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Developing Pre-service Teachers' Technology Integration Competencies in Science and Mathematics Teaching: Experiences from Tanzania and Uganda

Robert Kisalama[1,*], Ayoub C Kafyulilo [2]

[1] Monash University
[2] University of Dar es salaam [*Corresponding author. E-mail: rkis4@student.monash.edu]

Abstract. This study investigated the ICT integration practices in pre-service teacher education in the School of Education at Makerere University (College of Education and External Studies) in Uganda and Dar es salaam University College of Education (DUCE), a constituent college of the University of Dar es salaam in Tanzania. Specifically, the study aimed at establishing ways in which ICTs were being deployed in pre-service teacher training in the two colleges. It also investigated the factors constraining integration of ICTs in pre-service teacher education as perceived by the pre-service teachers and lecturers at the colleges. Using questionnaires and interview, data were collected from both the lecturers and final year pre-service teachers during the academic year (2009/2010). The findings revealed that, limited access to ICTs, limited lecturers' knowledge of ICTs and limited use of the available ICTs affected usage of the technologies. Thus, it emerged that there is a need to explore models situated in a more encompassing theoretical framework like Technological Pedagogical Content Knowledge (TPACK) so as to realise sustainable pedagogical practices in classrooms proliferated with technology.

Keywords: TPACK; Professional development; Science education

1 Introduction

While the need to have a more scientifically literate population to address the global challenges that humanity now faces continues to grow, the teaching and learning of science and mathematics continue to place a lot of challenges to teachers. This failure is setting an alarm to governments, parents and schools all around the world. Although many countries in the world are experiencing poor students' participation and performance in science and mathematics-related

subjects (Beauchamp & Parkinson, 2008; Martin et al, 2008), African countries have the worst experience in these subjects, particularly mathematics (Martin et al, 2008). Uganda and Tanzania are some of the African countries which experience high failure rates in science and mathematics at the primary and secondary levels of education (Uganda National Examination Board - UNEB, 2008; URT, 2008).

Failure in these subjects is raising a debate on how teachers teach and how students learn. Some see the failure as being born from teachers, due to lack of important teaching competencies (Kafyulilo, 2011), while others see the failure as resulting from lack of students motivation in science and mathematics (Yunus, & Ali, 2009). However, Koehler & Mishra (2009) see the problem as being caused by both teaching approaches and the way students learn. Thus, Koehler & Mishra (2009) call for an approach that treats teaching as an interaction between what teachers know and how they apply what they know in a unique circumstance or contexts within their classroom.

Luis, Illera & Escofet (2009), support the idea of Kohler & Mishra, by proposing the adoption of a learner- centred approach, an approach which is widely promoted throughout the world for its impact on students' learning. However, effective learner- centred approach requires flexibility among students in terms of location, time, materials, content and teaching approaches (Collis & Moonen, 2001). This flexibility can best be offered by ICT (Collis & Moonen, 2001). The use of ICT in teaching and learning can facilitate students' learning from any location, at any time and at a learner's preferred pace. According to Kafyulilo & Fisser (2011), ICTs such as mobile phones, are important tools for facilitating learning beyond the classroom walls. This helps learners to keep in touch with their teachers wherever they are.

1.1 ICT Integration in Education

In this article, ICT refers to all products that can store, retrieve, manipulate, transmit or receive information electronically in a digital form (Luppicini, 2005). Defining integration of ICTs in education remains problematic. However, it is generally agreed that, 'ICT integration' denotes a change in pedagogical practices that makes ICT less peripheral in classroom teaching (Law, Pelgrum & Plomp, 2008). This practice definition was adopted for the first phase of this study, as a benchmark for the researchers in investigating how ICTs are currently deployed within pedagogical practices of the lecturers for pre-service teachers in the School of Education at Makerere University in Uganda and Dar es salaam University College of Education in Tanzania.

