Developing Technological Pedagogical Content Knowledge (TPACK) among Pre-service Science and Mathematics Teachers at DUCE: The Role of Activity-Based Learning

AYOUB CHERD KAFYULILO[1]
Dar es Salaam University College of Education
E-mail: kafyulilo@duce.ac.tz

Abstract

This study explored the ways in which pre-service teachers at the Dar es Salaam University College of Education (DUCE) can develop the knowledge of integrating technology pedagogy and content in Science and Mathematics teaching. The study employed the pre and post-interventions analysis of pre-service teachers' competency of integrating technology, pedagogy and content. Some 29 pre-service Science and Mathematics teachers participated in the intervention and four instructors participated in the interview. The study findings reveal that teachers can develop technological pedagogical content knowledge (TPACK) when they engage in learning activities which reflect the real teaching process. Also, the pre- and post-intervention analysis confirmed a significant change in the pre-service teachers' knowledge of integrating technology, pedagogy and content after participating in the designed intervention activities. This implies that teachers' TPACK can be developed by engaging teachers in a real-life learning process rather than the theoretical learning through the interaction between technology, pedagogy and content.

Introduction

Technology integration in teaching is currently attracting the attention of educators, curriculum developers and policy-makers. Governments in both developing and developed countries are investing in research on how students' learning outcomes can be maximised through the use of technology (Graham et al, 2009). Previously, the attention was on how to bring technology into education and studies were more focused on the importance of technological tools' availability, teachers' technological skills and teachers' attitude towards technology (Knezek, Christensen, Hancock & Shoho, 2000; Knezek, Christensen & Fluke, 2003). However, studies by Graham et al (2009) and Niess et al (2009) have shown that bringing technology into education does not improve students' learning outcomes; thus what matters is how technology is integrated with pedagogy and content.

Other researchers (Keong, Horani & Daniel, 2005; Niess, 2005; Niess et al, 2009; Senzige & Sarukesi, 2003; Tilya, 2008; Voogt, 2003) have indicated the ways through which effective integration of technology in teaching and learning can enhance students' understanding of basic concepts in Science and Mathematics. According to Keong et al (2005), when ICT is properly integrated in Science and Mathematics classrooms, it can help improve learning through

[1] The author is an Assistant Lecturer, the Curriculum and Teaching Unit, the Dar es Salaam University College of Education.

increased collaboration and a high level of communication and sharing of knowledge among students. Teachers can also provide rapid and accurate feedback to students and allow them to focus on strategies and the interpretation of answers rather than spending time on tedious computational calculations. Collis and Moonen (2001), Tilya (2003) and Voogt (2003) assert that the constructivist learning approach is enhanced when technology is used in teaching. In constructivist learning, students use technology to explore and reach an understanding of mathematical concepts by concentrating on the problem-solving process rather than on calculations related to the problems. Keong et al (2005), Kohler and Mishra (2009), Niess et al (2005) and Voogt (2003) indicate that it is not learning about how to use technology which improves an understanding of Science and Mathematics, but the manner in which technology is used to support learning.

Thus, Niess et al (2009), Ozgun-Koca, Meagher and Edwards, (2010) and Webb (2008) propose that when teachers decide to use technology, they need to consider the Science or Mathematics content they will teach with the technology and the pedagogical methods they will employ. Niess (2005) sees the existing failure in Science and Mathematics teaching as resulting from the teachers' poor knowledge of the subject content and instructional strategies and their poor representation of particular science or mathematical topics supported by digital technology to demonstrate and verify, drill and practise (cf. Koehler & Mishra, 2009; Webb, 2008). According to Kafyulilo (2010) and Niess et al (2009), access to technology without the necessary knowledge of related Science and Mathematics curriculum materials does not have an impact on students' learning outcomes. As a result, Mishra and Koehler (2009) insist on the need for teachers to know, not only the subject matter they teach or the technology, but also the manner in which the subject matter can be changed by the application of technology in a given pedagogical approach. Teachers are, therefore, required to develop the knowledge of various technologies and in addition to know how Science and Mathematics teaching might change as the result of using particular technologies (Koehler & Mishra, 2006, 2009). Studies by Beyerbach et al (2001), LeBaron, McDonough and Robinson (2009), and Niess et al (2009) have revealed the overarching conception that teachers' beliefs about how to teach Science and Mathematics are generally aligned with how teachers learned the subjects at the teacher training college. Teachers who learned to solve Science and Mathematics problems by using graphing calculators, spreadsheets and some learning software are among the few who can embrace the use of those tools in teaching these subjects (Niess et al, 2009). Currently, researchers (LeBaron, McDonough & Robinson, 2009; Kirschner, Wubbels & Brekelmans, 2008) are questioning the efficacy of teacher preparation for effectively using technology in schools.

