of the female biology teachers

- X. There was a significant difference in the level of Technological Pedagogical Content Knowledge of qualified and less qualified biology teachers in favour of less qualified biology teachers
- XI. There was a significant difference in the level of Technological Pedagogical Content Knowledge of biology teachers based on teaching experience.

CHAPTER FIVE

DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

The results obtained in this study were discussed in details, conclusion and recommendations were made based on the outcome of the result in this chapter.

Three research hypotheses were posited for this study and tested at 0.05 level of significance. Hypotheses one and two were tested with t-test while hypothesis three was tested with One-way Analysis of Variance.

Discussion

The first finding of the study discovered that majority of the biology teachers possessed very good (53.8%) knowledge of teaching biology topics. This implies that biology teachers had a good mastery of the subject matter knowledge. Teachers' knowledge has been described as the body of information teachers teach and that students are expected to learn in a given subject matter or content area (edglossay.org, 2015).

Similarly, in the study conducted by Borowski, Neuhaus, Tepner, Wirth, Fischer, Leutner, (2010) which investigated the professional

knowledge of biology, chemistry and physics teachers and its impact on the teaching/learning processes and students' achievement and motivation in science. In the first place, the professional knowledge of the teachers is being assessed on a subject related by paper-and-pencil-tests. In the next step teachers' knowledge was measured, and their lessons were videotaped, then science knowledge and motivation of their students were tested. It became evident that teachers' high levels of knowledge produced a high level of academic performance in students.

In the same vein, lack of subject-specificity in Schmidt, Baran, Thompson, Mishra, Koehler and Shin, (2009) survey reduced the construct validity (Chai, Koh, Tsai, 2016). The adapted TPACK instrument Chai, Koh, Tsai, & Tan (2011) used in this study questionnaire underscored the subject-specific nature of TPACK and all the participants majored in the same subject (chemistry), which might help enhance the correlation between scores on the two measures (that is survey and rubric).

It was found that the majority of biology teachers (74.9%) did not possess adequate knowledge about modern digital technologies in the teaching of biology. This result implies that most of the biology teachers lacked basic knowledge about modern digital technologies. This might be as a result of the fact that most of the biology teachers were not ICT compliant

and tended to see the knowledge of ICT as a separate field of study and only to be studied by experts in that field.

Other reasons could be that majority of these biology teachers did not possess their own personal computers, which could actually be a driving force to make use of it in their teaching and learning process, more so, most teachers don't utilise the full functions on their respective phones as majority of them preferred watching movies, playing music or better still, playing games as the only activities engaged in with their phones despite the exotic devices majority of them are using.

Similarly, the study conducted by Jimoyiannis (2010); Polly, Mims, Shepherd, and Inan (2010) asserted that teachers' use of ICT for teaching and learning continued to be a growing concern for educators. Incorporating ICT into classroom instruction persist to be an intriguing task for many teachers (Shafer, 2008; So& Kim, 2009). In similar vein, Brush and Saye (2009); Kramarski and Michalsky (2010) observed that teachers felt poorly prepared for subject-specific use of ICT and deficient in robust theoretical framework.

This study indicated that the majority of the biology teachers (57.1%) did not make use of modern digital technologies in the teaching of biology

concept. This finding clearly suggests that biology teachers did not make use of modern digital technologies in their teaching process. This result is, however, in support of the above findings. They revealed the lack of knowledge of biology teachers about modern digital technologies. This is clear that the availability of this modern gadget in schools is one thing, the ability to access them is another.

What people do with the machine and not the machine itself is what matters. This was supported by Koehler and Mishra (2009), who asserted that the adoption of new technologies does not guarantee success. This result is in line with the findings of Graham, Burgoyne, Cantrell, Smith, Clair, and Harris (2009), who observed that educators have realised that a basic knowledge of how to use technological tools is not enough; what they really need is the ability to use these tools effectively in order to facilitate the learning process of their students.

Thus, research interest has focused on ways to incorporate the relevance of integrating technological tools in teaching. The success of any initiatives to integrate ICT in the classroom depends largely upon teachers' ability to handle technology and how it affects them in their use of technology in instruction Gilakjani, Leong, and Ismail (2013).

It was found in this study that the majority of biology teachers acquired self-training (53.5%) of ICT use. This implies that most of the biology teachers learn the knowledge of ICT devices independently without going through any formal training. This could be that where these gadgets are available teacher naturally will expect authorities of their respective schools to engage them in some form of training owing to the fact that majority of these teachers do not have the opportunity to undertake any of such training while they are in school. Hence, the self-training is likely to lack purpose which invariably might not give them the sense of integrating it (ICT) into their teaching. Another reason for this might be that teachers from schools where these ICT gadgets were available did not have access to training or retraining programmes that should be the responsibilities of the government or school administrators meanwhile, individual teachers also have the responsibility of engaging themselves in personal training.

It is in line with Prensky (2013) who asserted that even the cell phones that many now carry with them can be used to learn. For many, however, knowledge of technology is not in their day-to-day area of expert knowledge. It then means that teachers need the support of their respective schools to facilitate this development so that teachers can make the informed

decisions when it is right to use or not to use technology within the classroom.

The study also revealed that the majority of biology Teachers (64.2%) possessed a low level of Technological Pedagogical Content Knowledge. This result suggests that a larger percentage of the teachers seem to have a low level of technological pedagogical content knowledge. This could be due to the fact that majority of the teachers are not aware and conscious of the classroom condition. Most of the student now have numerous source of knowledge which will place a teacher on their toes if not well prepared.

Most of the information is already in public knowledge. Because of this, the of this; 21st-century teachers need to be aware of the challenges in the classroom, as such, most teachers need to be attuned with the current reality. Other thought could be some biology teachers are not well motivated to utilise ICT in educational practice, while very few share this affinity. For this reason, many researchers have focused on exact individual uniqueness associated with TPACK, such as teachers' attitudes, ease of use, and their self-efficacy.

This result is in line with the findings of Tearle and Golder (2008); Angeli and Valanides (2015) asserted that many studies demonstrated that

group work might mitigate feelings of insecurity of teachers in the low TPACK profile when they need to design technology-related curriculum materials. They concluded that teachers possess low TPACK profile. However, there are many factors affecting the teachers' usage of new technology MacCallum, Jeffrey, and Kinshuk (2014) proposed those factors as the following:

1. Teachers' beliefs about the perceived value of the “usefulness” of the new technology and the perceived attempt required to learn to use the new technology "ease of use";
2. Teachers' skills to use and integrate digital technology into their teaching "digital literacy"; and
3. Teachers' self-efficacy beliefs pertaining to their own level of competence and their attitudes towards technology adoption and ICT anxiety are considered as the tendency of a teacher to experience a level of uneasiness over his impending use of ICT.

Contrarily, teachers feel inadequately prepared for subject-specific use of ICT and robust theoretical framework Brush & Saye, (2009); Kramarski & Michalsky, (2010). To address the challenges, an important theoretical

framework that has emerged recently to guide research in teachers' use of ICT is the Technological Pedagogical Content Knowledge (TPACK).

The study shows that most ($4.74 \pm .583$) of the female biology teachers showed a high level of Technological Pedagogical Content Knowledge. This suggests that the female biology teachers possessed a higher level of TPACK than their male counterparts. This result might be as a result of the fact that majority of the female teachers possessed adequate content knowledge combined with the pedagogical knowledge but only showed their weaknesses in the Technological knowledge, while their male counterparts only showed their efficiency in Technological knowledge only. A combination of the earlier mentioned knowledge with a little knowledge of technology integration in teaching will overwhelm the deficiency of the female biology teachers in TPACK.