In this study, ICTs integration practices were conceived from a perspective of use of mediation tools such as, computers, cell phones, interactive white boards, digital cameras, the Internet etc to communicate, create, disseminate,

store and manage information (Luppicini, 2005). Several practices around the use of ICTs in education continue to emerge depending on whether ICTs are seen as production tools that can support scaffolding on the side of the learners or as mediation tools to support the social theories in education that encourage collaboration, interaction and inquisition as a way of learning. However, such practices require the teacher to possess an adequate subject matter knowledge, pedagogical knowledge and pedagogical content knowledge (Shulman, 1986).

Consequently, it was important to explore how teacher educators were negotiating the new roles arising from the shift in pedagogy that might result from integration of ICT in their teaching. Fluck (2009) argues that attention should be placed on the transformative view of use of ICTs as observed in the new ways of learning and teaching (pedagogies) in the daily practices in pre-service teacher education. This suggests that, ICTs integration practices should reflect more of the pedagogical appropriateness that support new instructional and learning experiences uniquely provided by ICTs. Such practices should enable pre-service teachers to transform their own understandings and extend their experiences with ICTs that are relevant both to enhance their understanding of the subject content and method of teaching within a classroom situation.

1.2 ICT and Transformation of Learning of Science and Mathematics

Several authors (e.g. Beauchamp & Parkinson, 2008; Keong, Horani & Daniel, 2005; Niess, 2005) observe that utilisation of ICTs improves the teaching of science and Mathematics-related subjects. ICTs present a paradigm shift from teacher-centred to learner-centred, from individual learning to collaborative learning, and from the teacher as a source of knowledge to a learner as source of knowledge (Collis & Moonen, 2001; Kafyulilo, Fisser & Voogt, 2011; Nieveen, Handelzalts, van den Akker & Homminga, 2005). The ability to harness ICT in the design of learning in the classroom can have an impact on the engagement of students through creating more options for learners to connect technology with their course content.

While the actual impact of using ICTs in education on the achievement of learners remains debatable, some studies (e.g. Wellington, 2005; Halls & Higgins, 2005; Clements, 2000) have reported high enhancement of the teaching/learning process when ICTs are used (cf. Keong, Horani, & Daniel, 2005). Appreciative of the potential of technology in education, the government of Uganda, through the Ministry of Education and Sports, is pursuing a new policy requiring science teachers to integrate ICTs in their normal teaching. The government of the United Republic of Tanzania, through its Ministry of Education and Vocational Training, is also implementing the ICT policy for

basic education through the "Tanzania beyond Tomorrow" project funded by the World Bank and the Swedish Government.

One might argue that, while the governments of Uganda and the United Republic of Tanzania are attempting to provide enabling conditions through provision of computers to schools; the existence of ICTs alone does not transform teachers' practices (Kafyulilo, 2011). Teachers' pedagogical philosophies are reported to often influence the types of usage of ICTs. For instance, teachers who use ICTs the most—and the most effectively—are less likely to use traditional 'transmission-method' pedagogies (LeBaron, McDonough & Robinson, 2009; Trucano, 2005). Instead, they tend to practice more "constructivist" pedagogies. However, Hargreaves (1992) asserts that, promotion of different teaching methods, and other educational reforms fail if they are introduced without a very substantial teacher education component.

Teachers' limited proficiency, to integrate technology particularly in instructional and learning activities is highly widespread (Olakulehin, 2007). This seems to suggest that, a holistic approach focusing on technology, content and pedagogy as interrelated aspects in teacher training is important. Makrakis (2005) clearly points out that, new technologies require new teacher roles, new pedagogies, and new approaches to teacher training. However, the responsibility of preparing teachers, who are ready to integrate technologies in their teaching, lies with Teacher Educators and the Teacher training institutions (Howland &Wedman, 2004: LeBaron, et al, 2009). In addition to equipping pre-service teachers with subject–specific expertise, teacher training courses should prepare their attendees for the challenges of a changing world, by imparting effective teaching practices, an understanding of technology and the ability to work collaboratively with other teachers and their future students. Boling (2003) clearly asserts that, "If teacher education programs hope to keep up with the changes that are occurring as a result of this new digital society, then it is imperative that we take a closer look at the role that technology can have in transforming teacher preparation" (Boling, 2003, p. 72).