Studies by Pope, Hare and Howard (2002) and Selinger (2001) cited in Angeli (2005) report that pre-service teachers are still learning about technology, pedagogy and content as independent subjects, not as integrated knowledge (cf. Kafyulilo, 2010). In this way, teachers have been prepared to teach technology as a discipline rather than use it as a tool with which to enhance students' learning (Beyerbach et al, 2001; Jimoyiannis, 2010; Schmidt et al, 2009). According to Beyerbach et al (2001) and UNESCO (2008a), teachers should not only learn how to teach information and communication technology (ICT) but also how to apply it in teaching to enhance students' learning. In fact, teachers should be prepared to change their orientation from thinking they would teach technology to thinking they would use technology to support students' learning (Beyerbach et al, 2001; Kirschner et al, 2008; Knezek, Christensen & Fluke, 2003; UNESCO, 2008a, 2008b; Webb, 2008). To develop this thinking among teachers, technology integration in teacher education should provide pre-service teachers with hands-on experiences as they explore how to use ICT and its applications in their teaching and learning. Educational courses should, therefore, model technology integration and field experiences in technology-rich classrooms.

The concept of TPACK

Effective teaching with technology requires that teachers understand 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 in a certain context. According to Koehler and Mishra (2009), teachers' knowledge of content, pedagogy and technology forms the heart of good teaching with technology, a process that has come to be known simply as TPACK, standing for Technological Pedagogical Content Knowledge. TPACK has been touted as "*the basis of effective teaching with technology, requiring an understanding of the representation of concepts using technologies; pedagogical techniques that use technologies in constructive ways to teach content; knowledge of what makes concepts difficult or easy to learn and how technology can help redress some of the problems that students face; knowledge of students' prior knowledge and theories of epistemology; and knowledge of how technologies can be used to build on existing knowledge to develop new epistemologies or strengthen old ones*" (Koehler and Mishra, 2009, p. 66).

The term TPACK, which was previously known as TPCK (Koehler & Mishra, 2005), provides the knowledge base needed by teachers to incorporate technology in their teaching (Guzey & Roehrig, 2009). According to Niess (2005), for technology to become an integral component in the teaching and learning process, pre-service teachers must develop an overarching conception of their subject matter with respect to technology and teaching approaches (TPCK). 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), as indicated in Figure 1, is what makes effective teaching with technology possible (Mishra & Koehler, 2006; 2009).

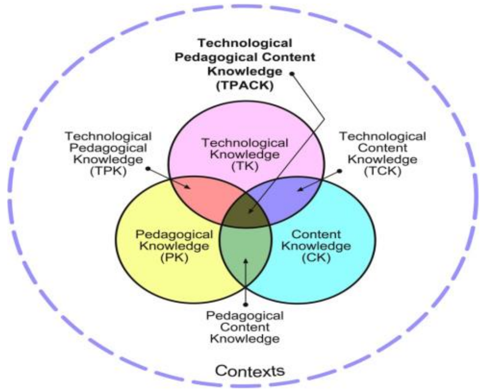

Figure 1: TPACK framework (Koehler & Mishra, 2009)

The different components of TPACK are described as follows:

Technological Knowledge: Technological knowledge is the knowledge of various technologies, ranging from low-tech technology, such as pencil and paper, to digital technology, such as the internet, digital video, and interactive whiteboard (Schmidt et al, 2009). Technological knowledge is related to the ability of the teacher to use hardware and software to deal with learning problems (Harris, Mishra & Koehler, 2009). However, Koehler and Mishra (2009) argue that technology is always more in a state of flux than content and pedagogy. What is seen as new technology today may become old technology soon after or in subsequent years; thus, it is 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 & Koehler, 2009). Content knowledge is about the knowledge a teacher possesses in the Mathematics or Science subjects he/she teaches. Shulman (1986) cited in Kohler and Mishra (2009) describes this as including the knowledge of concepts, theories, ideas, organisational frameworks, scientific facts and theories, knowledge of evidence and proof, as well as established practices and approaches for developing such knowledge.

Pedagogical Knowledge: This describes the knowledge of the teacher on the processes and practices of teaching and students' learning, encompassing educational purposes, goals, values, and strategies (Koehler & Mishra, 2009). According to Koheler and Mishra, pedagogical knowledge encompasses the broad spectrum of teaching approaches, from planning the lesson to students' assessment. It includes knowledge about the techniques or methods used in the classroom, the nature of the learners' needs and preferences, and strategies for assessing students' understanding (Harris, Mishra & 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 of developing better teaching practices in the content area (Schmidt et al, 2009). Koehler and Mishra (2009), adopting the idea of Shulman, describe PCK as the transformation of subject matter for teaching, which occurs when a teacher interprets the subject matter and finds various ways of presenting it, and adapts and tailors the instructional materials to alternative conceptions and the 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 particular ways (Koehler & Mishra, 2009). It is the knowledge of how various technologies can be used in teaching as well as 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 given subject matter (Koehler & Mishra, 2009; Niess, 2005). An example of technological pedagogical knowledge may include the use of an 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. According to Koehler and Mishra (2009), "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 about understanding the manner in which technology and content influences and constrains one another. Teachers tend to master not only the subject matter but also the manner in which the subject matter can be changed by the application of particular technology (Koehler & Mishra, 2009).

Technological, Pedagogical and Content Knowledge: This refers to the knowledge required by teachers for integrating technology in 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 whenever 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.

Statement of the Problem

Knowledge of technology, pedagogy and content is important for pre-service teachers in their attempt to effectively integrate technologies in the teaching of Science and Mathematics. Thus, teacher training institutions, as gateways to effective teaching with technology, are required to develop these ICT integration competencies in pre-service teachers. Although there is evidence from the courses offered in teacher training colleges in Tanzania that pre-service teachers are taught how to use ICT in teaching Science and Mathematics, studies (Hare, 2007; Kafanabo, 2006; Sugiyama, 2005; Tilya, 2008) have reported a low level of ICT uptake in schools. Also, the extent to which teachers integrate technology in teaching depends largely on the way they learned using technology (Doering et al, 2003; LeBaron, McDonough & Robinson, 2008). The latter statement suggests that the poor uptake of technology in teaching is dialectically linked to teachers' poor training in college. However, there is no evidence yet to prove that pre-service teachers are not well-trained in integrating technology in teaching. Most of the studies carried out in Tanzania on integrating ICT in teaching paid attention to the teachers' use of ICT in teaching at school rather than how they were prepared to use ICT in teaching. This makes it difficult to explain the way pre-service teachers are trained to integrate technology, pedagogy and content in teaching. Thus, this study investigated the competencies that pre-service teachers develop at college to integrate ICT in teaching, effective practices that can enhance pre-service teachers' ability to integrate technology, pedagogy and content, and the impact of those practices in developing pre-service teachers' technological pedagogical content knowledge (TPACK).