Similarly, Koh, Chai and Tsai (2010) in their study of 1185 pre-service teachers in Singapore, concluded that there are gender differences in Technology Knowledge, Content Knowledge and Knowledge of Teaching with Technology. They also suggested that this gap may reduce as computers become more commonplace in schools. In contrast to Koh and Sing (2011) in their study of 214 pre-service teachers, they reported that no significant difference by gender existed.

Similarly, male instructors were reported to have lower CK and PK but their TK assisted and facilitated them to overcome the weaknesses (Low, 1999; Shaharom & Faridah, 2010). The studies of Lin, Tsai, Chai, & Lee, (2013) and Oz, (2015) and also supported the result by finding that teachers' gender contributes to the development of pedagogical knowledge. Female teachers pose higher self-confidence in pedagogical knowledge, but lower self-confidence in technological knowledge than male teachers.

It was found in this study that (4.36 ± 1.294) of the less experienced biology teachers have higher 47.4% of Technological Pedagogical Content Knowledge. This means that the less experienced biology teachers showed higher 47.4% level of knowledge of Technological Pedagogical Content Knowledge than the experienced biology teachers. This finding may be related to the fact that most of the less experienced biology teachers are found in private senior secondary schools, where schools engage their teachers in periodic training or retraining programmes and where ICT resources are most readily available to complement their training, while in public schools, mostly experienced biology teachers are found, no facilities are put in place or are sparsely available and no proper retraining programme is set in place to develop already existing knowledge of biology teachers.

This result is in line with Niess (2013) who found that, in the first (recognizing) stage, teachers are found to have the ability of using the spreadsheet and recognize the potential of spreadsheets as a tool to compute data. In the accepting stage, teachers started to recognize the capabilities of the spreadsheet as a tool for problem-solving and for teaching some topic in Mathematics. When teachers are in the adapting stage, they already engaged students to work with a spreadsheet, but more, an additional tool to enrich students' understanding after learning mathematics.

The study found that gender has a significant influence ($p < 0.05$) on the level of Technological Knowledge Pedagogical Content Level of biology teachers. This finding implies that the level of Technological Pedagogical Content Knowledge of biology teachers differs based on their gender. Male and female biology teachers have exhibited a different level of knowledge of TPACK. This is contrary to the findings of Koh and Sing (2011) in their study of 214 pre-service teachers, where they reported that no significant differences by gender exists in the level of TPACK. To explore this further, an earlier study by Albion, Jamieson-Proctor, and Finger (2010) indicated that female teachers show less confidence in the usage of ICT for teaching and learning. In another study by Markauskaite, Bachfischer, Goodyear, and

Kali (2011), they argued that males and females had significant differences in ICT capabilities, with males scoring higher (65%) than females (45%).

Lin, Tsai, Chai, and Lee (2013); The study of Oz (2015) also supported this finding that teachers' gender contributes to the development of pedagogical knowledge. Female teachers pose higher self-confidence in pedagogical knowledge, but lower self-confidence in technological knowledge than male teachers.

It was found from the study that there was a significant difference in the TPACK of biology teachers based on their qualification. This finding implies that there is a great difference in the level of TPACK of biology teachers based on their qualification. The reason for this outcome is probably because there is a clearer orientation gap between the qualified teachers and the less qualified teachers without proper connection with content knowledge, Pedagogical Knowledge and Technology knowledge Oz (2015). This is in consonance with a study conducted on teachers, pre-service teachers, and educators from different branches, the effectuality, effectiveness and utility of the TPACK model were stressed in environmental planning and assessments (Doering, Scharber, Miler & Veletsianos, 2009; Graham, Cox & Velasquez, 2009; Akkoç, 2010; Bauer,

2010; Williams, Foulger & Wetzel, 2010; Hofer, Grandgenett, Harris & Swan, 2011; Otrell-Cass, Khoo & Cowie, 2012).

Timur and Taşar (2011) stated that science teachers' TPACK reliance levels oriented to the use of technology were low throughout science teaching, and this can be compensated for with professional development activities oriented to the use of technologically enhanced environments in science teaching. Similarly, Selim, Tatar and Öz (2017) determined that mathematics pre-service teachers' mathematics knowledge levels (CK) and their PK levels were in consonance with the changes in the quality of the computer-supported teaching materials that they had prepared.

It was found out in this study that there was a significant difference in the Technological Pedagogical Content Knowledge between experienced, moderately experienced and less experienced biology teachers ($p < 0.05$) in favour of the less experienced biology teachers and then the experienced biology teachers. This result means that TPACK of teachers differs significantly based on their teaching experience. This conclusion could be as a result of the fact that the majority of the new generation biology teachers possess the knowledge of ICT and its integration into instructional practices. The moderately experienced teachers seem to withdraw from it, perceiving technological integration as a distraction to learning and for the few that

have craved for the use. Experienced biology teacher, seem to get along well with the use of ICT probably because most of them have few years in service and are more likely to be engaged in several job interviews which could require them using ICT since every sector is technology driven. According to Koehler, Mishra and Yahya (2007), unless a teacher views technology use as an integral part of the learning process, it will remain a peripheral ancillary to his or her teaching.

The findings of this study are in consonance with Brush and Saye (2009); Kramarski and Michalsky (2010) who submitted that teachers feel inadequately prepared for subject-specific use of ICT and robust theoretical framework is lacking. Similarly, the findings of Koh, Chai, and Tsai (2015) found that there was a significant difference in the level of knowledge that exists between experienced ones and less experienced chemistry teachers. The result shows that the ways the teachers reacted to their teaching differs. Some teachers reflected more on students' difficulties while others are more concerned about their individual performance. Even experienced in-service teachers may feel perplexed when trying to figure out the differences between content and pedagogy (Archambault & Crippen, 2009).

Schmidt, Baran, Thompson, Mishra, Koehler and Shin, (2009) showed significant growth in Teachers' TPACK throughout the study.

Through the teachers' lesson plans, they demonstrated adequate TPACK. Finally, teachers' reflections demonstrated that teachers mostly focused on their TPK for technology integration.

Conclusions

There is a growing body of research interest in assessing biology teachers' TPACK, evident in a considerable body of research. A number of researchers such as Angeli and Valanides (2009) and Graham (2011) warned of drawing too many conclusions from research reporting to measure TPACK knowledge, arguing that there are a number of theoretical issues that need to be addressed.

This current study was aimed to assess the TPACK of biology teachers in senior secondary schools considering the influence of their gender, qualification and teaching experience.

Biology teachers although possess a good mastery of subject but quite a number of them still find ICT not directly applicable in the teaching and learning process. This has hampered the smooth instructional process in the classroom. It was however concluded that there was a significant difference in the TPACK of biology teachers in Kwara State, Nigeria based on gender,

qualification and teaching experience. Hence, the Senior Secondary School biology teachers' TPACK is low.

Implication of the Study

The main aim of this study was to access the TPACK of biology teacher in senior secondary schools in Kwara State, Nigeria. This was done by examining the level of knowledge of biology teachers in teaching biology, the extent of their ICT knowledge in teaching biology, the availability of ICT gadgets to the teachers and the influence of their gender, qualification, and teaching experience their TPACK. The Senior Secondary School biology teachers' TPACK is low and this implies that although biology teachers had good mastery of their subject matter but no ICT-integration in their instructional approach due to lack of ICT knowledge, which could contribute to teachers' inability to cope with the 21st century ICT demand in the classroom.

Recommendations

Based on the findings of this study, the following recommendations were made;

Biology teachers should intensify efforts in developing themselves on their subject matter knowledge as it goes a long way to make teaching and

learning easy for them and their students. A better understanding of their content knowledge will allow them to recognise what makes a specific topic easy or difficult to learn and what better approach can be used in instructional practices. They should desist from the attitude of limiting their knowledge to what they have been taught in school and engage in continuous learning habits like use of the internet, newspapers, use of the library and many others for instructional resources as learning never stops.