However, according to a UNESCO report by Khvilon and Patru (2002), no comprehensive framework of teacher training in ICT use in Africa was in existence and the few that were being used had been mostly developed outside of Africa. Shafika (2006) equally, pointed out the general absence of conceptual clarity, on the objectives of teacher professional development programmes for ICT initiatives in the African region. The situation in Uganda and Tanzania has not been any different. From a recent survey in Uganda (Ndidde et al, 2009) and Tanzania (Kafyulilo, et al, 2011) it was reported that, in addition to the failure of the current teacher training to mainstream ICT in the curriculum; many of the continuous professional development programmes for educators, rarely included ICT integration.

1.3 Problem and Research Questions

There is considerable literature on the effective use of ICTs in pre-service teacher education (cf. Kay, 2006; Shoffner, 2009; Sølvberga , Rismarka , & Haalanda, 2009). Despite this corpus of knowledge, many of the studies above were carried out in the developed world and have identified the need for more similar studies in different contexts to generate universal findings. Indeed, as pointed out by LeBaron et al (2009), there still exists a dearth of literature on the ICT integration in teacher education in Tanzania and Uganda. It is in acknowledgement of such need that the researchers undertook this study.

The main research question addressed in this study was: To what extent are pre-service teachers in Uganda and Tanzania prepared to effectively integrate technology in science and mathematics teaching? This general research question was answered by working out the following specific questions:

1. What is the level of accessibility to technology by the pre-service teachers and lecturers at the University of Makerere and Dar es salaam University College of Education?
2. What is the current pre-service teachers' technology integration competency in Tanzania and Uganda?
3. What are the constraining factors to ICT integration in pre-service teacher education as perceived by the pre-service teachers and lecturers?

2 Methodology

This study adopted the cross sectional survey research design to explore the status of technology integration in teacher training colleges in Tanzania and Uganda. According to Olsen & St. George, D.M. (2004) in a cross-sectional study design, either the entire population or a subset thereof is selected, and from these individuals, data are collected to help answer research questions of interest. In this study, pre-service teachers from DUCE and School of Education, Makerere University were selected to represent the other teacher training colleges in the Tanzania and Uganda.

2.1 Participants

Participants in this study were the final year pre-service teachers from Makerere University and Dar es salaam University College of Education (DUCE), and lecturers from the School of Education at Makerere University in Uganda and DUCE in Tanzania. Makerere University was chosen because it is the most technologically equipped, boasting of a regional IT academy and producing the biggest number of pre-service teachers in Uganda, whereas DUCE was selected

because it is one of the two constituent colleges of the University of Dar es salaam which solely prepare teachers in Tanzania and have the role to ensure that teachers are equipped with the knowledge required for better delivery of learning to students. DUCE has a population of 3550 students and 175 members of academic staff. Of these 29 pre-service teachers and 4 academic staffs participated in the study. The School of Education Makerere has a population of 107 members of the academic staff and about 3500 students. 505 of these students are pursuing a Bachelor of Science with education degree.

Twenty questionnaires targeting lecturers who were at the time teaching pre-service teachers were administered. Sixteen out of the twenty lecturers agreed to participate in this study providing a response rate of 80%. Sixty-nine out of the eighty questionnaires administered for the final year pre-service teachers were returned, giving a response rate of 86%. At the time of the study, these pre-service teachers were in their final semester of training for the academic year 2009/10. The pre-service teachers from School of Education Makerere were being trained to become secondary school teachers, while those in Tanzania were undertaking a degree leading to the award of Bachelor of Education in Science and were being trained to become college tutors.

2.2 Data collection:

2.2.1 Questionnaire for Lecturers:

The researchers designed a 59-item questionnaire comprising of questions that were specifically for this research while several other items were adapted and modified from two previous survey instruments developed by Ropp (1999), and the International Society of Technology in Education in 1998. The items were adopted because the current technological use in the context of this study is not any much different from the one, at the time these items were developed for the previous studies elsewhere. The scales as used in other studies (i.e. Markauskaite, 2007; Rekabdarkolaei & Amuei, 2008) were maintained. The questionnaire for lecturers comprised of six sections; a section for demographic information, computer proficiency and competency, frequency of use, current technological tools, access to support in University context and access to various forms of technology in three different contexts.

