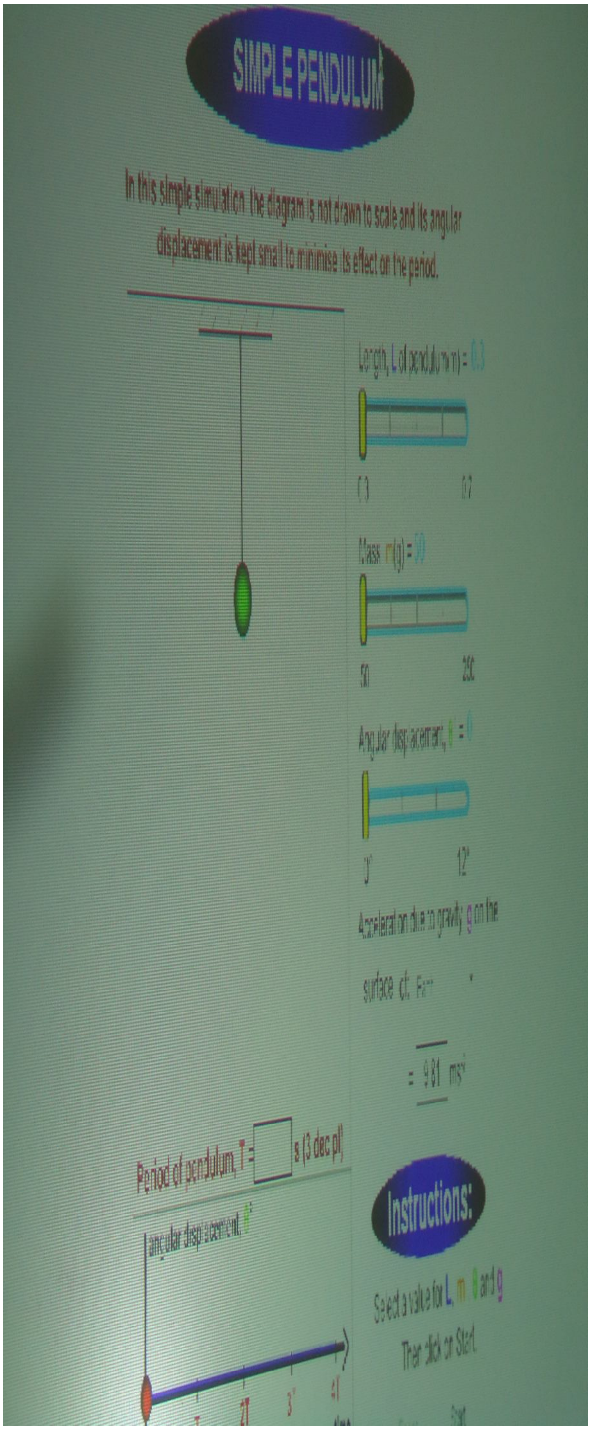
TPACK for Pre-service Science and Mathematics Teachers



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Preface

This article is focused on unveiling the concept of TPACK in relation to teaching and learning in science and mathematics as well as the meaning of TPACK for pre-service science and mathematics teachers training. In describing this, different literatures were consulted on the meaning of TPACK, its origin and the way it can be integrated in pre-service science and mathematics teacher preparation. It was noted from literature that TPACK is the core of good teaching with technology, and that it's important for teachers to have an understanding of TPACK. Studies further show that the way pre-service teachers are taught to integrate technology, pedagogy and content is the same way they can implement the approach in their own teaching. In addition, studies argue for pre-service teachers to learn on how technology can help to enhance students learning in science and mathematics rather than learning how to teach technology. Different frameworks have been proposed on how to shift from teaching technology to using technology to enhance learning. For example some studies provide the curricular plans for developing pre-service teachers' competencies of integrating technology pedagogy and content. To enhance pre-service teachers' competency in technology integrations, some studies have reported the need for pre-service science and mathematics teachers to engage in the hands-on activities that reflect the real teaching with technology. Example of hands activities proposed in most studies includes planning of a lesson, presenting it to peers, getting critics from peers and re-planning it again. The cyclic development of the lesson is reported to enhance pre-service teachers' competency in working with technology in a real classroom situation. It is therefore concluded that implementation of TPACK in pre-service teachers training should start with orientation of the pre-service teachers to the use of technology in teaching by providing them with sufficient opportunity to engage in hands-on activities.

Key words
Pre-service teachers, ICT, Technology integration, Teaching, Science and Mathematics

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CHAPTER ONE

Science, Mathematics and ICT

1.1 Introduction

Science and mathematics subjects are currently placing a lot of challenges to teachers on how they teach and to students on how they learn. The increasing failure rates in these subjects have become a concern of all stakeholders in education: government, parents, students, curriculum developers and schools (Beauchamp & Parkinson, 2008; Ezeife, 2003). Many countries are experiencing a gradual dropdown on students' participation and performance in science and mathematics subjects (Beauchamp & Parkinson, 2008; Mwinshekke, 2003; Royal Society, 2008). Some people see the failure in science and mathematics as resulting from the curriculum, others think is the result of poor teaching approaches and some think it results from students' dislikes of those subjects (Beauchamp & Parknson, 2008). A study by 'Trends in International Mathematics and Science Study (TIMSS)' shows that, achievement in science and mathematics is decreasing all over the world. Only few countries are having scores above the significantly TIMSS scale average which is 500, with the majority of countries having scores below 500 (Martin et al., 2008).

To enhance learning in science and mathematics, teachers need to have a focus on the relationship that exists between the educational task, the scientific concepts and technological tool that students use in responding to the task (Jahreie, 2010). According to Jahreie, majority of teachers and schools are paying more attention on pedagogy and content, forgetting the technological domain. The current discussion on teaching and learning all around the world are demanding the adoption of the learner centered approach rather than the traditional teacher centered approaches. However the adoption of learner centered approach, an approach widely promoted throughout the world, requires the use of educational technology which allows students to engage in a flexible learning that allow dynamism of learning in terms of location, time, materials, content and teaching approaches (Collis & Moonen, 2001).