Teachers of biology should be encouraged to go for training and retraining programmes on ICT and its application to teaching, keeping in mind the advantage of integrating ICT into instruction, teachers must be aware of the latest ICT resources for teaching. Teaching with technology can also familiarise students with the latest technological tools and prepare them in solving issues relating to ICT tools.

Biology teachers should be encouraged to make use of their digital devices such as their mobile phones, projectors and other modern digital devices for teaching. It is what people do with the machine, not the machine itself that can bring about the desired result. Meanwhile, the adoption of new technologies does not guarantee success but the ability to integrate these devices into classroom instruction is the key.

Biology teachers should be made to identify relevant software packages that could help them in teaching biology topics conveniently. However, as gathered in this study, ICT self-training cannot be overemphasized but it is best when a teacher possesses a formal training which can be built self-training, provided there is the availability of the ICT in schools.

Teachers of biology should be inspired to always put in mind their students' prior knowledge of specific biology concepts before starting to integrate ICT into the teaching of biology topics and more importantly, get to know their misconceptions, alternative conceptions and of course, their positive conception of a particular biology concept. They pose more challenge to the student by making them competitive among themselves, which will make them see beyond the four walls of the classroom, and better understand the use of ICT in the learning process.

Stakeholders in the education sector should provide a level playing ground for teachers irrespective of their gender in the assessment of Technological Pedagogical Content Knowledge. Female biology teachers have proven to have weak TK but possess adequate CK and PK that complement the knowledge gap. Similarly, male teachers were reported to have lower CK and PK but their TK enabled them to overcome the

weaknesses. Effort should be intensified on these areas of weaknesses on both gender since gender has a significant influence on the level of their TPACK.

School administrators, Government, and Educational stakeholders should all give teachers, irrespective of their qualifications, equal opportunities for ICT training and retraining programmes and provide necessary access to some of the ICT devices as practice bring about perfection. This will give room for more challenges for teachers in the classroom instruction and making them become the 21st-century teachers.

Stakeholders in the education sector should realise that teaching is a profession and that whoever must be chosen to go to class must go through teacher training as this will to a certain extent enhance their experience before going to class to teach. This will set the standard for teachers to possess a minimum level of Bachelor's degree in Education before eligible to teach. More so, teaching experienced cannot be overemphasised in the recruitment into teaching job or a measure for judging the biology teachers' TPACK as research has shown that there is a significant difference in the level of Technological Pedagogical Content Knowledge of biology teachers based on their teaching experience.

The main aim of this study was to assess the TPACK of biology teacher in senior secondary schools in Kwara State, Nigeria. This was done by examining the level of knowledge of biology teachers in teaching biology, the extent of their ICT knowledge in teaching biology, the availability of ICT gadgets to the teachers and the influence of their gender, qualification, and teaching experience on their TPACK.

Suggestions for Further Studies

Based on the findings of this study, the following suggestions were made:

- Further studies can be replicated in other parts of the country to assess the Technological Pedagogical Content Knowledge of Biology Teachers in Senior Schools in Nigeria.
- There is a need for this research topic to be replicated at the primary school level, and, tertiary education so as to provide basis and prospect for students in ICT integration
- Other variables like school type and teachers' background would be added to the independent variables to see the effect on Technological Pedagogical Content Knowledge of teachers.
- This study selected Biology Teachers to assess Technological Pedagogical Content Knowledge of teachers; other researchers

could select other teachers from other subjects offered at secondary school.

- Further studies could focus on the academic performance of students taught by teachers with a high level of Technological Pedagogical Content Knowledge compared to those that are taught by teachers with low Technological Pedagogical Content Knowledge.
- Future research should further enhance TPACK assessment in teacher education and evaluation of ICT courses.
- Future researchers may find most intensely to study the peculiarity of TPACK and its connection with respective fields of study.
- Only three of the six components of Technological Pedagogical Content Knowledge were examined in this study (Content Knowledge, Pedagogical Knowledge and Technological knowledge), other components of TPACK such as Knowledge of teachers' educational context, teachers' knowledge of the purpose of education and curriculum knowledge could also be further examined.

REFERENCES

- Abbitt, J. T. (2011). An investigation of the relationship between self-efficacy beliefs about technology integration and technological pedagogical content knowledge (TPACK) among preservice teachers. *Journal of Digital Learning in Teacher Education*, 27(4), 134–143.
- Abimbola, I. O. (2013). *Philosophy of science degree students*. Ilorin: Bamitex Printing and Publishing Enterprise.
- Akingbemisilu & Ayegbo (2019). Implications of Biology Exclusion on Nigerian Non- Science Senior Secondary School Students' Capacity Building in Education. *Journal of African Studies and Development*. Vol 5 (1) pp. 1-7.
- Akkoç, H. (2010). Investigating the Development of Prospective Mathematics Teachers' Technological Pedagogical Content Knowledge with regard to Student Difficulties: The Case of Radian Concept. *Informal Proceedings of the British Society for Research into Learning Mathematics (BSRLM) Day Conference, 13 November 2010* (Vol. 30, No.3, pp. 1-6). Newcastle University, England.
<http://www.bsrlm.org.uk/IPs/ip30-3/BSRLM-IP-30-3-Full.pdf>
(Retrieved from 09.02.2018)

- Alazam, A. O., Bakar, A., Hamzah, R., & Asmiran, S. (2013). Teachers' ICT skills and ICT integration in the classroom: the case of vocational and technical teachers in Malaysia. *Creative Education*, 3(8), 70–76.
- Alazzam, B. (2012). Effects of demographic characteristics, educational background, and supporting factors on ICT readiness of technical and vocational teachers in Malaysia, *International Education Studies*, 5(6), 229-243.
- Albion, P., Jamieson-Proctor, R., & Finger, G. (2010). Auditing the TPACK confidence of Australian pre-service teachers: The TPACK confidence survey (TSC). In D. Gibson & B. Dodge (Eds.), *Proceedings of Society for Information Technology & Teacher Education International Conference 2010* (pp.3772-3779). Chesapeake, VA: AACE
- American Association for the Advancement of Science (2013). *The handbook of technological pedagogical content knowledge (TPACK) for educators*. Mahwah, NJ: Lawrence Erlbaum Associates.
- American Association of Colleges for Teacher Education (AACTE) Committee on Innovation and Technology. (2008). *Handbook of technological pedagogical content knowledge (TPCK) for educators*. New York: Routledge.