Objectives of the Study

The main objective of this study was to "investigate the different ways through which pre-service teachers at DUCE can acquire competencies for integrating technology, pedagogy and content". This main research objective was tackled through three specific objectives, which were to:

- Assess the pre-service science and mathematics teachers' knowledge of ICT use in teaching;
- Identify the learning activities that are effective in promoting TPACK among pre-service science and mathematics teachers;
- Assess the impact of the identified learning activities in developing pre-service teachers' TPACK

Research Design

This study employed an action-based research design. According to Mertler (2006), this is a research method intended to solve the practical problems of an individual, a group or an institution through planned intervention in their day-to-day work. The study employed the pre and post-intervention analysis of pre-service teachers' competency in integrating technology, pedagogy and content. Adopting the approach used by Howden (1998) and Lundeberg, Bergland, Klyczek and Hoffman (2003), prior to intervention, pre-service teachers participated in a survey and microteaching, which were aimed at identifying their competency in integrating technology in teaching. This was followed by a TPACK training course and discussion with peers, which enabled them to identify weaknesses in how they integrated technology in teaching. Based on the weaknesses identified during the discussion, pre-service teachers developed alternative approaches to enhance the integration of technology, pedagogy and content in teaching. The new approaches guided them in the redesigning of the lesson, which later on was presented to colleagues for the second time. At the end of the intervention, pre-service teachers participated in another survey and reflected on the intervention activities.

Participants

Four instructors from the department of curriculum and teaching and 29 pre-service Science and Mathematics teachers participated in the study. College instructors were involved in the study to provide an overview of the pre-service teachers' preparation processes. Their information was useful for gaining an understanding of the level of pre-service teachers' TPACK. However, a large part of the study involved the Bachelor of Education in Science (BEd Sc.) students, who discussed the technology integration weaknesses and proposed alternative approaches for integrating technology in their teaching. Participants were taken as "a case" for the study because at the time the study was conducted, they were in the last month of their bachelor programme. Thus, they were expected to demonstrate an exemplary competence level that pre-service teachers acquire at DUCE. Also, the BEd (Science) programme includes students who specialised in Mathematics, Chemistry, Physics and Biology, which were the focus subjects of this study (i.e. Mathematics and Science).

Instruments

Data were collected using questionnaires, researcher's log book, interviews with instructors and an observation checklist. A questionnaire was administered to student teachers for pre and post-intervention assessment of pre-service teachers' knowledge and competency in using technology and integrating it in pedagogy and content. In addition, there was a reflective questionnaire, with both closed and open-ended questions that related to the second and third research questions. The questionnaires were adopted from Schmidt et al (2009). Interview questions were also used to gather information about the instructors' knowledge of TAPCK and whether their technological knowledge was similar to that of the pre-service teachers. Interviews with the instructors were important for establishing the relationship between what pre-service teachers learn from their instructors and what they can demonstrate in teaching with technology. All interview questions were semi-structured with open-ended questions, modified from UNESCO (2008a) and Schmidt et al (2009). As regards the observation checklist, it was based on the technological standards of ISTE (2008), Schmidt et al (2009) and UNESCO (2008a). The checklist was used to investigate the pre-service teachers' use of technology during microteaching (pre-intervention), and during lesson presentation (post-intervention). In addition, the researchers' log book was used to maintain a record of activities and events occurring during the intervention process, which could not be recorded using the observation checklist. The researcher's log book was also used during peer appraisal, TPACK training and lesson design.

Instruments' Validity

All research instruments were evaluated by three experts from the University of Twente, who were doing research on TPACK and teaching courses on educational technology. The evaluation of the instruments by experts led to a change in the observation checklist scales, from continuous scales (0 to 10) to categorical scales (Yes or No). Questions about the technological tools used in the pre-service teachers' learning at the college were modified to exclude all tools that were not available at the college, such as interactive whiteboard. However, the survey questions and observation checklist, which were directly adopted from Schmidt et al (2009), did not change.

Results

Pre-service Teachers' Knowledge and Competencies in using Technology

A survey was conducted prior to the intervention to assess the pre-service teachers' knowledge of technology. The survey revealed that pre-service teachers' technological knowledge was average, (M = 3.18, SD = 0.99), on a 5-point scale, where 1 = *Strongly Disagree* and 5 = *Strongly Agree* (Table 1).