Thus this paper proposes the adoption of information and communication technology (ICT) in science and mathematics teaching, as an alternative method to enhance teaching and leaning in these subjects. ICT implies any product that will store, retrieve, manipulate, transmit or receive information electronically in a digital form (Luppicini, 2005). Examples of ICTs includes; personal computers, digital television, email, digital camera and other electronic hardware and software. However, for the purpose of this paper more focus will be given on ICT in education, which refers to the instructional use of computers, television, and other kinds of electronic hardware and software (Luppicini, 2005). ICT in education or educational technology is sometimes used interchangeably with instructional technology which refers to the theory and practice of using technology for design, development, utilization, management, and evaluation of processes and resources for learning (Moller, Huett & Harvey, 2009).

Many writers on educational technology describe technology in terms of digital and analogy technologies, but Koehler & Mishra (2009) argue that, "on an academic level, a pencil and a software simulation are both technologies. But the latter, is qualitatively different in that its functioning is more opaque to teachers and offers fundamentally less stability than more traditional technologies" (p. 61). According to Koehler & Mishra, by their nature, newer digital technologies, which are protean, unstable, and opaque, present new challenges to teachers who are struggling to use more technology in their teaching. Some of these challenges include social and contextual factors (Koehler and Mishra, 2009). To overcome these challenges, Kohler & Mishra call for an approach that treats teaching as an interaction between what teachers know and how they apply what they know in the unique circumstance or contexts within their classroom. In doing this, it is important for a teacher to realize that, "at the heart of good teaching there are three components: content, pedagogy, and technology, plus the relationship among and between them" (p.62). These three components form the core of the technological, pedagogical content knowledge (TPACK) framework (Mishra & Koehler, 2006, 2009). The interplay between the various components of TPACK at a given context is what makes effective teaching with technology. This implies that technology integration in teaching science and mathematics should take into consideration the context under which learning is taking place and the specific characteristics of science and mathematics that can be supported by that particular technology.

1.2 Problem Statement

The presence of computers, televisions, radio, mobile phones, iPods, cameras etc in schools may not necessarily imply technology integration in education. The major question that schools and educational planners need to ask themselves is how best those technologies are being used to enhance learning. According to Bayler & Ritchie (2002), there are some schools which opt to place computers in labs, whereas others use group techniques in the classroom. As well there are teachers who focus on learning about computers while others focus on learning with computers. These differences on how technology is viewed and used by each educational stakeholder are hampering the positive effects that technology can bring on students' learning. Given these differences on the view of technology among teachers and schools, the question "how can these schools and teachers integrate technology in education?" can be asked.

Although the integration of technological, pedagogical and content, is currently receiving great emphasis in the educational world, there is no evidence that teachers are properly integrating these components in their teaching. Thus this review is expected to provide the framework for developing technology integration skill and an understanding of TPACK framework and its meaning to pre-service science and mathematics teachers' preparation. This will be done by proposing the required pre-service teachers' training that can enhance pre-service teachers' competencies in TPACK. This will help to define the role of teacher training colleges in developing ICT competencies for prospective teachers.

1.3 Study Questions

Based on the problem stated in the previous paragraph, the main question for this literature study is formulated as *"What are the possibilities of the TPACK framework in relation to pre-service science and mathematics teachers preparation?"* This question leads to other sub-questions as follows:

1. What is TPACK?
2. What do we know about TPACK in relation to science and mathematics teaching?
3. What does TPACK mean for pre-service science and mathematics teachers' training?

1.4 Rationale of the Study

Technology integration in education is not a new phenomenon; it started since 1990s when computers were first introduced in education. Thus any discussion or study about technology integration in education should first analyze what was done from 1990s, what is being done and the future prospects of technology integration in education. In this regards, this literature study is carried out to draw a theoretical framework of what has been done to have technology integrated in education, what is being done at present and what are the possible opportunities in the integration of technology in education.

In recent years, a new model for teachers' technology integration has been developed. This model requires teachers' competency in technology pedagogy and content to form the technological pedagogical content knowledge (TPACK). To develop an understanding of the opportunities and challenges available in TPACK for pre-service science and mathematics teachers' preparation, it is considered important to review what other researchers have done so far, what challenges they have encountered and what opportunities are available and how to utilize those opportunities. Additionally, this literature study was considered important in developing an understanding of underlying theories, principles, opportunities and challenges for developing pre-service science and mathematics teachers' competency in TPACK.

1.5 Overview of this study

This book is organized into four chapters, each having specific areas of focus in addressing an understanding of TPACK and its meaning to science and mathematics teaching and pre-service teachers' preparation. The first chapter introduces the concept of science and mathematics in relation to ICT, statement of the problem, research question and rationale of the paper. You will also find the concept of TPACK, and the interplay between components of TPACK in chapter two. Chapter three describes the relationship between TPACK and teaching of science and mathematics where as chapter four presents the meaning of TPACK for pre-service science and mathematics teaching.

1.5 Definition of terms

In this study the following terms will have the following meanings:

Technology will mean the know-how and creative processes that may assist people to utilize tools, resources and systems to solve problems and to enhance control over the natural and made environment in an endeavour to improve students' learning.

Educational technology refer to the study and ethical practice of facilitating learning and improving performance by creating, using and managing appropriate technological processes and resources.
Technological Pedagogical Content Knowledge (TPACK) the essential qualities of knowledge required by teachers for technology integration in their teaching, while addressing the complex, multifaceted and situated nature of teacher knowledge. At the heart of the TPACK framework, is the complex interplay of three primary forms of knowledge: Content (CK), Pedagogy (PK), and Technology (TK).

Teacher education will refer to the policies and procedures designed to equip prospective teachers with the knowledge, attitudes, behaviors and skills they require to perform their tasks effectively in the classroom, school and wider community. With regard to this study, teacher education is divided into two categories:

- **Pre-Service Teacher** which will refer to students that are studying the required coursework in pedagogy, content of their specialty and technology and have not entered the teaching
- **In-service teacher** denotes the one who is delivering teaching/training whether paid or unpaid institution/organization

Pre-service Teacher Education is the education and training provided to student teachers before they have undertaken any teaching.

Competency refers to the ability to do something to a set agreed standard, normally measured by undertaking an observable process or producing a final product. Competency will be measured through knowledge, skills and ability to perform a given task.