- Angeli, C., & Valanides, N. (2009). Epistemological and methodological issues for the conceptualization, development, and assessment of ICT-TPCK: Advances in Technological Pedagogical Content Knowledge (TPCK). *Computers & Education*, 52(1), 154-168.
- Angeli, C., & Valanides, N. (2015). Pre-service elementary teachers as information and communication technology designers: An instructional systems design model based on an expanded view of pedagogical content knowledge. *Journal of Computer Assisted Learning*, 21(4), 292–302.
- Archambault LM, Barnett JH (2010) Revisiting technological pedagogical content knowledge exploring the TPACK framework. *Computer Education* 55(4):1656– 1662
- Archambault, L., & Crien, K. (2009). Examining TPACK of k-12 online distance education in the United States. *Contemporary Issues in Technological and Teacher Education*, 13(1), 71-88.
- Archambault, L. (2016). Exploring the use of qualitative methods to examine TPACK. In M. Herring, M. Koehler, & P. Mishra (Eds.), *Handbook of technological pedagogical content knowledge for educators* (2nd ed., pp. 65-86). New York, NY: Routledge

- Ayoub, K. (2015). TPACK development in teacher design teams: assessing the teachers perceived and observed knowledge in R. McBride, & M. Searson (Eds.) *Proceedings of Society for Information Technology and Teacher Education International Conference 2013* (pp. 4698-4703) Chesapeake, VA: AACE.
- Barbara Vilhar (2017). University of Ljubljana, Biotechnical Faculty, Department of *biology*, Večna pot 111, SI-. 1000 Ljubljana, Slovenia barbara.vilhar@bf.uni-lj.si.<https://www.merriam-webster.com/dictionary/biology>, 2018
- Baser, D., Kopcha, T. & Ozden, M. (2015). Developing a technological pedagogical content knowledge (TPACK) assessment for preservice teachers learning to teach English as a foreign language, *Computer Assisted Language Learning*.
- Bauer, W. (2010). Technological Pedagogical and Content Knowledge for Music Teachers. In D. Gibson & B. Dodge (Eds.). *Proceedings of Society for Information Technology & Teacher Education International Conference 2010*(pp. 3977-3980). Chesapeake, VA: AACE.
- Becker, H.J.; Ravitz, J.L, & Wong, Y (1999). Teacher and teacher directed student use of computers and software. Center for Research on

Information Technology and Organisations, University of California, Irvin, and University of Minnesota.

Bello, R. A. & Abimbola, I. O. (2016). Model of the elements of pedagogical content knowledge. *Unpublished M'Ed. Thesis Department of Science Education, Faculty of Education, University of Ilorin, Nigeria.*

Borowski, A., Neuhaus, B.J., Tepner, O., Wirth, J., Fischer, H.E., Leutner, D., (2010). *Professionswissen von Lehrkräften in den naturwissenschaften (ProwiN) – kurzdarstellung des BMBF-Projekts. Zeitschrift für Didaktik der Naturwissenschaften.*

Brush, T., & Saye, J. W. (2009). Strategies for preparing preservice social studies teachers to integrate technology effectively: Models and practices. *Contemporary Issues in Technology & Teacher Education*, 9(1), 46-59.

Canbazoğlu Bilici, S. (2012). *Fen Bilgisi Öğretmen Adaylarının Teknolojik Pedagojik Alan Bilgisi ve Özyeterlikleri*. Unpublished Doctoral Thesis. Ankara: Gazi University Institute of Educational Sciences.

Cavanagh, R. & Koehler, M. J. (2013). A turn towards specifying validity criteria in the measurement of technological Pedagogical content

- knowledge (TPACK). *Journal of Research in Technology Education*, 11(3), 85-92.
- Cavin, R.M. (2007). Developing Technological Pedagogical Content Knowledge in Preservice Teachers through Microteaching Lesson Study. (*Unpublished doctoral dissertation*). The Florida State University, the United States of America.
- Chai, C. S., Koh, J. H. L., Tsai, C.C., & Tan, W. L. (2011). Modeling primary school preservice teachers' Technological Pedagogical Content Knowledge (TPACK) for meaningful learning with information and communication technology (ICT). *Computers & Education*, 57, 1184-1193
- Chai, C. S., Koh, J. H. L., & Tsai, C.-C. (2016). A review of the quantitative measures of technological pedagogical content knowledge (TPACK). In M. Herring, M. Koehler, & P. Mishra (Eds.), *Handbook of technological pedagogical content knowledge for educators* (2nd ed., pp. 87-106). New York, NY:Routledge.
- Charalambos, V., Michalinos, Z., & Chamberlain, R. (2004). The design of online learning communities: Critical issues. *Educational Media International*, 41(2), 135-143.

- Clare, K., Dharamshi, P., & Menna, L. (2019). From Tinkering Around the Edges to Reconceptualizing Courses: Literacy/English teacher Educator's Views and Use of Technology. *International Research, Policy and Practice in Teacher Education*. (63-73)
- Covey, S. (2011). *The 3rd Alternative: Solving Life's Most Difficult Problems*. New York: Free Press.
- Cox, S., & Graham, C. R. (2009). Diagramming TPACK in practice: Using and elaborated model of the TPACK framework to analyse and depict teacher knowledge. *TechTrends*, 53(5), 60–69.
- Devin, K. (2018). Investigating teacher certificate program in Turkey prospective teachers' Technological Pedagogical Content Knowledge. Necatibey Faculty of Education. *Electronic J. Sci. Mathe. Edu.* 9(2): 252-274.
- Doering, A., Scharber, C., Miller, C., & Veletsianos, G. (2009). GeoThentic: Designing and Assessing with Technology, Pedagogy, and Content Knowledge. *Contemporary Issues in Technology and Teacher Education*, 9(3), 316-336.
- Gess-Newsome, J. (2002). Pedagogical content knowledge: an introduction and orientation. In J. Gess-Newsome & N. Lederman (Eds), *PCK and*

science education (pp. 3–17). New York, NY: Kluwer Academic Publishers.

Gilakjani, Abbas Pourhosein, Leong, Lai-Mei, & Ismail, Hairul Nizam. (2013). Teachers' Use of Technology and Constructivism. *I. J. Modern Education and Computer Science*, 4, 49-63. doi: 10. 5815/ijmecs. 2013. 04. 07

Graham, C. R. (2011). Theoretical considerations for understanding technological pedagogical knowledge (TPACK). *Computers & Education*, 57, 3, 1953–1960.

Graham, C. R., Borup, J., & Smith, N. B. (2012). Using TPACK as a framework to understand teacher candidates' technology integration decisions. *Journal of Computer Assisted Learning*, 28 (6), 530–546. doi: 10.1111/j.1365-2729.2011.00472.x

Graham, C. R., Burgoyne, N., Cantrell, P., Smith, L., Clair, L. S. & Harris, R. (2009). TPACK development in science teaching: measuring the TPACK confidence of inservice science teachers. *TechTrends*, 53, 5, 70–79.

Graham, C., Cox, S., & Velasquez, A. (2009). Teaching and Measuring TPACK Development in Two Preservice Teacher Preparation Programs. In I. Gibson et al. (Eds.), *Proceedings of Society for*

Information Technology & Teacher Education International Conference 2009(pp. 4081-4086). Chesapeake, VA: AACE.

Gronseth, S., Brush, T., Ottenbreit-Leftwich, A., Strycker, J., Abaci, S., Easterling, W., & Leusen, P. V. (2010). Equipping the next generation of teachers: Technology preparation and practice. *Journal of Digital Learning in Teacher Education*, 27(1), 30-36.

Hammond, T. C., & Manfra, M. (2009a). Digital history with student-created multimedia: Understanding student perceptions. *Social Studies Research & Practice*, 4(3), 139-150.

Han, I., Eom, M., & Shin, W. S. (2013). Multimedia case-based learning to enhance pre-service teachers' knowledge integration for teaching with technologies. *Teaching and Teacher Education*, 34(2), 122–129.