2.2.2 Interview for Lecturers

Lecturers from the DUCE participated in the interview with the researcher regarding their technology use in pre-service teachers training. Lecturers were asked about their knowledge about Technological pedagogical content knowledge (TPACK) framework and whether or not they were using this framework in the preparation of pre-service teachers. They were further asked

on the challenges and opportunities they experience in technology integration in their teaching and whether or not technology can enhance teaching and learning in science and mathematics. Lecturers at DUCE did not participate in the filling of questionnaire, because there were only few lecturers who were willing to participate in the study.

2.2.3 Questionnaire for Final Year Pre-service Teachers

The researchers also designed a 26-item questionnaire for pre-service teachers comprising of 19 close-ended items and seven open ended ones. Equally, the open-ended items addressed similar issues and same theoretical justification as those in one for the lecturers only that they were designed from the perspective of a student respondent. The questionnaire for the final year pre-service teachers was adopted from Schmidt et al (2009) and comprised four sections. These included a section for demographic information, another about computer proficiency and competency, technology integration competencies (with a focus on the understanding of TPACK) and a final section about access to various forms of technology in three different contexts.

3 Results

Findings indicated that pre-service teachers and lecturers had a limited access to technological tools. An analysis of the extent to which different technological tools were accessible to pre-service teachers and lecturers in different courses, revealed that the access to audios, iPod and digital photo camera were low in a five-point Likert scale where 1 = never, 2 = once a month, 3 = once a week, 4 = about 3 times a week and 5 = daily. The findings were as presented in Table 1.

Table 1: Access to Technological Tools among Pre-service Teachers

	Dar es salaam University College of Education			Makerere University School of Education		
	N	M	SD	N	M	SD
Access to Computer	29	3.34	0.55	69	3.55	0.69
Access to Radio	29	3.21	0.86	69	2.78	0.76
Access to Audio Equipment	29	2.34	0.67	69	2.34	0.71
Access to iPods	29	1.24	0.58	69	1.84	0.90
Access to Mobile Phone	29	3.73	0.94	69	3.61	0.53
Access to digital Camera	29	1.40	0.54	69	2.67	0.64
Access to television	29	2.97	0.82	69	3.48	0.63

Scale: 1=never, 2 = monthly, 3 = once a week, 4 = about 3 times a week, 5 = daily

The accessibility to technological tools among pre-service teachers at DUCE (Table 1) had an average mean of 2.60 (SD = 0.71) and the School of Education

Makerere University had an average mean of 2.90 (SD = 0.69). Mobile phones were the most freely accessible technological tools to pre-service teachers at both DUCE and Makerere University.

Similarly, responses of lecturers from DUCE and Makerere University indicated results similar to those of the pre-service teachers; where lectures from DUCE claimed in the interview with the researcher that, they had limited access and use of technology at the college for teaching process, while those from School of Education Makerere University indicated technology use on a daily basis.

Lecturers from DUCE argued that they have their personal laptops, which they use mostly for preparing exams, writing reports and preparation of students examination results, but they don't use these laptops for teaching process. One of the reasons for the continued use of local teaching methods was reported to be the lack of other technological tools at the college such as computers and beam projectors.

On the other hand, findings from School of Education Makerere University have indicated a high level of access to technological tools at the University as well as high level of uses of these tools for teaching and learning process. Table 2: indicate the level of access to technology by the lecturers at Makerere University, at home, at the university and other places.

Table 2: Makerere University Lecturers' Access to Technology

		Daily	2 to 3 times a week	Once a week	Never
At home	Mobile phone	87.5% (14)	6.25% (1)	-	6.25%(1)
	Computer/laptop	62.5% (10)	31.3% (5)	-	6.25%(1)
	iPod	6.25%(1)	-	6.25% (1)	87.5%(14)
	Internet	25%(4)	12.5%(2)	-	62.5% (10)
At University	Mobile phone	87.5% (14)	6.25%(1)	-	6.25%(1)
	Computer/laptop	68.8%(11)	31.3% (5)	-	-
	iPod	6.25%(1)	-	6.25% (1)	87.5% (14)
	Internet	87.5%(14)	12.5% (2)	-	-
Others(e.g. cafés)		-	12.5% (2)	18.8% (3)	37.5%(6)

As it was to the pre-service teachers, lecturers were as well having more access to mobile phones compared to other technological tools such as iPods, Mp3, digital camera etc.