CHAPTER TWO

The Origin of TPACK and Its Meaning in Education

2.0 Introduction

One of the first pioneers of the integrated knowledge of teachers to deliver better learning outcomes was Shulman (1986) who focused on the importance of treating pedagogy and content knowledge as basic requirement for teacher training. Shulman traced literature as far back as 1870, when pedagogy was ignored and attention was paid on content, and further in 1980 when it was conspicuously absent. "*I propose that we look back even further than those 1875 tests for teachers and examine the history of the university as an institution to discern the sources for this distinction between content knowledge and pedagogical method* (Shulman, 1986, p. 6)*.*" Since the presentation of the idea of pedagogical and content knowledge as basis for teachers' competencies necessary to deliver the required learning outcomes, there existed quietness until the early 1990s when the idea of technology started to be introduced in schools. In 1993, Marcinkiewicz, in his paper on factors influencing computer use in the classroom, tried to describe how easily or difficult computer technology could be integrated in teaching (cf. Voogt, 1993). Marcinkiewicz (1993) and Voogt (1993) focused their discussion on how the attitude of teachers towards computer use in teaching is important in having technology integrated in education. These publications were followed by development of the so called National Educational Technology Standards for teachers and students by ISTE in1998. These standards were reviewed by Roblyer in 2000 and provided a clear description on how best technology can be integrated in teaching to offer pleasing learning outcomes.

However most of studies done from 1990s to 2000 had more focus on the overall use of technology in education. These studies put less attention on the relationship between technology and the previously identified competencies for teachers on pedagogical and content knowledge (Shulman, 1986). In 2005 two publications were made on the integration of pedagogy, content and technology. Niess (2005) tried to make a link between pedagogical content and technological knowledge, and described how the three components can interact to bring TPCK. Mishra & Koehler (2005) also came up with the idea of TPCK as an important component for technology integration in teaching being as well built on previous idea of Shulman. However the difference between the concepts put forward by Mishra & Koeler and that proposed by Niess, is that while Mishra & Koehler consider technology as everything that can support learning (pencil, chalkboard, analogy and digital equipments), Niess discussed technology in reference to analogy and digital equipments alone.

It is Thompson and Mishra (2007-2008) who reported the change of the name from TPCK to TPACK after an extensive meeting with stakeholders at the education summit to discuss the best name for TPCK. It was in the same year when context was added to TPACK to emphasize the idea of Total PACKage. According to Mishra & Koehler, context is described in terms of grade level of the students, schools or a class in which the technology is used. According to Koehler & Mishra (2009), teachers need to know what and how they apply technology in the unique contexts within their classrooms. A teacher is urged to also develop an ability to flexibly navigate the spaces defined by the three elements of content, pedagogy, and technology and the complex interactions among these elements in specific contexts.

2.1 The Concept of TPACK

Technology integration in teaching requires teachers understanding of the content they want to teach, the pedagogy which is concurrent with the content of the subject to be taught and the technology that can support students' learning under a certain context. According to Koehler & Mishra (2009) teachers' knowledge on content, pedagogy and technology forms the heart of good teaching with technology which is TPACK. The term TPACK which was previously known as TPCK (Koehler & Mishra, 2005), has a knowledge base needed by teachers to incorporate technology in teaching (Guzey & Roehrig, 2009). TPACK is the short term for Technological, Pedagogical and Content Knowledge, built on Schulman's (1986) idea of pedagogical and content knowledge (PCK) (Harris, Koehler & Mishra, 2009; Koehler & Mishra, 2006, 2009; Niess et al, 2009; Schmidt et al, 2009). The interplay between the various components of TPACK; technological knowledge (TK), Pedagogical Knowledge (PK), content knowledge (CK), technological content knowledge (TCK), technological pedagogical knowledge (TPK) and pedagogical content knowledge (PCK) at a given context is what makes effective teaching with technology possible (Mishra & Koehler, 2006, 2009) (Figure 1).

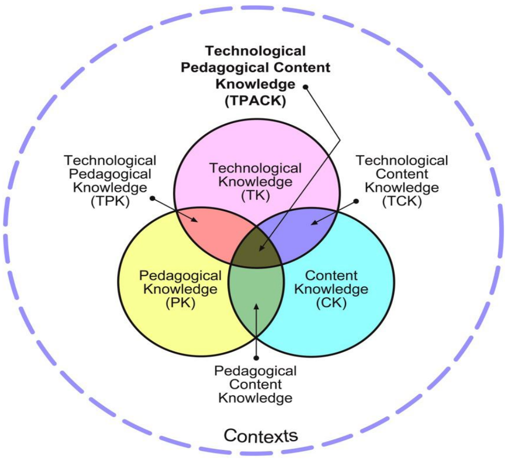

Figure 1: TPACK framework (Koehler & Mishra, 2009)

The different components of TPACK are described as follows:

2.1.1 Technological Knowledge

Technological knowledge is the knowledge about the various technologies, ranging from low-tech technology such as pencil and paper to digital technology such as the internet, digital video, interactive whiteboard etc (Schmidt et al., 2009). Technological knowledge is related to the ability of the teacher to use hardware and software to solve learning problems (Harris, Mishra & Koehler, 2009). However, Koehler & Mishra (2009), argue that technology is always in a state of flux, more than content and pedagogy. What is seen as new technology today may become an old technology in few days or years to come; thus, it's difficult to provide a clear definition of technological knowledge.

2.1.2 Content Knowledge

This is the knowledge of the actual subject matter that is to be learned or taught (Mishra & Koehler, 2009). Content knowledge is about the knowledge that a teacher is having on Mathematics or Science subjects which he/she teaches. Shulman (1986) cited in Kohler & Mishra (2009) describe this as including the knowledge of concepts, theories, ideas, organizational frameworks, scientific facts and theories, knowledge of evidence and proof, as well as established practices and approaches towards developing such a knowledge.

2.1.3 Pedagogical Knowledge

This describes the knowledge of the teacher about the processes and practices of teaching and students learning, encompassing educational purposes, goals, values, strategies etc (Koehler & Mishra, 2009). According to Koheler and Mishra, pedagogical knowledge encompasses the broad spectrum of teaching approaches, from planning of the lesson to students' assessment. It includes knowledge about techniques or methods used in the classroom, the nature of the learners' needs and preferences, and strategies for assessing student understanding (Harris, Mishra & Koehler, 2009).