Table 1: Pre-service Teachers' Technological Knowledge

Technological Knowledge	*M*	*SD*
I can use technology without problems	3.34	0.86
I know how to solve my own technical problems	2.97	0.98
I can learn about technology easily	3.55	0.91
I have the technical skills I need to use technology	3.59	1.02
I keep up with important new technology	3.31	1.29
I have sufficient opportunities to work with technology	2.66	0.86
I know about a lot of different technologies	2.86	1.03

Pre-service teachers had basic technological knowledge, but were not able to use technology effectively to facilitate the teaching and learning process. As reported by the survey, limited competency in using technology resulted from the low level of technological use in their teaching and learning. The level of technology use by pre-service teachers at DUCE was below the mean, with high standard deviations (M=2.96, SD = 1.82) on a 6-point Likert scale where 1 = *never*, 2 = *rarely*, 3 = *less than half the time*, 4 = *half the time*, 5 = *almost always*, 6 = *always*. The limited use of technology at the college was also found to be caused by limited access to technology, and overall access to technology was found to be restricted (M = 1.87, SD = 0.40) on a 3-point Likert scale where 1 = *Not available*, 2 = *restricted access* and 3 = *free access* (Table 2).

Table 2: Use of and Access to Technological Tools at DUCE

Technological Tools	Use		Access	
	M	*SD*	*M*	*SD*
Computers (College computer lab)	3.34	1.71	2.34	0.55
Learning management system/VLE	3.17	1.79	2.21	0.86
Audio equipment	2.66	1.73	1.34	0.67
Digital camera	1.59	1.37	1.24	0.57
Mobile Phones	3.45	2.18	2.03	0.94

Projection systems	3.48	1.72	2.00	0.53
Television	3.00	2.20	1.97	0.82

In a correlation analysis, there was a significant positive correlation ($r\ (28) = 0.40$, $P = 0.03$) between the use of technological tools (computer, learning management system, mobile phones, camera) and the development of technological knowledge. However, there was insignificant correlation ($r\ (28) = 0.15$, $P = 0.44$) between access to technological tools and the development of technological knowledge. The results imply that the more pre-service teachers had an opportunity to use technological tools in their learning, the more competent they became in using that knowledge. However, the presence of technology at the college without it being used had no impact on developing teachers' technological knowledge.

Pre-service teachers' competency in TPACK

In a survey on pre-service teachers' competency in TPACK, technological knowledge had the lowest mean value ($M = 3.18$, $SD = 0.65$) on a 5-point Likert scale where 1 = *strongly disagree* and 5 = *strongly agree,* whereas content knowledge and pedagogical knowledge had the highest mean (Table 3).

Table 3: Pre-service Teachers' Competencies in TPACK

Competency area	M	SD
Technological Knowledge	3.18	0.65
Pedagogical Knowledge	4.29	0.46
Mathematics	4.55	0.48
Physics	4.58	0.47
Biology	4.58	0.47
Pedagogical Content Knowledge	4.17	0.57
Technological Content Knowledge	3.54	0.53
Technological Pedagogical Knowledge	4.03	0.67
Technological Pedagogical and Content Knowledge	3.46	0.58

Teachers' TPACK was also measured by observing the student teachers' use of technology in the classroom in the micro-teaching session. The outcome of the observation made by both the researcher and peers during micro-teaching showed that mean values for content knowledge and pedagogical content knowledge were the highest on a 2-point scale (1= *No* and 2 = *Yes*) (Table 4).

Table 4: TPACK Competency of Pre-service Teachers during Micro-teaching

	M	SD
Technological Knowledge	1.50	0.28
Content Knowledge	1.68	0.20
Pedagogical knowledge	1.38	0.27
Technological Pedagogical knowledge	1.54	0.41
Technological Content Knowledge	1.41	0.33
Pedagogical Content Knowledge	1.74	0.32
Technological Pedagogical and Content Knowledge	1.41	0.22