A further analysis of pre-service teachers and lecturers on their technological competencies, revealed a limited knowledge of both pre-service teachers and lecturers on the use of technology in teaching and learning. Results from pre-service teachers questionnaire on their knowledge of technology, pedagogy, content and the integration between these components revealed low level of

pre-service teachers' Technological Pedagogical Knowledge, Technological Content Knowledge, Technological Knowledge as well as Technological Pedagogical Content Knowledge.

Table 3: Competencies in TPACK among Pre-service Teachers (Makerere University School of Education Makerere University and DUCE)

Competency area	Mean	SD
Technological Knowledge	2.43	0.65
Pedagogical Knowledge	3.87	0.46
Content knowledge	3.85	0.48
Pedagogical Content Knowledge	3.67	0.57
Technological Content Knowledge	2.54	0.53
Technological Pedagogical Knowledge	3.03	0.67
Technological Pedagogical Content Knowledge	2.46	0.58

Results in Table 3 show the average values of mean and standard deviations for both Tanzania and Uganda. Data from individual countries indicated that pre-service teachers from Tanzania thought that they knew more about technology integration than it was reported by Ugandan pre-service teachers. However, when pre-service teachers from Tanzania were subjected to practical use of technology, their competencies were found to be limited. Overall, results from the questionnaire indicate that pre-service teachers' technological knowledge, technological pedagogical knowledge, technological content knowledge and technological pedagogical content knowledge were more limited than the knowledge of pedagogy, content as well as pedagogical content knowledge which have for a long time been the focus knowledge for teachers' preparations. On the other hand, interview with lecturers from DUCE on their technology integration competencies had the responses presented in Table 4.

Table 4: Summary of Interview with College Instructors

Question	Interviewee 1	Interviewee 2	Interviewee3	Interviewee 4
How can you rate your own technological competency?	I have a moderate competency. …this is caused by the limited supply of ICT facilities at the college… the college lacks ICT tools such as interactive white board, learning environment etc	…my technological competency is very low. …I don't have knowledge about ICT tools that can facilitate learning. I also don't know the software and some computer programs that I can support learning.	Majority of teachers at this college are missing the skills of using CT…but I can't say I am excellent, I think I am average	I have moderate competency. …we don't have most of the technological tools here… it becomes very difficult to work with technology.

The results presented in Table 4 imply that even the lecturers still have limited Technological Pedagogical Content Knowledge. This may further imply limited

use of technology to enhance teaching and learning. This is likely to have an impact on the development of technological knowledge among the pre-service teachers.

Several factors were reported to contribute to the low level of technology integration in education in both Tanzania and Uganda. During the interview with pre-service teachers on the possible factors influencing their technology integration in teaching and learning process, it was revealed that some of the most common factors were; Limited technological knowledge among both pre-service teachers and lecturers, also lack of technological tools in most of the educational institutions. It was reported by both lecturers and pre-service teachers that the availability of technological tools in schools was another factor contributing limited use of technology in teaching.

Findings from DUCE have shown that, the college has two computer labs, one in the faculty of education with approximately 10 working computers and the other in the faculty of science with approximately 20 working computers. In total there are 30 computers for 3500 students. Similarly there is one computer for the college staffs in each department with about 15 members of staff.

Thus, the computer to student ratio is 1:117 and computer to staff ratio is 1:15. Computer labs are mostly open when there is an ICT related class which requires the use of computer. There is also one laptop and one projector in each faculty with over 60 academic staffs. In addition, the college has only one television set to facilitate students learning. Overall, the college gets a very low internet bandwidth which makes it difficult for most synchronous communication and access to some learning sites that requires high bandwidth such as YouTube.