2.1.4 Pedagogical Content Knowledge

This refers to the content knowledge that deals with the teaching process (Shulman 1986). Pedagogical content knowledge blends both content and pedagogy with the goal being to develop better teaching practices in the content area (Schmidt et al., 2009). Koehler & Mishra (2009), adopting the idea of Shulman, describes PCK as the transformation of subject matter for teaching, which occurs when a teacher interprets a subject matter and finds various ways of presenting it, and adapts and tailors the instructional materials to alternative conceptions and students' prior knowledge.

2.1.5 Technological Pedagogical Knowledge

This is about the teachers' understanding of the way teaching and learning can change when particular technologies are used in a particular ways (Koehler & Mishra, 2009). It is the knowledge of how various technologies can be used in teaching and an understanding that using technology may change the way teachers teach (Schmidt et al., 2009). A teacher should know where and how a particular technology can be used to enhance teaching in a given subject matter (Koehler & Mishra, 2009; Niess, 2005). An example of technological pedagogical knowledge may include the use of interactive whiteboard to engage students in the process of interacting with the materials in the process of learning.

2.1.6 Technological Content Knowledge

This is the knowledge of how technology can create new representations for specific content. Koehler & Mishra (2009) argue that, "understanding the impact of technology on the practices and knowledge of a given discipline is critical to developing appropriate technological tools for educational purposes" (p. 65). It is also an understanding of the manner in which technology and content influence and constrain one another. Teachers are argued to master not only the subject matter but also the manner in which the subject matter can be changed by the use of particular technology (Koehler & Mishra, 2009).

2.1.7 Technological, Pedagogical and Content Knowledge

This refers to the knowledge required by teachers for integrating technology into their teaching and content area (Schmidt et al., 2009). Koehler and Mishra (2006, 2009) argue that, by simultaneously integrating knowledge of technology, pedagogy and content, expert teachers bring TPACK into play any time they teach. They also argue that "*there is no single technological solution that applies for every teacher, every course, or every view of teaching. Rather, solutions lie in the ability of a teacher to flexibly navigate the space defined by the three elements of content, pedagogy and technology and the complex interactions among these elements in specific contexts* (p. 66)." Schmidt et al. (2009), describe TPACK as a useful framework for thinking about what knowledge teachers must have to integrate technology into teaching and how they might develop this knowledge. They further argue that, measuring teaching knowledge could potentially have an impact on the type of training and professional development experiences that are designed for both pre-service and in-service teachers.

2.2 Developing TPACK in Education

The process to bring technology into content and pedagogy to form the technological pedagogical content knowledge is not an easy one; Koehler & Mishra (2009) said the process is complex and challenging. According to Niess et al (2009), the development of this knowledge takes several steps. Figure 2 presents steps that teachers should go through to be able to effectively integrate technology in teaching.

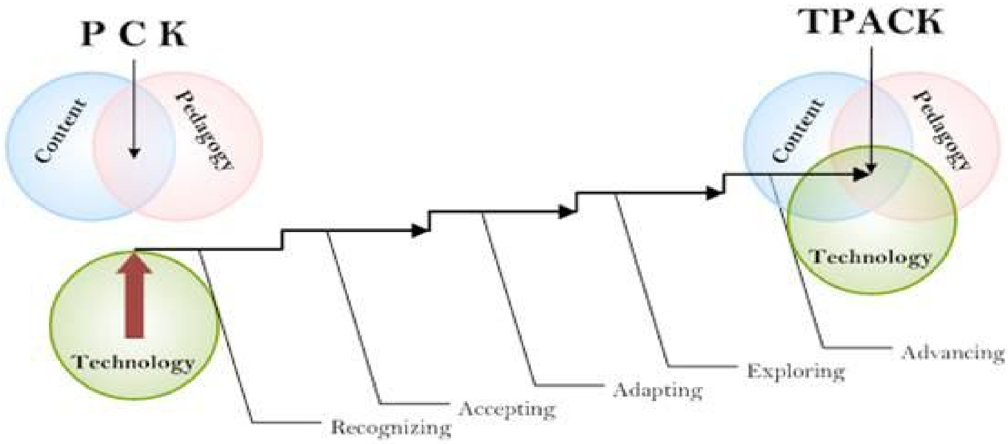

Figure 2: Stages in Teachers TPACK Development (Niess et al, 2009)

Figure 2, depicts levels in which teachers engage as they develop their knowledge and understandings in ways that merge multiple knowledge bases: technology, content, and pedagogy. On the left side of the graphic, the figure highlights PCK as the intersection of pedagogy and content build on Shulman. According to Niess et al (2009), as knowledge of technology expands and begins to intersect with pedagogical and content knowledge, the teacher knowledge base that emerges is TPACK; where teachers actively engage in guiding student learning of a subject matter with appropriate technologies (cf. Koehler & Mishra, 2009). Niess et al, describe these stages as in Table 1.

Table 1: *Stages in Teachers' TPACK Development (Adapted from Niess et al, 2009)*

	Stage	**Description**
1	Recognizing (knowledge)	Teachers are able to use the technology and recognize the alignment of the technology with mathematics content yet do not integrate the technology in teaching and learning science and mathematics.
2	Accepting (persuasion)	Teachers form favourable and unfavourable attitude towards teaching and learning science and mathematics with technology
3	Adapting (decision)	Teachers engage in activities that lead to a choice to adopt or reject teaching and learning science and mathematics with appropriate technology
4	Exploring (implementation)	Teachers actively integrate teaching and learning of science and mathematics with an appropriate technology
5	Advancing (confirmation)	Teachers evaluate the results of the decision to integrate science and mathematics teaching and learning with appropriate technology

On the basis of Niess et al (2009) arguments it can be deduced that, technology integration in teaching requires a mutual attraction between the components (TK and

PCK) so as to make them integrated. This requires some conditions that will promote the attraction between the two components. Koehler and Mishra (2009), describe social and institutional support for teachers as well as knowledge and experience of the teacher in working with technology as some of the important condition for integration of technology with content and pedagogy. However, Bitner & Bitner (2002), cited in Velázquez (2006), proposed eight “keys” to successfully integrate the three components together: “*(1) overcoming fear of change, (2) technology training in basics, (3) personal use of technology, (4) provision of teaching models with technology, (5) emphasis on a learning approach to teaching, (6) flexible climate to experience technology, (7) motivation, and (8) technical and curricular support* (pg 22).” It is therefore the responsibility of teacher training colleges to identify and develop these conditions to pre-service teachers so as to pave their understanding and use of TPACK.