Learning activities to promote TPACK

The TPACK survey results and observation of teachers' use of technology during micro-teaching implied that pre-service teachers were competent as regards content and pedagogical content knowledge; however, they needed to learn about technology and pedagogy so as to develop TPACK. Thus, training was organised to equip pre-service teachers with these necessary knowledge components. During the training, a variety of technological tools that can support learning were discussed. The technological tools discussed included iPod, wikis, online games, blogs, television, computers, mp3, e-portfolio, course management systems, simulations and mobile phones. The procedure for choosing the technological tool in relation to content and pedagogy was also discussed. Finally, the integration of technology, pedagogy and content in teaching was discussed. Using the concepts of Koehler and Mishra (2009), the student teachers and the researcher discussed the concept of TPACK, paying particular attention to:

1. The representation of concepts using technology;
2. Pedagogical techniques that use technology in constructive ways to teach content;
3. Knowing what makes concepts difficult or easy to learn and how technology can help address some of the problems that students face;
4. Knowledge of students' prior knowledge and knowledge of how technology can be used to build on existing knowledge to develop new knowledge; and
5. The fact that no single technological solution applies to every teacher, every course, or every view of teaching.

Also different learning activities were discussed in relation to the compatible technology that can support each activity, as well as the science or mathematics content that can be taught through different activities and different technologies. After the training, pre-service teachers participated in the redesigning of a lesson that integrates technology, pedagogy and content.

After this, four groups were formed to design the lesson: two groups prepared a Mathematics lesson, one group prepared a Physics lesson and one prepared a Biology lesson. As there was only one Chemistry student teacher, he was advised to join the Physics group. Each group was assigned a number shown in Table 5. The subject, topic/learning objectives and the technology and pedagogy to be used were decided on by the students themselves.

Table 5: Group Participation in Lesson Preparation

Group number	Subject	Topic	Technology and pedagogy
Group No. 1	Physics	Simple pendulum: Relationship between angle of release, length of time and number of oscillations	Simulations: Inquiry and collaborative learning
Group No. 2	Mathematics	Circles: Calculation of radius and diameter of the circle.	Microsoft Word: Task-based learning
Group No. 3	Mathematics	Statistics: drawing Charts in Mathematics	Spreadsheet: Task-based learning
Group No. 4	Biology	Genetics: DNA coding with the mRNA and tRNA	Simulations: Inquiry learning

During lesson preparation, the researcher consistently played four main roles: as the overall supervisor of all teacher learning activities during the study; as an observer (observing pre-service teachers' progress in the design process by posing some questions concerning their choices of technology, pedagogy and content); as a facilitator (providing highlights for the overall design in addition to the guiding questions that were developed by the students themselves); and as a teacher (during the training in TPACK).

The Impact of the Intervention on TPACK Competency

After the survey, micro-teaching, training, and designing the lesson, another lesson presentation session similar to micro-teaching was organised. Another observation of classroom practices was made in a manner similar to the one adopted in the micro-teaching. Finally, another survey was carried out, using the same instrument, to assess the change in knowledge between the pre-intervention and post-intervention phases. In a paired sample t-test to assess the change in the pre-service teachers' TPACK competency between pre-intervention and post-intervention, there was a significant change in TK, TCK, TPK and TPACK, between the pre and post-intervention survey. However, the change was insignificant for PK, CK and PCK (see Table 6).

Table 6: Pre-service Teachers' Pre and Post-intervention TPACK Knowledge

	Pre-intervention	*Post-intervention*	
	M ***(SD)***	***M*** ***(SD)***	***P***
Technological knowledge	3.18 (0.67)	3.66 (0.50)	0.05
Pedagogical knowledge	4.29 (0.43)	4.35 (0.32)	0.95
Content knowledge	4.58 (0.14)	4.89 (0.24)	0.64
Pedagogical content knowledge	4.17 (0.61)	4.64 (0.45)	0.38

Technological content knowledge	3.54 (0.57)	4.27 (0.43)	0.04
Technological pedagogical knowledge	4.03 (0.76)	4.35 (0.43)	0.05
Technological pedagogical content knowledge	3.46 (0.51)	4.17 (0.38)	0.02

As Table 6 illustrates, PK, CK and PCK were insignificant because pre-service teachers were already competent in these aspects as the pre-intervention study (see Table 3) had confirmed.