Harris, J. B., Grandgenett, N., & Hofer, M. (2010) Testing a TPACK Based Technology Integration Assessment Rubric. In D. Gibson & B. Dodge (eds.), *International Conference 2010*, Chesapeake, VA: Association for the Advancement of Computing in Education (AACE), pp.3833-384. Retrieved from <http://publish.wm.edu/bookchapters/6>

Harris, J. B., & Hofer, M. J. (2011). Technological pedagogical content knowledge in action: A descriptive study of secondary teachers'

- curriculum-based, technology-related instructional planning. *Journal of Research on Technology in Education*, 43(4), 211.
- Harris, J., P. Mishra, & M. J. Koehler. (2009). Teachers' Technological Pedagogical Content Knowledge and Learning Activity Types: Curriculum-based Technology Integration Reframed. *Journal of Research on Technology in Education*. 41(4), 393-416.
- Harris, J. B., Mishra, P., & Koehler, M.J. (2007). *Teachers' technological pedagogical content knowledge: Curriculum-based technology integration reframed*. Paper presented at the 2007 Annual Meeting of the American Educational Research Association, Chicago, IL.
- Hasniza N., (2014). Pre-Service Teachers' TPACK and Experience of ICT Integration in Schools in Malaysia and New Zealand. University of Canterbury, New Zealand.
- Hew, K. F. & Brush, T. (2007). Integrating technology into K-12 teaching and learning: current knowledge gaps and recommendations for future research. *Education Tech Research Development*, 55, 3, 223–252.
- Hicks, T. (2006). Expanding the conversation: A commentary toward revision of Swenson, Rozema, Young, McGrail, and Whitin. *Contemporary Issues in Technology and Teacher Education*, 6(1), 46-55.

- Hofer, M., & Grandgenett, N. (2012). TPACK development in teacher education: A longitudinal study of preservice teachers in a secondary MA Ed. program. *Journal of Research on Technology in Education*, 45(1), 83-106.
- Hofer, M., Grandgenett, N., Harris, J., & Swan, K. (2011). Testing a TPACK-Based Technology Integration Observation Instrument. In M. Koehler & P. Mishra (Eds.), *Proceedings of Society for Information Technology & Teacher Education International Conference 2011*(pp. 4352-4359). Chesapeake, VA: AACE.
- Horzum, M. B. (2013). An investigation of the technological pedagogical content knowledge of pre-service teachers. *Technology, Pedagogy and Education*, 22(3), 303-317. doi: 10.1080/1475939X.2013.795079
- Information and Communication Technology. (2017). How information and communication technology can achieve the sustainable development goals. Key research insights.
- ISTE (2002). *National Educational Technology Standards and Performance Indicators for All Teachers*. Retrieved March 10, 2010, from <http://cnets.iste.org/teachers/tstands.html>.

- Jen, T. H., Yeh, Y. F., Hsu, Y-S., Wu, H-K., & Chen, K. M. (2016). Science teachers' TPACK-Practical: Standard-setting using an evidence-based approach. *Computers and Education*, 95, 45-62.
- Jimoyiannis, A. (2010). Designing and implementing an integrated technological pedagogical science knowledge framework for science teachers' professional development. *Computers & Education*, 55(3), 1259-1269. doi: 10.1016/j.compedu.2010.05.022
- Junnaina, H. C., & Hazri, J. (2014). The Effect of Field Specialization Variation on Technological Pedagogical Content Knowledge (TPACK) Among Malaysian TVET Instructors. *The Malaysian Online Journal of Educational Technology*, 2(1), 36–44.
- Kanuka, H. (2006). Instructional design and e-learning: A discussion of pedagogical content knowledge as a missing construct. *The e-Journal of Instructional Science and Technology*, 9(2). [online]. Retrieved January 25, 2008, from http://www.usq.edu.au/electpub/ejist/docs/vol9_no2/papers/full_papers/kanuka.htm
- Kathryn MacCallum, Lynn Jeffrey, & Kinshuk. (2014). Factors impacting teachers' adoption of mobile learning. *Journal of Information Technology Education*, 13.

Kara, R. (2015). *Biology*. Encyclopedia Britannica. Retrieved from <http://www.britannical.com/science/biology>.

Karasavvidis, I., & Kollias, V. (2014). Technology integration in the most favorable conditions: findings from a professional development training program. In C. Karagiannidis (Ed.), *Research on e-learning and ICT in education* (pp. 197–224). New York: Springer.

Kay, R. H. (2006). An analysis of methods used to examine gender differences in computer-related behavior. *Journal of Educational Computing Research*, 8(3), 323-336.

Kazua, I. & Demirkol, M. (2014). Effect of blended learning environment model on high school students' academic achievement. *The Turkish Online Journal of Educational Technology* 13(1).

Khaddage, Ferial, & Knezek, Gerald. (2013). *Introducing a Mobile Learning Attitude Scale for Higher Education*. Paper presented at the X World Conference on Computers in Education, Toruń, Poland.

Koehler, M. J., Mishra, P., & Yahya, K. (2007). Tracing the development of teacher knowledge in a design seminar: Integrating content, pedagogy and technology. *Computers & Education*, 49(3), 740-762.

Koehler, M. J., Shin, T. S., & Mishra, P. (2012). How Do We Measure TPACK? Let Me Count the Ways. In R. N. Ronau, Rakes, C. R., &

- Niess, M. L. (Ed.), *Educational Technology, Teacher Knowledge, and Classroom Impact: A Research Handbook on Frameworks and Approaches* (pp. 16-31).
- Koehler, M. J. & Mishra, R. (2005). What happens when teachers design educational technology? The development of technological pedagogical content knowledge. *Journal of Educational Computing Research*, 32, 2, 131–152.
- Koehler, M. J. & Mishra, R. (2008). Introducing TPACK. In AACTE committee on innovation and technology (Ed.), *Handbook of technological content knowledge (TPCK)* (pp. 3–30). New York: Routledge.
- Koehler, M. J., & Mishra, P. (2009). What is technological pedagogical content knowledge? *Contemporary Issues in Technology and Teacher Education (CITE Journal)*, 9(1), 60-70.
- Koh, J. H. L., & Divaharan, S. (2011). Developing pre-service teachers' technology integration expertise through the TPACK-developing instructional model. *Journal of Educational Computing Research*, 44(1), 35-58.
- Koh, J. L., Chai, C. S., & Tsai, C. C. (2015). Examining the technological pedagogical content knowledge of Singapore preservice teachers with a

- large-scale survey. *Journal of Computer Assisted Learning*, 26(6), 563-573. doi:10.1111/j.1365- 2729.2010.00372.x
- Kramarski, B., & Michalsky, T. (2010). Preparing preservice teachers for self-regulated learning in the context of technological pedagogical content knowledge. *Learning and Instruction*, 20(5), 434–447.
- Kyriakidou, Maria, Chrisostomou, Charalambos, & Banks, Frank. (1999). Primary Teachers' Attitude to the Use of ICT: a comparative study between Cyprus and the UK. Paper presented at the the European Conference on Educational Research, Lahti, Finland
- Lee J. (2010). Design of blended training for transfer into the workplace. *British Journal of Educational Technology*, 41(2), 181-198.
- Lee, M. H., & Tsai, C. C. (2010). Exploring teachers' perceived self-efficacy and technological pedagogical content knowledge with respect to educational use of the World Wide Web. *Instructional Science*, 38, 1–21.
- Lee, M. H., Tsai, C. C., & Chang, C. Y. (2008). *Exploring teachers' self-efficacy toward the Web Pedagogical content knowledge in Taiwan*. Paper presented at the Annual Meeting of the American Educational Research Association (March 24-28). New York City. Retrieved from

<http://www.docin.com.cn/p-753966186.html>MEB. (2005). 4–7

İlköğretim sosyal bilgiler öğretim programı. Ankara: MEB.

Lin, T. C., Tsai, C. C., Chai, C. S., & Lee, M. H. (2013). Identifying biology teachers' Perceptions of Technological Pedagogical and Content Knowledge (TPACK). *Journal of Biology Educational Technology*, 13(22), 325-336.

LiveScienc. (2017). 08-11:3:29pm. *The Science and Study of Living Organisms*. Retrieved from [https:// www.livescience.com](https://www.livescience.com).

Loughram, J., Mulhall, P., & Berry, A. (2004). In search of pedagogical content knowledge in science: Developing ways of Articulating and Documenting professional practices. *Journal of Research in Science Teaching*. 41(4), 370-391.