CHAPTER THREE

TPACK in Science and Mathematics Teaching

3.0 Introduction

In most cases, schools and governments have been struggling to introduce technology in education, particularly science and mathematics teaching and learning. According to Moonen (2008), majority of developing countries are more focused on hardware procurements and more attention is given on installing these hardware in schools rather than how those hardware are used in schools. However, Mishra and Koehler (2006) argue that, merely introducing technology to the educational institutions is not enough. The extent to which teachers will integrate technology in their teaching is the most important. Studies on ICT in science and mathematics (cf. Grouws & Cebulla, 2000; Keong et al., 2005; Tilya, 2008), show that the integration of technology in education has numerous advantages in students' learning. The more teachers treat ICT as an integral part of the students learning in science and mathematics is the more the improvement in students' achievements. A research by Keong et al. (2005) reports that, the use of ICT in teaching science and mathematics improves by increasing collaboration among students and enhancing level of communication and sharing of knowledge. Teachers can also be able to provide a rapid and accurate feedback to students and allow students to focus on strategies and interpretations of answers rather than spending time on tedious computational calculations. Several studies (cf. Tilya, 2008; Voogt, 2003), report the value of ICT in supporting constructivist pedagogical approach in which learners use technology to explore and reach an understanding of scientific and mathematical concepts by concentrating on problems solving process rather than on calculations related to the problems.

There is a growing body of research which indicates that, technologies, including graphing, and some computer based mathematics learning programs can enhance young students' conceptual and procedural knowledge of mathematics (Özgün-Koca, Meagher & Edwards, 2010). According to Ozgun-Koca et al (2010) *"As teachers decide whether and how to use technology in their teaching, they need to consider the science or mathematics content that they will teach, the technology that they will use, and the pedagogical methods that they will employ"* (p.11). In doing this, teachers are argued to reflect on the critical relationships between science or mathematics concepts, the technology to use, and the pedagogy that can support learning. In reference to arguments put forward by Ozgun-Koca et al, the question of what teachers need to know in order to appropriately integrate technology in science and mathematics teaching is the most important and is supposed to be the primary focus on studying how technology is used in teaching and learning (Mishra & Koehler, 2006).

The way pre-service teachers will learn to use technology in their teaching it is likely that they will also use it in the same way in their teaching (LeBaron et al, 2009). According to Richardson (2009) in order for technology to become a tool for learning mathematics, mathematics teachers must develop an overarching conception of their subject matter with respect to technology and what it means to teach with technology. Niess et al (2009) adds that, in the late 1980s and early 1990s, an examination of teachers' science and mathematics, revealed an overarching conception that teachers' beliefs about how to teach science and mathematics generally were aligned with how they learned science and mathematics. Teachers who learned to solve science and mathematics problems through the use of graphing calculators, spreadsheets and some learning software were among the few who embraced the use of those tools in teaching science and mathematics. Niess and colleagues, further argue that, the low uptake of technology by teachers is in most cases associated with the poor knowledge of science and mathematics instructional strategies and representations of a particular science or mathematical topics supported by digital technologies to demonstration, verification, and drill and practice (cf. Jimoyiannis, 2010, Webb, 2008). Also their knowledge of students' understandings, thinking, and learning in mathematics held to the importance of mastery of skills with paper and pencil prior to using modern digital technologies (Kastberg & Leatham, 2005, cited in Niess et al, 2009). In addition, in their study, Niess and colleagues found that, access to technology without necessary knowledge of related science and mathematics curriculum materials did not encourage teachers to incorporate the technology in their classroom instruction. In connection to this, Ferrini-Mundy & Breaux (2008) argue that, "in the absence of professional development on instructional technology and curriculum materials that integrate technology use into the lesson content, teachers are not particularly likely to embed technology-based or technology-rich activities into their courses" (p. 437).

3.1 The Process of Integrating Technology, Pedagogy and Science/Mathematics

For the integration of pedagogy, content and technology to occur, teachers need to know not just the science and mathematics subjects they teach but also the manner in which the subject matter can be changed by the application of technology (Koehler & Mishra, 2009). Thus, as it is in Koehler & Mishra (2009) and Richardson (2009), teachers should have the knowledge of various technologies as they are used in teaching and learning settings, and conversely, knowing how science and mathematics teaching might change as the result of using particular technologies. Niess et al. (2009) argue that, such kind of knowledge among teachers cannot be developed in a one step move; there is a need for a model that captures the progression of science and mathematics TPACK as teachers integrate technology into the teaching and learning (cf. Wentworth, Graham &Tripp, 2008). In the process of developing teachers' technological competencies there are a number of challenges. As it is in Wentworth et al (2008), the development of technology integration among teachers can be hindered by the availability of tools, attitudes of teachers towards technology etc. For example, Wentworth et al (2008) argue that when technology was first introduced into education, both university instructors and public school teachers were either unable or unwilling to integrate technology into their curricula. According to Wentworth and colleagues, the reason for the reluctance of teachers to integrate technology includes computer illiteracy; computer phobia, disinterest, lack of equipment, and lack of time to learn appropriate uses of technology in instruction (cf. Cox et al, 1999).

The factors mentioned by Wentworth are considered to carry a substantial impact on the overall technology integration in education. Different researches on ICT in education have revealed the difficulties that teachers experience in integrating technology into pedagogy and science or mathematics teaching. For example, in a survey about ICT use in mathematics teaching, conducted by Keong et al. (2005) in Malaysia, it was revealed that, 71.1% of 111 respondents were using computers on a regular basis. They further reports that, although there was a majority of teachers (over 71%) who were interested in using computers in science and mathematics teaching, many of them were not using it properly to deliver better learning outcomes in these subjects. A large number of teachers were using word processing program and less were using learning related programs such as spreadsheet, databases, simulations, and multimedia to support pedagogical approaches to learning of science and mathematics (Keong et al., 2005). It was also found that, although internet is considered as an important aspect that support variety of instructional approaches, Keong and colleagues found the internet being used for communication among teachers and for browsing. In their study they further found that the level of use of ICT for instruction in science and mathematics was still low, whereby over 39.6% of respondents reported to have not used ICT in teaching at all and 32.1% having used ICT infrequently and only 5.7% reported to have fully integrated ICT into science and mathematics instructional programmes (Keong et al, 2005).