While the School of Education at Makerere University has about 91 computers and 336 data points for accessing the Internet, most of these are located in a lockable computer laboratory and information kiosks which are manned by laboratory attendants leading to limited hours of access. This situation is found to affect the ICT use among instructors and pre-service teachers. Pre-service teachers at the school of education in Makerere urged the university administration to stop protecting internet like gold. Arguing that the process where computers are kept under a lock and key limits students' opportunity to practice the use of computers to prepare lessons and search teaching materials. One of the respondents from Makerere University noted: "I have not learnt many skills because of limited practice, I do not own a computer yet the laboratory is rarely open when I am free…".

4 Discussion

Findings from this study revealed a limited technological knowledge among pre-service teachers and lecturers, and limited ability to integrate technology,

pedagogy and content, thus poor technological pedagogical content knowledge (TPACK) in both DUCE and Makerere University. Although pre-service teachers had the basic ICT knowledge, they could not integrate ICT with content and pedagogy. Pre-service teachers had all the theoretical knowledge of ICT and its integration in teaching but had not experienced the way it works in a real context.

The observed incompetency among pre-service teachers in technology and its integration with pedagogy and content was attributed to ill-structure and components of ICT and pedagogical courses offered at the college, shortage of technological tools and instructors' incompetency in using ICT in teaching.

Both Makerere University and DUCE were reported to offer courses on methodology for teaching different disciplines (Physics, Chemistry, Biology, Mathematics etc), also a course on ICT in Science and Mathematics education. However, these courses are taught separately, there is no opportunity for a learner to experience the combination of ICT, pedagogy and science subjects. Pre-service teachers at DUCE miss the opportunity to learn and practice the integration of technology pedagogy and content also they miss an exemplary technology integrated lesson because their lecturers are not using 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 from the college depends on the extent they learned with technology. Since there were limited opportunities for pre-service teachers to experience learning with technology, they could not make it explicitly how competent are they in using technology to teach. Beyerbach et al (2005) propose for the presence of a model in which pre-service teachers can follow in their endeavour to develop technology integration competencies.

One of the major findings of this study was that, the conceptualisation of ICTs by the lecturers in the School of Education at the University of Makerere was simply an add-on to the normal teacher-centred strategies, whereas at DUCE ICT was conceptualised as the tool for administration purposes. Bétrancourt (2007,cited by Enochsson & Rizza,2009) points out that, despite the emphasis put on the use of ICT in order to support an active pedagogy such as socio-constructivism, the majority of the ICT tools currently available in institutions, indeed, simply support traditional transfer pedagogy hence limiting the use of ICT to presentations (documents) or evaluations (quizzes). In fact, Fuller (2003,cited in Selwyn2007), further argues that, by maintaining a material-semiotic infrastructure of business, many technology training environments like Blackboard and PowerPoint demand and dictate an already predetermined hierarchical and linear modes of technology use, premised on presentation and one- way distribution of information. It might therefore not be strange that, about 62.5% of the respondents mentioned "the use of ICTs in knowledge delivery" as their definition for integration of ICTs in education.

When the pre-service teachers were asked as to whether the use of ICTs by their lecturers had been of help to overcome their ICT related challenges, about 51.7%, felt they had been assisted while more than 48.3% felt they had not.

The pre-service teachers were further asked to justify how they had been helped, and approximately 55.5% of pre-service teachers mentioned acquisition of information, retrieval skills from the internet, while about 20% mentioned acquisition of technical skills especially the use of the Overhead projector (OHP). Of those who felt they had not been assisted, 64% mentioned limited use of ICTs by the Lecturers. Lecturers themselves also acknowledged that they have been using these ICT tools quite rarely to support teaching and learning process. Some pre-service teachers made comments like:

"Our Lecturers are still traditionalistic..."

"Those who use ICTs do so very fast, and so we never get to master anything..."

"…more skills guiding students on how to use ICTs should be given…"

These findings seem to suggest that, while some lecturers may be making an effort to integrate ICTs in their teaching; their approach is not well received by the pre-service teachers and does not seem to model the much-desired transformation in learning with and through technologies.

Further research about this study using more qualitative methods involving students at various stages of their pre-service teacher training may be needed. Such a study should aim at the development of models on successful strategies for using the most affordable ICTs to change pedagogical practices using case studies in pre-service teacher training in the two Colleges.

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