Lux, N. J. (2010). *Assessing Technological Pedagogical Content Knowledge*. Unpublished 3430401, Boston University, United States - Massachusetts.

Magnusson, S., Krajcik, J. & Borko, H. (1999). Nature, sources, and development of pedagogical content knowledge for science teaching. In J. Gess-Newsome & N. Lederman (Eds), *PCK and science education* (pp. 3–17). New York, NY: Kluwer Academic Publishers.

- Mahdum. (2015). Technological pedagogical and content knowledge (TPACK) of English teachers in Pekanbaru, Riau, Indonesia. *Mediterranean Journal of Social Science*, 6(5), 168-176.
- Manfra, M., & Hammond, T. C. (2008). Teachers' instructional choices with student-created digital documentaries: Case studies. *Journal of Research on Technology in Education*, 41(2), 223-245.
- Maor, D. & Roberts, P. (2011). Does the TPACK framework help to design a more engaging learning environment? In T. Bastiaens & M. Ebner (Eds.), *Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications 2011* (pp. 3498-3504). Chesapeake, VA: AACE.
- Margerum-Leys, J., & Marx, R. W. (2002). Teacher knowledge of educational technology: A case study of student/mentor teacher pairs. *Journal of Educational Computing Research*, 26(4), 427-462.
- Markauskaite, L., Bachfischer, A., Goodyear, P., & Kali, Y. (2011). Beyond technology, pedagogy and content: Insights into the knowledge bases for collaborative elearning design. Paper presented at the American Educational Research Association Annual Meeting, New Orleans, Louisiana.

- Markauskaite, L. (2006). Gender issues in pre-service teachers' training: ICT literacy and online learning. *Australian Journal of Educational Technology*, 22, 1-20.
- Mayr, E (2004). What makes biology unique? Consideration on the autonomy of a scientific discipline. Harvard University: Cambridge University Press, New York.
- Mehan, H. (1989). Microcomputers in classrooms: Educational technology or social practice? *Anthropology & Education Quarterly*, 20(1), 4-22.
- Merriam-webstar (2014). Definition of Biology Retrieved from <https://www.merriam-webstar.com/biology>.
- Miller, S.M. (2008). Teacher learning for new times: Repurposing new multimodal literacies and digital video composing for schools. In J. Flood, S.B. Heath, & D. Lapp (Eds.), *Handbook of research on teaching literacy through the communicative and visual arts*. New York: International Reading Association/Simon & Schuster Macmillan.
- Mims, C., Polly, D., Shepherd, C., & Inan, F. (2006). Examining PT3 projects designed to improve pre-service education. *Tech trend* 5(3), 17-24.

- Mishra, P & Koehler, M. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record*, 108(6) 1017– 1054
- Mishra, P. & Koehler, M. J. (2005). What happens when teachers design educational technology? The development of technological pedagogical content knowledge. *Journal of Educational Computing Research*. 32(2), 131-152.
- Mishra, P. (2012). Is TPACK Fundamentally Flawed? A Quick Response, Retrieved June 1st 2012 from <http://punya.educ.msu.edu/2012/01/24/is-tpack-fundamentally-flawed-a-quick-resonse/>
- Mishra, P., & Koehler, M. J. (2008). *Introducing Technological Pedagogical Content Knowledge*. Paper presented at the Annual Meeting of the American Educational Research Association. Retrieved from http://punya.educ.msu.edu/presentations/AERA2008/MishraKoehler_AERA2008.pdf
- Mishra, P., Koehler, M. J., Zellner, A., & Kereluik, K. (2012). Thematic Considerations in Integrating TPACK in a Graduate Program. In D. Polly, C. Mims & K. A. Persichitte (Eds.). *Developing Technology-*

- Rich Teacher Education Programs: Key Issues (pp. 1-12). Hershey, PA: IGI Global.
- Murphy, R., Penuel, W., Means, B., Korbak, C., Whaley, A. (2001). E-DESK: A review of recent evidence on the effectiveness of discrete Educational Software. Menlo Park, CA: SRI International.
- Nasution, Sriyati, Riandi & Safitri. (2017). Mastery of Content Representation (CoRes) Related TPACK High School Biology Teacher. *Journal of Physics: Conference Series*, 895(1). DOI: 10.1088/1742/89-65965/1/012125.
- National Council of Teachers of Mathematics (2000). *The Technology Principle*. Retrieved from <http://standards.nctm.org/document/chapter2/techn.htm>
- National Research Council. (2000) *How people learn: Brain, mind, experience, and school*. Washington, DC: National Academy Press.
- Niess, M. L. (2005). Preparing teachers to teach science and mathematics with technology: Developing a technology pedagogical content knowledge. *Teaching and Teacher Education*, 21(5), 509-523.
- Niess, M. L. (2013). TACK in the classroom: Developing Technological Pedagogical, and Content Knowledge. Retrieved May 30th 2013 from

<http://www.igi-global.com/newsroom/archive/tack-classroom-developing-technologies/1547/>

- Niwat, S. (2012). Student Teachers' Perceptions of Computerized Laboratory Practice for Science Teaching: A Comparative Analysis. *Procedia-Social and Behavioral Sciences 2012* (Vol.46,pp.4031-4038).DOI: 10.1016/j.sbspro.2012.06.192
- Olatoye, M. A. & Nieya, P. T. (2014). The impact of designed-object based game on the performance of JSS 2 students in Mathematics. *American Journal of Educational Research* 2(8): pp 674-682. DOI: 10.12691/education-2-8-17.
- Otrell-Cass, K., Khoo, E., & Cowie, B. (2012). Scaffolding with and through Videos: An Example of ICT-TPACK. *Contemporary Issues in Technology and Teacher Education*,12(4), 369-390
- Oz, H. (2015). Assessing pre-service English as a foreign language teachers' technological content knowledge. *Int. Educ. Stud.* 8(5): 119-130.
- Özgün-Koca, S. A., Meagher, M. & Edwards, M.T. (2010). Preservice Teachers 'Emerging TPACK in a Technology-Rich Methods Class. *The Mathematics Educator*, Vol. 19, No. 2, 10–20

- Pamuk, S., & Marino, M. T. (2013). Understanding pre-service teachers' technology use through TPACK framework. *J. Computer Assisted learn.* 28:425-439.
- Papanikolaou, K., Gouli, E., & Makri, K. (2014). Designing pre-service teachers training based on a combination of Educational Sciences (WCES-2013). *Procedia-Social and Behavioral Science.* 116, 3437-3442.
- Parker, J. & Heywood, D. (2000). Exploring the relationship between subject knowledge and pedagogic content knowledge in primary teachers learning about forces. *International Journal of Science Education*, 22(1): 89-111.
- Peruski, L., & Mishra, P. (2004). Webs of activity in online course design and teaching. *Research in Learning Technology*, 12(1), 37-49.
- Petra, F., Joke V., Johan, V.B., & Jo, T. (2015). The SAGE Encyclopedia Technology: *Measuring and Assessing Technological Pedagogical Content Knowledge.* 490-493. Thousand Oaks
- Pierson M. E. (2001) Technology integration practice as a function of pedagogical expertise. *Journal of Research on Computing in Education* 33, 413–430.