Another study by Owre (2006) cited in (Holden et al., 2008) reported that although there were over 90% of teachers in USA who were using computers daily, only 31% used computers for instructional purposes. In another survey conducted in USA, it was also found that 90% of teachers claimed to use internet for monitoring attendance, distributing grades, creating materials for instruction and communication with colleagues (Holden, et al., 2008). Teachers were using computers, primarily for administrative purposes rather than instruction in science and mathematics. The tendency where ICT tools have been made available in schools while teachers do not use them properly have consequently led to many researches concluding that ICT use in education has no significant impacts on students learning in science and mathematics (Pelgrum, 2001). For example, Yuen, Lee, Law & Chan (2008) argue that, ICT has not helped to narrow the achievement gap in science and mathematics among students nor the socioeconomic divide. Yuen and colleagues see ICT uptake by teachers as being highly associated with teachers' perceptions towards ICT which in turn has a profound effect on the science and mathematics teaching-learning process.

The integration of technology, learning approaches and the science and mathematics subjects faces setbacks that results from poor technological knowledge, poor access to technology tools and negative attitude towards technology (Wentworth et al., 2008). For example, a study by Tella, Tella, Toyobo & Adika (2007) reported that, only 30.3% of teachers in Nigeria were able to access ICT tools (computers) for 11-15 hours per week with majority having less than 5 hours access per week. In their study, Tella and colleagues found that all teachers had no access to internet services leading to ineffective use of ICT in some pedagogical approaches which require online collaboration. In addition, a study by Mbangwana (2008) in Cameroon showed that, although numerous schools had multimedia centre connected to internet, there was a great variation in the access and use of ICT in teaching between teachers and between schools. In one of the school, Mbangwana found only 10% of trained teachers were using ICT in science teaching.

Studies (Pelgrum, 2001; Yuen et al., 2008) report that poor uptake of technology by teachers is caused by lack of teachers' motivation in using technology in teaching and learning. Lack of motivation may be highly caused by lack of technological knowledge (Cox, Preston & Cox, 1999), which causes teachers inability to integrate technology, pedagogy and content (TPC). McKenney (2001) argue for the importance of taking into consideration the target audience's motivation to use computer and their level of existing computer literacy when planning for ICT integration in education.

3.2 Summary and Way Forward

Overall, studies (Grouws & Cebulla, 2000; Keong et al., 2005; Tilya, 2008 and Niess et al., 2009) acknowledge the importance of ICT in science and mathematics teaching. However, some studies report that the level of integration of technology, pedagogy and content is minimal in most schools (Wentworth et al 2008). An assessment of teachers' uptake of technology in science and mathematics teaching, indicates that most teachers are at the accepting stage (see stages in Table 1), where by majority are still not confident if ICT can enhance learning while others have negative attitude towards ICT use. In reference to observations made by Keong et al. (2005), Tella et el. (2007), Holden et al. (2008) and Mbangwana (2008), there are several evidences that, teachers are using computers, primarily for administrative purposes rather than instruction purposes. The tendency where ICT tools have been made available in schools while teachers do not use them properly have consequently led to many researches concluding that ICT use has no significant impacts on students learning (Pelgrum, 2001). For example, Yuen, Lee, Law & Chan (2008) argue that, ICT has not helped to narrow the achievement gap in science and mathematics among students nor the socioeconomic divide. According to Pelgrum (2001) the insufficient integration of technology in science and mathematics teaching, is largely caused by the poor uptake of technology by teachers. Pelgrum (2001) and Yuen et al. (2008), report that lack of technological knowledge causes teachers' inability to integrate technology, pedagogy and content, thus inability to develop the technological pedagogical content knowledge (TPACK). This leads to a conclusion that, although TPACK is reported to enhance learning in science and mathematics, teachers are not yet integrating it in their teaching. The poor integration of TPACK is reported to be caused by poor technological knowledge among teachers, unavailability of technological tools and teachers' lack of motivation to use ICT in teaching. These findings from literature, maybe suggesting for development of teachers programmes for science and mathematics teachers which cultivate the development of technological knowledge and positive attitude towards the use of technology.

CHAPTER FOUR

TPACK Framework for Pre-service Teachers

4.0 Introduction

In order to develop teachers who are competent in using ICT in teaching, teachers' preparation should focus on the development of teachers' competencies in technology, pedagogy and content. At present, researchers (cf. LeBaron, McDonough & Robinson, 2009) are questioning the efficacy of teacher preparation for successful application of technology in school and classrooms. LeBaron et al. (2009) believe that the quality of teaching depends in some significant measure, on the way teachers were taught. This argument calls for more attention on how teachers are prepared to use ICT. Schmidt et al. (2009), argue that, when thinking about the knowledge that teachers must have, to integrate technology into teaching and how they might develop this knowledge, it's worthwhile to use TPACK framework. However there are still some challenges in most teachers' training colleges on how the TPACK framework can be used to develop teachers' competencies in technology use. What a teacher is taught and how the teacher experience the use of ICT maybe a necessary question to ask ourselves when thinking of developing teachers' ability to integrate technology in their teaching.

According to UNESCO (2008a) teachers should not only be taught how to teach ICT to students but how ICT can help them to teach and enhance students' learning. In this regard, pre-service teachers should be treated in a way that they can change their views of technology infusion, from thinking they would teach about technology, to thinking they would use technology as a tool to support student learning (Beyerbach, Walsh and Vannatta, 2001; Knezek, Christensen & Fluke, 2003). Beyerbach and colleagues further argue that the technology integration in teacher education should provide pre-service teachers with: hands-on experiences exploring computer technologies and their applications in teaching and learning; education courses that model technology integration; field experiences in technology rich classrooms; and a rich, constructivist vision of technology infusion possibilities. At the end of these activities, student teachers should be able to demonstrate different educational technology integration competencies which make up TPACK (UNESCO, 2008a).