Another paired sample t-test analysis between the first and second micro-teaching (lesson presentation) revealed that all components of TPACK, except content knowledge and pedagogical content knowledge, were significant at $P < 0.01$ (see Table 7 below). As in Table 6, the pre-service teachers were already competent in content and pedagogical content; thus, there was no significant change in those components of TPACK.

Table 7: Paired Sample T-test for Pre and Post-intervention Presentation of the Lesson

	Pre intervention	***Post intervention***	
	M (SD)	***M (SD)***	***P***
Technological knowledge	1.50 (0.28)	1.68 (0.26)	0.00
Pedagogical knowledge	1.38 (0.20)	1.62 (0.19)	0.00
Content knowledge	1.68 (0.41)	1.71 (0.39)	0.10
Pedagogical content knowledge	1.74 (0.27)	1.83 (0.36)	0.07
Technological content knowledge	1.41 (0.33)	1.61 (0.35)	0.00
Technological pedagogical knowledge	1.54 (0.32)	1.72 (0.38)	0.01
Technological pedagogical content knowledge	1.41 (0.22)	1.60 (0.28)	0.00

The results presented in Tables 6 and 7 show that the intervention activities carried out during the study had impact on developing pre-service teachers' TPACK. Also, the post-intervention survey results show that pre-service teachers were able to integrate technology, pedagogy and content in their teaching (see Table 8 below).

Table 8: Pre-service teachers' Competency in Specific TPACK Areas

Competencies	***M***	***SD***
I can teach a lesson that appropriately combines Science/Maths, technology and	4.18	0.66

teaching approaches		
I can use strategies that can combine content, technology and teaching approaches that I learned during the interventions	4.18	0.66
I can select which technology to use in my classroom that enhances what I teach, how I teach, and what students learn	4.32	0.57
I can choose technologies that enhance the content of a lesson	4.23	0.43
I can provide leadership in helping others to coordinate the use of content, technologies and teaching approaches in my classroom	3.95	0.72

Although most of the items in Table 8 had values above the mean on a 5-point scale, the data revealed that pre-service teachers' competency in providing leadership in the use of TPACK had the lowest mean and highest standard deviation. This implies that, despite competency in integrating technology, pedagogy and content that the pre-service teachers had gained from the interventions, they still lacked confidence in using the knowledge they had acquired to teach others. In fact, most of the pre-service teachers were more competent and confident using ICT for their own learning and development than using it to provide leadership to others.

Discussion

The study's findings reveal limited technological knowledge among pre-service teachers, and limited ability to integrate technology, pedagogy and content, leading to poor technological pedagogical content knowledge (TPACK). Although the pre-service teachers in the study had basic ICT knowledge, they were unable to integrate this knowledge with content and pedagogy (Kafyulilo, 2010). The pre-service teachers were lacking specific skills to effectively use technology and integrate it with pedagogy and content. In other words, the pre-service teachers had all the theoretical knowledge of ICT and ideas about integrating it in teaching but had not actually experienced how it is integrated in real classroom teaching. The observed lack of knowledge of technology among pre-service teachers and integrating it with pedagogy and content was attributed to the inadequate structure and components of ICT and the pedagogical courses offered at the college, the shortage of technological tools and instructors' incompetence in using ICT in teaching.

The college offers courses in the methodology for teaching different disciplines (Physics, Chemistry, Biology, Mathematics, etc) as well as a course in using ICT in Science and Mathematics education. These courses are taught separately, hence offering limited opportunities for pre-service teachers to experience the combination of ICT, pedagogy and subject matter. On the whole, pre-service teachers at DUCE miss out on the opportunity to learn about and practise integrating technology pedagogy and content, as well as an example of a technology-integrated lesson because their instructors do not use technology in teaching (cf. Beyerbach et al, 2001; LeBaron et al, 2009). According to LeBaron et al (2009) and UNESCO (2008a), the impact of what pre-service teachers learned at college depends on the extent to what the pre-service teachers themselves learned about technology. Since there were limited opportunities for pre-service teachers to experience learning with technology, they could not teach using technology either, as observed during the micro-teaching session.