- Polly, D., McGee, J. R., & Martin, C. S. (2010). Employing technology-rich mathematical tasks in professional development to develop teachers' technological, pedagogical, and content knowledge (TPCK). *Journal of Computers in Mathematics and Science Teaching*, 29, 455-472.
- Prensky, M. (2013). Listen to the natives. *Educational Leadership*, 63(4), 8-13.
- Pusparini, F., Riandi, R., & Sriyati, S. (2017). Developing Technological Pedagogical Content Knowledge (TPACK) in Animal Physiology. *Journal of Physics: Conference Series*, 895(1).
- Ringstaff, C., & Kelley, L. (2002). The learning return on our educational technology investment. WestEd.
- Rogers, Joshi, & Green (2019). Basic Concepts of Biology Retrieved from <http://coporate.botannica.com>
- Sahin, I. (2011). Development of survey of technological pedagogical and content knowledge (TPACK). *TOJET—The Turkish Online Journal of Educational Technology*, 10, 1, 97–105.
- Schmidt, D. A., Baran, E. A., (2009). Technological Pedagogical Content Knowledge (TPACK). The Development and Validation of an Assessment Instrument for Preservice Teachers, 123-149.

- Selim, Y., Tatar, E., & Öz, R. (2017). Matematik Öğretmen Adaylarının Hazırladıkları Öğretim Materyallerinin TÖMAB Modeli ile İncelenmesi. *EÜFBED -Fen Bilimleri Enstitüsü Dergisi*,2(2), 239-251.
- Shaharom, N., & Faridah, S. (2010). Tahap Pencapaian Pengetahuan Pedagogi Dan Kandungan Dalam Kalangan Bakal Guru Fizik. *Repository Universiti Teknologi Malaysia*.
- Shulman, L. S. (1987). Knowledge and teaching: foundations of the new reform. *Harvard Educational Review*, 57, 1, 1–22.
- Shulman, L.S. (1986). Those who understand: Knowledge growth in teaching. *Educational Research*, 15(2): 4-14.
- So, H. J. & Kim, B. (2009). Learning about problem based learning: Student teachers integrating technology, pedagogy and content knowledge. *Australasian Journal of Educational Technology*, 25(1), 101-116.
- Soyibo, K., Ekpunobi, E. N., Akinade, E. A., Muhammed, S. A. & Tureta, M. S. A. (2013). Revised Edition. *Nelson functioned biology for senior secondary schools*. Nelson Publishers. Ibadan, Nigeria.
- Strawhecker, J. (2005). Preparing elementary teachers to teach mathematics: How field experiences impact pedagogical content knowledge. *Issues in the Undergraduate Mathematics Preparation of*

- School Teachers: The Journal*, 4. [online]. Retrieved December 19, 2007, from <http://www.k-12prep.math.ttu.edu/journal/curriculum/strawhecker/article.pdf>
- Subramony, D. P. (2007). Understanding the complex dimensions of the digital divide: Lessons learned in the Alaskan arctic. *The Journal of Negro Education*, 76(1), 57-67.
- Syh-Jong, J., & Kuan-Chung, C. (2010). From PCK to TPACK: Developing a transformative model for pre-service science teachers. *Journal of Science Educational Technology*, 19, 553–564.
- Timur, B. & Taşar, M. F. (2011). In-Service Science Teachers' Technological Pedagogical Content Knowledge Confidences and Views about Technology-Rich Environments. *Center for Educational Policy Studies (CEPS) Journal*, 1(4), 11-25.
- Tseng, J. J. (2014). Developing an instrument for assessing technological pedagogical content knowledge as perceived by EFL students. *Computer Language Learning*: 29(2), 302-315.
- UNESCO (2002). Information and communication technology in education- A curriculum for schools and program of teacher development. Paris: UNESCO.

- Voogt, J., Fisser, P., Pareja Roblin, N., Tondeur, J., & van Braak, J. (2013). Technological pedagogical content knowledge (TPACK) – A review of the literature. *Journal of Computer Assisted Learning*, 29, 109–121.
- Wang, W., Schmidt-Crawford, D., & Jin, J. (2018). Preservice Teachers' TPACK Development: A Review of Literature. *Journal of Digital Learning in Teacher Education* 34 (4),234-258.
- Williams, M. K., Foulger, T., & Wetzel, K. (2010). Aspiring to reach 21st Century Ideals: Teacher Educators' Experiences in Developing their TPACK. In D. Gibson & B. Dodge (Eds.), *Proceedings of Society for Information Technology Teacher Education International Conference 2010*(Vol. 13, pp. 3960-3967). AACE.
- Wetzel, K., Buss, R., Foulger, T. S., & Lindsey, L. (2014). Infusing educational technology in teaching methods courses: Successes and dilemmas. *Journal of Digital Learning in Teacher Education*, 30(3), 89-103
- Wu, Y., & Wang A. Y. (2015). Technological pedagogical content knowledge in teaching English as a foreign language: Representation of primary school teachers of English in Taiwan Asia-Pac. Educ. Res. 24(3): 525-533.

- Yapici, İ. Umit, & Hevedanli, Murat. (2012). Pre-Service Biology Teachers' Attitudes towards ICT Using in Biology Teaching. *Procedia - Social and Behavioral Sciences* 64 633 – 638. doi: 10. 1016/j. sbspro. 2012. 11. 074
- Yager, R.E. (2000). The constructivist learning model. *The Science Teacher*, 67(1): 44-45.
- Zhang, Y. (2005). Development and validation of an Internet use attitude scale. *Computers and Education*. Available at: <http://www.sciencedirect.com/science> {Accessed 10 February 2006}.
- Zhao, Y. (2003). What teachers should know about technology: Framing the question. In Y. Zhao (Ed.), *What should teachers know about technology: Perspectives and practices*. Greenwich, CT: Information Age Publishi

APPENDIX I
DEPARTMENT OF SCIENCE EDUCATION
FACULTY OF EDUCATION
UNIVERSITY OF ILORIN
QUESTIONNAIRE ON TECHNOLOGICAL PEDAGOGICAL
CONTENT KNOWLEDGE OF BIOLOGY TEACHERS IN SENIOR
SECONDARY SCHOOLS IN KWARA STATE, NIGERIA

Dear Sir/Ma,

The purpose of this instrument is to gather relevant information on senior secondary school biology teachers' technological pedagogical content knowledge. Technological Pedagogical Content Knowledge refers to the complex interrelationship between a teacher technology use, instructional methods, and understanding of the subject matter.

Kindly respond to all items by ticking (✓) where appropriate. Your responses will be treated with utmost confidentiality.

Thank you in anticipation of your cooperation.

Bello, Abdulrazak Agboola

SECTION A: PERSONAL INFORMATION

1. (a). Name of School_____
2. Sex: Male () Female ()
3. Qualifications: Ph.D () M.Ed () M.sc () P.G.D.E () B.sc (Ed) ()
B.sc () HND () OND () NCE ()
Others please specify_____
4. Teaching experience:
Below 5 years () 5-10years () 10 years and above ()

SECTION B: Please indicate appropriately the availability and accessibility of ICT Gadgets with Available (AV), Not available (NV), Accessible (AS) and Not Accessible (NA). However kindly rate your level of expertise in the following ICT gadgets. (1) Needs Improvement (2)-Fair (3)-Average (4)-Good (5)-Very Good (6)-Excellent

ICT Gadgets	Availability		Accessibility		Confidence Level						Challenge in usage		
	AV	NV	AS	NA	1	2	3	4	5	6	Formal Training	Informal Training	Self-Training
SOFTWARE													
MS Word													
Power Point													
MS Excel													
Paint Editor													
Corel Draw													
Animations in biology													
Computer Base Test													
HARDWARE													
Computer in the classroom													
CD ROM													
RAM													
Media Player													
DVD													
Printer													
Projector													
Scanner													
Digital Camera													
Interactive white board													
Mobile device													
Podcast													
Digital Camera													
Digital video													
Wireless classroom microphone													
SOCIAL MEDIA													
Email													
Facebook													

ICT Gadgets	AV	NV	AS	NA	1	2	3	4	5	6	Formal Training	Informal Training	Self-Training
WhatsApp													
MSN messenger													
Class blog													
Wikipedia													
Class website													
Online media													
Online Study tools (example flashcard,Study Group, classnote)													
Qzone													
WeChat													
LinkedIn													
Skype													
Google+													
Twitter													
Viber													
Snapshot													
Myspace													
Badoo													
Flicks													
Classmate													
Weeworld													
Livejournal													
Netlog													
Studiv													
Friendster													
Cyworld													
51.com													

SECTION C: Please rate your level of expertise in teaching biology.