However, studies (cf. Pope, Hare, & Howard, 2002; Selinger, 2001) cited in Angeli (2005) found that pre-service teacher education does not adequately prepare future teachers to teach with technology. In many cases teachers have been prepared to teach technology rather than using technology (Beyerbach et al., 2001). Thus, UNESCO (2008a) presents specific ICT competencies that teachers should acquire at the college to be able to integrate technology in teaching in the most appropriate way. Such competencies includes: the ability to manage information, structure problem tasks, and integrate open-ended software tools. Also the ability to integrate subject-specific applications with student-centered teaching methods as well as collaborative projects in support of students' deep understanding of key concepts and their application to solve complex, real-world problems (UNESCO, 2008a). Recent calls for educational reform in teacher education stress the need for innovative teacher education restructuring to ensure that pre-service teachers not only understand how to use a computer but also how to design high quality technology-enhanced lessons (Niess et al., 2009).

4.1 Required TPACK Competencies for Teachers

According to UNESCO (2008a), teachers should be able to use network resources to help students collaborate, access information, and communicate with external experts to analyze and solve their selected problems. More over, teachers are supposed to be able to use ICT to create and monitor individual and group student project plans, as well as access experts and collaborate with other teachers and experts in supporting their own professional development. Table 2 summarizes the overall competencies required by teachers to be able to integrate technology in teaching.

Table 2: *Teacher training curricular goals and skills to be developed in each competency area (UNESCO, 2008a)*

Competency area	**Curricular**	**Teacher skill**
Curriculum and assessment	Improve basic literacy skills through technology and adding development of ICT skills into relevant contexts, which will involve time in the curricula of other subjects for the incorporation of a range of relevant ICT resources.	Teachers must have a firm knowledge of the curriculum standards for their subject, as well as knowledge of standard assessment procedures. In addition, teachers must be able to integrate the use of technology and technology standards for students into the curriculum.
Pedagogy	Changes in pedagogical practice involve the integration of various technologies, tools, and e-content as part of whole class, group, and individual student activities to support didactic instruction.	Teachers must know where, when (as well as when not), and how to use technology for classroom activities and presentations. Teachers must have the skills to help students create, implement, and monitor project plans and solutions.
ICT	The technologies involved in this approach include the use of computers along with learning software; drill and practice, tutorial, and web content; and the use of networks for management purposes.	Teachers must know basic hardware and software operations, as well as productivity applications software, a web browser, communications software, presentation software, and management applications. Teachers must also be aware of a variety of subject specific tools and applications and able to flexibly use them in teaching.
Teacher professional development	The implications of this approach for teacher training focus on the development of digital literacy and the use of TPACK framework for professional improvement.	Teachers must have the technological skill and knowledge of Web resources necessary to use technology to acquire additional subject matter and pedagogical knowledge in support of teachers' own professional development.

Table 2, puts it clear on what kind of competencies that teachers should develop in order to be able to transfer the knowledge from the college to the work place. According to UNESCO (2008a), on top of technological, pedagogical and content knowledge there is professional development. Pre-service teachers are argued to engage in continuous learning that is geared towards advancing their career development to deepen their understanding about teaching and technology.

According to Jimoyiannis (2010), teachers should focus on developing their competency on how ICT is integrated in teaching to enhance learning rather than how students can learn ICT. The more competent is the teacher, the more he becomes interested, motivated and confident to use technology in teaching (Cox et al, 1999; Kirschners et al, 2008). Thus, a better understanding of TPACK among pre-service teachers can enhance technology integration, which is thought to enhance students' learning outcomes. Research (Cox et al., 1999; Kirschner et al, 2008; Jimoyiannis, 2010; Webb, 2008; Unwin, 2005) has shown that, teachers uptake of ICT in teaching is highly impaired by the worry of loosing ones self esteem, fear to damage the computer, unfriendly jargon and the likely that the technology can go wrong. Thus, the question of what teachers should learn from the college in order to appropriately incorporate technology into their teaching is supposed to be the primary focus in studying how technology enhances learning (Jimoyiannis, 2010; Mishra & Koehler, 2006).

4.2 TPACK Training Package for Pre-service Science and Mathematics Teachers

In order to move from teaching technology to using technology, teachers should be prepared to see technology as part and parcel of their daily classroom activities. The way prospective teachers are set to interact with technology can help to transform their thinking about technology and be able to support students' learning (Beyerbach et al., 2001). Different approaches to working and learning with technology have been proposed by Beyerbach et al. (2001) and UNESCO (2008b). If these activities are properly adopted in the teachers training colleges, they are likely to enhance pre-service teachers TPACK competencies. Table 3, shows the technological infusion activities.

Table 3: *Technological Infusion Activities for Pre-service Teachers* (Beyerbach et al., 2001; ISTE, 2001; UNESCO, 2008b)

Competency areas	**Training objectives**	**Training activities**
Curriculum and Assessment	Teachers should be able to; identify key characteristics of classroom practices and help students to acquire ICT skills within the context of their courses. They should also be able to use ICT to assess students' acquisition of subject matter and provide feedback on their progress	Select subject-specific software packages and identify specific curriculum standards that are associated with these packages Prepare a lesson plan that includes the use of ICT, such as word processors, web browsers, email, blogs, wikis, and other technologies Incorporate ICT and other software for formative and summative assessment into their lesson plans
Pedagogy	Teacher should be able to: Use didactic teaching and ICT to support students' learning, Design appropriate ICT activities to support students' learning. Use presentation software and digital resources to support instruction.	Use of ICT to support students' learning and demonstrate how technology can supplement didactic classroom teaching. Design lesson plans that incorporate tutorial and drill and practices software, e-resources and e-content and have participants share these plans and receive recommendations from peers.
ICT	Describe the Internet and the World Wide Web; elaborate their uses, and how a browser works. Describe the function of tutorial and drill and practice software and how they support students' learning. Use common communication and collaboration technologies, such as text messaging, video conferencing, and web-based collaboration and social environments	Discuss the purpose and structure of the Internet and the World Wide Web, have participants use a browser to access popular websites Demonstrate a variety of tutorial and drill and practice packages in the subject domains of the participants and describe how they support students' learning. Discuss the purposes and advantages of various communication and collaboration technologies; and have participants use these technologies to communicate and collaborate with others in the group
Teacher Professional Development	Use ICT resources to support their own acquisition of subject matter and pedagogical knowledge	Discuss different ICT resources that participants can use to increase their subject matter and pedagogical knowledge