It was established from the intervention activities carried out during the study that the process of planning a lesson, presenting it to colleagues, getting critiques from colleagues and re-planning in a cyclical way was effective in enhancing pre-service teachers' competency in TPACK. The findings of this study agree with those of Somekh (2008), who found that pre-service teachers' participation in different hands-on activities was effective in enhancing technology use in teaching. Indeed, the participation in activities that reflect the actual teaching provides an opportunity for pre-service teachers to learn how to bring together the technological, pedagogical and content knowledge they learn as separate disciplines. As reported in Polly, Mims, Shepherd and Inan (2009), teachers' technological skills alone cannot result in the effective use of technology in teaching in ways that are likely to impact students' learning. In fact, effective technology integration occurs when pre-service teachers participate in activities that enable them to experience first-hand how technology can be effectively integrated in their teaching to enhance students' learning.

It was observed during the intervention that micro-teaching, training (lecture) in TPACK, lesson design, presentation and peer appraisal were necessary components for developing technological integration competency. Studies by Guzey and Roehrig (2009), Killic (2010) and Niess et al (2009) also acknowledge the importance of hands-on activities, such as lesson design (what to teach, how to teach and with what technology to teach) for enhancing pre-service teachers' TPACK. The lesson design activity, subjected pre-service teachers to an inquiry process, which was guided by questions such as what to design, why to design this, what technology, with what methodology, etc. This exposure accorded the pre-service teachers the opportunity to reflect on the critical relationship between content, technology and pedagogy (cf. Guzey & Roehrig, 2009; Ozgun-Koca et al, 2009). According to Özgün-Koca et al (2010), as teachers decide how to use technology in their teaching, they need to consider the Science or Mathematics content they would teach, the technology they would use, and the pedagogical methods they would employ.

Participating in activities that reflect the challenges that can be experienced in real teaching was found to enhance pre-service teachers' confidence and motivation to use technology (cf. Cox et al, 1999; Kirschner et al, 2008). The pre-service teachers' confidence in using technology was found to increase the probability that they would be able to integrate technology in their teaching. Studies (Cox et al, 1999; Tondeur, Valcke & Braak, 2008; Thomas & Knezek, 2008; Webb, 2008) confirm that the extent to which technology is used in teaching depends significantly on the extent to which a teacher is competent and confident enough to use it. However, in the study the majority of the pre-service teachers were more confident using the technology for their own development than in developing specific competencies for teaching students and providing TPACK leadership. A study by Agyei and Voogt (in press) reported on the relationship between teachers' anxiety and the adoption of technology in teaching. As this study has revealed, the more pre-service teachers had the opportunity to use technology the more they learned and developed the confidence to integrate ICT in their teaching. Thus, training in specific technological skills and the availability of technological tools are other important components in the effective development of TAPCK among pre-service teachers.

Conclusion

The results of this study have shown that pre-service teachers do not acquire the necessary TPACK competencies to enable them to confidently integrate technology when teaching Science and Mathematics in secondary schools. Therefore, the poor integration of ICT in Science and Mathematics teaching in secondary schools in Tanzania which has been reported by other studies (Hare, 2007; Ottervanger et al, 2007; Sugiyama, 2005; Tilya, 2003) seems to result from teachers' poor pre-service preparation programme. However, as this study has established, the competency of pre-service teachers to effectively integrate technology can be developed when they in authentic learning processes, which reflect teaching in the real context. In addition, for teachers to engage in authentic learning activities, they need a sufficient supply of technological tools to be in a position to regularly deploy technology in various teaching and learning processes. Also, training geared to developing specific technological skills are considered important for developing teachers' competencies and the confidence to integrate technology in different teaching and learning contexts and to develop TPACK to enhance students' learning. On the basis of the evidence established at DUCE, the adoption of the Will Skill Tool Model appears to be important for developing TPACK among pre-service and in-service teachers in Tanzania.

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