Rating scale: (1) Needs Improvement

(2)-Fair

(3)-Average

(4)-Good

(5)-Very Good

(6)-Excellent

	1	2	3	4	5	6
CONCEPT OF LIVING						
Character of living things						
Cell Structure/Cell Theory						
REPRODUCTION						
Basic Ecological Concepts						
Habitat						
Ecosystem						
ECOLOGICAL SYSTEM						
Ecological Successions						
Trophic Level						
Pyramid of Energy						
Pollution						
Conservation						
PLANT AND ANIMAL NUTRITION						
Nutrition/Macronutrient						
Photosynthesis						
Osmosis						
Osmoregulation						
RESPIRATION						
Cellular						
Respiration						
Insectivorous Plants						
CONSERVATION OF MATTER & ENERGY						
Conservation						
Thermodynamics						
VARIATION AND VARIABILITY						
Variation						
Variability						
EVOLUTION						
Theory of Evolution						
Hybrid						
Competition						
GENETICS						

Mendel's Laws

Genotype

Phenotype

Hybrid

Mutation

Probability

Section D: Please rate your level of confidence in the following Technological Pedagogical Content Knowledge.

Rating scale: (1) Needs Improvement

(2) Fair

(3) Average

(4) Good

(5) Very Good

(6) Excellent

Key: Technological Knowledge (TK), Pedagogical Knowledge (PK), Content Knowledge (CK), Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK) and Technological Pedagogical Content Knowledge (TPACK)

TPACK COMPONENT (I have knowledge in...)	COMPONENT	1	2	3	4	5	6
Keeping up with important new technologies	(TK)						
using different devices for teaching	(TK)						
using ICT tools to allow students to observe pictures and diagrams	(TK)						
solving technical problem with the computer	(TK)						
using projector	(TK)						
using digital camera	(TK)						
using a printer	(TK)						
adapting my teaching style to different learners	(PK)						
assessing students performances	(PK)						
eliminating individual differences	(PK)						

applying different learning theories (for example, Constructivist learning, multiple intelligence theories).	(PK)
using different evaluation methods	(PK)
been aware of possible student difficulties	(PK)
been aware of possible student misconceptions	
knowing about key concepts in biology	(CK)
developing class activities	(CK)
follow recent developments and applications in biology	(CK)
following conferences and activities in biology.	(CK)
following up-to-date resources (such as books, journals) in biology.	(CK)
recognizing leaders in biology concepts	(CK)
selecting effective teaching methods to guide student thinking and learning in biology	(PCK)
developing evaluation test and surveys in biology	(PCK)
preparing a lesson plan including class-school-wide activities	(PCK)
making connection among related concepts in biology	(PCK)
meeting objectives described in my lesson	(PCK)

supporting concepts in biology with outside (out-of-school) activities	(PCK)
technologies that I can use for understanding biology	(TCK)
using technologies helping to reach course objective easily in my lesson plan	(TCK)
preparing a lesson plan requiring use of instructional technologies	(TCK)
developing class activities involving use of instructional technologies	(TCK)
choosing technologies appropriate for my teaching/learning approaches	(TPK)
using computer applications that enhance students' learning	(TPK)
being able to select technologies useful for my teaching career	(TPK)
evaluating appropriateness of a new technology for teaching and learning	(TPK)
integrating appropriate instructional methods and technologies into biology	(TPACK)
teaching successfully by combining my content, pedagogy, and technology knowledge	(TPACK)
Taking a leadership role among colleagues in	(TPACK)

the integration of content, pedagogy, and
technology knowledge

Teaching a subject with different instructional (TPACK)
strategies and computer applications

APPENDIXII

Dissemination of Major Findings

The findings of this study will be explained as below:

Journal publications: The result of the study will be published in a reputable journal of high academic standard.

Workshops: The researcher would organize workshops for Biology Teachers based on the study on how they can integrate the use of ICT into teaching of biology in Senior Secondary School.

Seminars: the researcher would organize seminar for Biology Teachers on the relevance of integrating ICT in Teaching of biology in order to promote effective teaching and learning.

Print Media: Various articles would be published in the media to make the progress of the ICT integration and possible problem encountered by the Biology Teachers in the process of teaching biology.

Organize Talk: The researcher would organize talks among secondary school biology teachers for improving the teaching of biology.

APPENDIX III

DESCIRPTON OF ITEM		EXPECTED FROM SPONSOR	STUDENT	TOTAL OTHERS
1.0	Personal Costs Assistances			
1.1	3 Research Assistant #20,000 Per head	STUDENT	#60,000	
1.2	3 Researcher information #20,000 Per head	STUDENT	#60,000	
1.3	3 Technical Assistant #20,000 Per head	STUDENT	#60,000	
	Subtotal (not>30% of budget)	STUDENT	#10,000	
2.0	Equipment (list and specify)	STUDENT		
2.1	Laptop	STUDENT	#170,000	
2.2	Printer HP LaserJet P1005	STUDENT	#35,000	
2.3	Modem	STUDENT	#5,000	
	Subtotal (not 20% of budget)	STUDENT	#210,000	
3.0	Supplies Consumables	STUDENT		
3.1	Papers	STUDENT	#10,000	
3.2	Toner	STUDENT	#15,000	
3.4	Textbooks	STUDENT	#15,000	
3.5	Monthly subscription of data #2,000 per month	STUDENT	#100,000	
	Subtotal	STUDENT	#140,000	
4.0	Data Collection and Analysis	STUDENT		
4.1	Analysis	STUDENT	#40,000	
4.2	Cost of Administering the Questionnaire	STUDENT	#200,000	
	Subtotal	STUDENT	#240,000	
5.0	Travels	STUDENT	#200,000	
5.1	Researcher	STUDENT	#10,000	
5.2	Research Assistant #10,000 Per head	STUDENT	#30,000	
	Subtotal	STUDENT	#240,000	
6.0	Dissemination	STUDENT		
6.1	Conferences	STUDENT		

			#80,000
6.2	Journal publication	STUDENT	#40,000
6.3	Proposal Presentation	STUDENT	#50,000
6.4	Oral Examination	STUDENT	#300,000
	Sub Total	STUDENT	#470,000
7.1	Miscellaneous	STUDENT	#100,000
	GRAND TOTAL		#1,580,000

APPENDIX IV

Ph.D. RESEARCH TIME LINE

	19-10-2016	19-11-2016	19-12-2016	19-01-2017	19-02-2017	19-03-2017	19-04-2017	19-05-2017	19-06-2017	19-07-2017	19-08-2017	19-09-2017	19-10-2017	19-12-2017	19-12-2017	19-01-2018	19-02-2018	19-03-2018	19-04-2018	19-05-2018	19-06-2018	19-07-2018	19-08-2018	19-09-2018	19-10-2018	19-11-2018	19-12-2-18	19-01-2019	19-02-2019	19-03-2019
Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
TASK																														
Survey of Literature																														
Write Proposal																														
Gather Data																														
Thesis Writing																														
Writing introduction																														
Revise introduction																														
Write Methodology																														
Revise Methodology																														
Result and Discussion																														
Revise Result and Discussion																														
Write Conclusion																														
Revise Conclusions																														
Acknowledgement and Appendix																														
Revise First Draft																														
Proof reading																														
Printing and binding																														