In table 3, the discussion on how pre-service teachers should be prepared to properly integrate technology in their teaching, has tried to focus on curriculum (content), pedagogy and ICT (technology). This is inline with what Polly, Mims, Shepherd and Inan (2009) argued that, teachers' technological skills alone may not result in the effective use of technology in teaching in ways that are likely to impact students learning. Thus it is important for technological courses to be linked to methodological courses and field experiences to let the prospective teachers witness firsthand how technology can be effectively integrated in their teaching (Polly et al., 2009). According to Polly et al.

(2009), effective teaching with technology requires teachers to have the knowledge of the technologies, pedagogies, content and the intersections of those three components (cf. Koehler & Mishra, 2009). This integration of technology, pedagogy, content and professional development in the process of teachers' preparations as discussed by Beyerbach et al. (2001), Polly et al. (2009) and UNESCO (2008a) affirms the use of TPACK as a framework for teachers' preparation. Use of TPACK can enable them to engage with content, pedagogy, and technology in tandem to develop knowledge of how technology can help students learn specific science and mathematics concepts (Groth, Spickler, Bergner, Bardzell, 2009).

In conclusion, studies (Beyerbach et al, 2001; UNESCO, 2008a) have reported that colleges are not properly training teachers to integrate technology in teaching. Use of hands on activities has been proposed as the best approach of developing pre-service teachers' understanding of TPACK framework. UNESCO (2008b) proposes a number of training activities that can cultivate teachers' knowledge in curriculum (subject matter), teaching approaches and assessment (pedagogy) and technology. Example of activities that have been proposed by UNESCO includes; teachers' participation in lesson preparation, demonstration of teaching competencies with technology through presentation, and finally discussion with peers about the resulting outcomes of their presentation with technology (UNESCO, 2008a, 2008b). In addition, Jimoyiannis (2010) presents an integrated framework which combine TPACK model and authentic learning approach. According to Jimoyiannis (2010), given that pre-service teachers are willing to learn and develop new skills related to their instruction through design authentic activities, it is reasonable to engage them in solving meaningful instruction problems through authentic ICT-based learning activities with a sound pedagogical background (cf. Beyerbach et al 2001; Mcdougall, 2008).

Studies (Kilic, 2010; Peker, 2009; Harris & Hofer, 2009) confirm that, when teachers engage in a practical works such as microteaching and lesson designs, they get opportunities to develop skills in drawing learners' attention, asking questions, using and managing time effectively and bringing the lesson to a conclusion. Also, through hands on activities, student teachers acquire the skills to choose appropriate technologies to support certain learning activities and overcome difficulties encountered during the process of teaching science and mathematics. According to Kilic (2010), teacher candidates can also improve their skills in giving feedback and measurement and evaluation when they engage in a field related activities and get challenged by peers about their performance. In this regard development of TPACK competencies among pre-service science and mathematics teachers can take the approach proposed by Peker (2009) in which several cycles can be followed in developing technological, pedagogical and content knowledge. According to Peker pre-service teachers should engage in the process of designing a lesson, present it to peers, get critics from peers and re-design the lesson again. Repeated design, presentation and challenges helps in developing confidence and competencies in TPACK.

CHAPTER FIVE

Conclusion and Recommendation

The discussion made in this paper focused on moving from teaching ICT to using ICT in facilitating students learning. The analysis of various studies found that, although many schools around the world are having ICT tools, their use differs greatly from one school to another. Studies (Koehler & Mishra, 2009; Niess et al, 2009) have shown the importance of developing technological pedagogical content knowledge among teachers for good teaching with technology. However, many studies (c.f. Angeli, 2005; Keong et al, 2005) reports that ICT is largely used for administrative purposes or for personal activities such as communication among teachers and only a small percentage of the ICT tools are used for instructional purpose. Other studies (cf. Kafanabo, 2006), report that teachers are teaching ICT to students instead of using ICT to enhance learning in science and mathematics. In developing competencies for teachers to appropriately integrate ICT in teaching, Beyerbach et al. (2001) and UNESCO (2008), presents some competency standards for teachers and provid a syllabus for teachers training that integrate content, pedagogy, technology and professional development. This is believed to develop pre-service teachers' understanding of technological pedagogical content knowledge and the interplay between and among all TPACK components.

However, Polly et al. (2009) raised a question on the aspects of TPACK that are most critical to develop in teachers as well as the learning experiences that can facilitate the development of various components of TPACK. Use of activities based instruction in preparing teachers to use technology has been proposed as interesting solution for developing pre-service teachers' competencies in TPACK. Thus Peker (2009) and Kilic (2010) proposes the use of microteaching, lesson design and peer evaluation in order to develop pre-service teachers confidence and acquaint them with the field experience. But is not clear on whether teachers training colleges are clearly integrating technology, pedagogy and content knowledge in an appropriate way to enable teacher develop the competencies necessary for their work? Much has been said on how teachers are inappropriately using technology in the process of teaching but less is said on how teachers are prepared to develop such competencies.

In addition, though there are some literatures that mention lack of motivation to use ICT (Cox et al., 1999) as one of the hindrance to ICT use in teaching, few have discussed about the prospective teachers' attitudes towards the use of ICT in their teaching. Most of the literature (Koehler & Mishra, 2009; UNESCO, 2008) assumes that once teachers have acquired ICT competencies they will automatically use it in teaching, something which may not be true in a real situation. Holden et al. (2008) revealed that, there is a very big difference between the perceived ICT use and the real situation in schools. Thus, it is recommended that a study on "The Practical use of ICT in Science and Mathematics Teachers' Training" be conducted to assess the way pre-service teachers are taught to integrate technology pedagogy and content and whether pre-service teachers are going to use such knowledge.

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