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TRACK FOR PRE-SERVICE SCIENCE AND MATHEMATICS TEACHERS IN NIGERIA

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Abstract

The paper critically examines the concept of TPACK, particularly in relation to teaching and learning in science and mathematics, and its integration in pre-service science and mathematics teacher-preparation. To achieve this, different related literatures were consulted on the meaning of TPACK, its origin and the way it could be integrated in pre-service science and mathematics teacher-preparation. From a wide range of literature review, it was noted that TPACK occupies the centre-stage of good teaching with technology. Furthermore, studies show that the way pre-service teachers are taught to integrate technology, pedagogy and content appears to be similar to the way they can implement the approach in teaching. In addition, the cyclic development of the lesson is reported to enhance pre-service teachers'

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 (Grouws and Cebulla, 2010; Keong, 2015; Tilya, 2014), show that the integration of technology in education has numerous advantages in students' learning. The more teachers treat ICT as an integral part

Competency in working with technology in a real classroom situation. Consequently, it becomes essential for teachers to have a good understanding of TPACK and its implementation in pre-service teachers' training, starting with the orientation of pre-service teachers on the use of technology in teaching by providing them with sufficient opportunities to engage in hands-on activities. Based on the foregoing, some recommendations were made.

Keywords: *Pre-service teachers, ICT, Technology integration, Teaching, Science and Mathematics*

Of the students learning in science and mathematics is the more the improvement in students' achievements.

A research by Keong. (2015) 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 (Tilya, 2014; Voogt, 2013), 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 (Ozgün-Koca, Meagher and 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. 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). 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 (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 and Leatham, 2013, 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 and 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.

The Origin of TPACK and Its Meaning in Education

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. Shulman, (1986) proposed 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. 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 (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 (2009) tried to make a link between pedagogical content and technological knowledge, and described how the three components can interact to bring TPCK. Mishra & Koehler (2006) 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 and Koeler and that proposed by Niess, is that while Mishra and Koehler consider technology as everything that can support learning (pencil, chalkboard, analog and digital equipments), Niess discussed technology in reference to analog 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 and 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.

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 and 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 and Mishra, 2005), has a knowledge base needed by teachers to incorporate technology in teaching (Guzey and 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 and Mishra, 2009; Koehler and 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 and Koehler, 2006, 2009) (Figure 1).

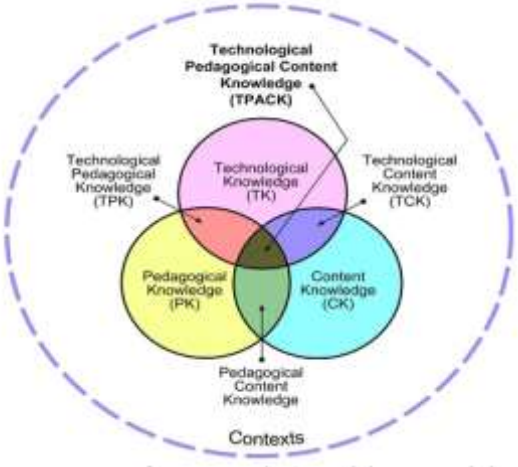

Figure 1: TPACK framework (Koehler and Mishra, 2009)

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The different components of TPACK are described as follows:

- **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 and Koehler, 2009). However, Koehler and 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.

- **Content Knowledge:**

This is the knowledge of the actual subject matter that is to be learned or taught (Mishra and 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 and 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 knowledge.

- **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 and 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 and Koehler, 2009).

- **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 and 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.

- **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 andMishra, 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, 2009). 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.

- **Technological Content Knowledge:**

This is the knowledge of how technology can create new representations for specific content. Koehler and 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. 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 and Mishra, 2009).

- **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. 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.

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 and 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.

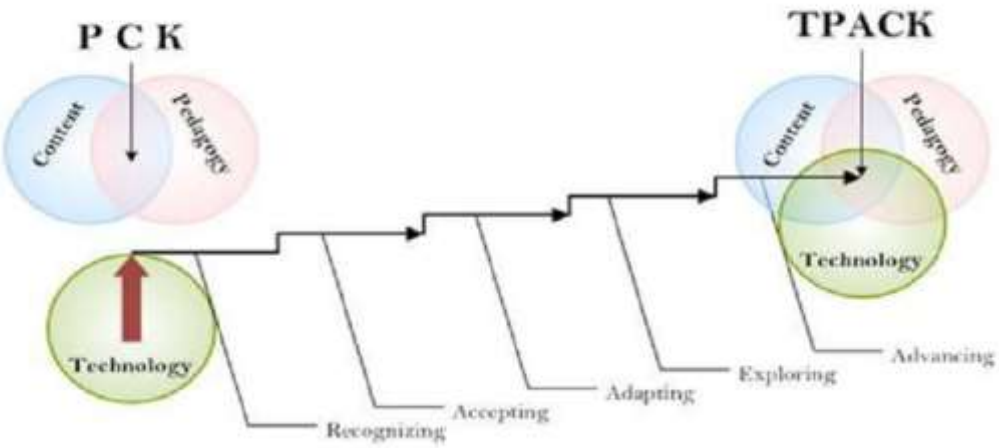

Figure 2: Stages in Teachers TPACK Development (Niess et al, 2009)

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 (Koehler and 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 (2010), 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
(8) Technical and Curricular support

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.

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 and 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 (Wentworth, Graham and 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 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, 2011). For example, Yuen, Lee, Law and 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 and Adika (2017) 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 (2018) 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, 2011; 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 and Cox, 1999), which causes teachers inability to integrate technology, pedagogy and content (TPC). McKenney (2011) 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.

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. Moreover, 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.

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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 losing one's 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).

Conclusion:

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 and 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 (Angeli, 2015; 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 (Kafanabo, 2016), 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. (2011) and UNESCO (2008), presents some competency standards for teachers and provide a syllabus for teachers training that integrate content, pedagogy, technology and professional development. This is believed to develop preservice teachers' understanding of technological pedagogical content knowledge and the interplay between and among all TPACK components.

Recommendation:

- 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.
- teachers training colleges should 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.
- Universities, Colleges and schools management should motivate their teachers towards use ICTs for teaching and learning.
- Government and stake-holders should enrich our schools by organizing regular workshop and staff training for science and mathematics teachers on proper integration of technology in their teaching.
- Curriculum planners should make provision for adoption of technology towards mathematics and science contents.
- Communities and parents should support the integrations of technology in various schools.

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