

Applying Rogers' Diffusion of Innovations Theory to Investigate Technology Training for Secondary Mathematics Teachers in Kenya

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Abstract

This current study examined the extent technology training influence secondary mathematics teachers' decisions to adopt or not to adopt technology in the classroom practice from Nairobi and Nyandarua counties in the Republic of Kenya. The study applied the case study research design and the Rogers' (2003) diffusions of innovations theory to investigate the research problem. The study found that mathematics teachers have not received adequate technology training relevant for mathematics teaching because of technologically unskilled trainers, lack technology software related to mathematics teaching, and teachers are not motivated to attend training for lack of incentives. The study suggests radical changes be undertaken on how training of mathematics teachers by the Center for Mathematics Science and Technology Education in Africa (CEMASTEA) and the National ICT innovation and Integration Centre (NI3C) and the teacher training programs at the public universities and colleges. The study also recommends that further research is needed to understand technology training for mathematics teachers in Kenya.

Keywords: Kenya, technology adoption, Rogers' theory, diffusion of innovations, mathematics

Background of the Study

Recognizing the potential of ICT and its importance in teaching and learning compared to the traditional print sources (Valmont & Wepner, 2000), and buoyed by the prospects of greater economic, social, educational and technological gains, many developing countries have adopted national policies on technology integration in education to boost the quality of education. One such developing country that is currently rolling out ICT in schools is the Republic of Kenya to improve the quality of education. The Kenyan education system is hampered by many challenges, among them related to poorly trained teachers and students' weak performance in the national examinations (Sulungai, Toili, &Amadalo, 2011). In fact according to Sulangi et al., the issue of Kenyan secondary school students performing poorly in some subjects, including mathematics in the Kenyan National Examination Certificate (KCSE) is attributed to weak pedagogical skills among the teachers.

As a result, to respond to these challenges the government and other stakeholders have initiated efforts to reverse the trend of poor performance in mathematics in Kenyan secondary schools by training teachers through projects such as *Strengthening Mathematics and Science in Secondary Education* (SMASSE project, 1998) and the NI3C. The SMASSE project initiated in 1998 through in-service training for teachers (INSET) center for mathematics education in Africa, recently widened its focus to include a larger target area, and thus the name of the project changed to the CEMASTEA. This project was designed to reach over 22,000 teachers and school managers (Yara &Wanjohi, 2011), yet these efforts have not quite improved students' performance in mathematics. For instance, the analysis for KCSE mathematics examination results for 2009-2010, showed that in 2009 students had a mean grade of E, which is 21.1%, and similarly—a mean score of 21.8% was documented in the 2010 KCSE results (Kenya National Bureau of Statistics [KNBS], 2012). Thus, one of the challenges that remain in secondary mathematics education in Kenya today is how to improve students' performance in mathematics and upgrading of pedagogical and ICT skills for existing teachers to improve the quality of education for the Kenyan students.

Without doubt, the need for in-service training for teachers has been highly sought and recognized by teachers and schools. Evidence shows that in-service training in technology may support teachers in gaining knowledge, skills and confidence for technology adoption in their classrooms (Ertmer & Ottenbreit-Leftwich, 2010). Hartsell, Herron, Fang and Rathod (2009) study revealed that the technology workshop improved the teachers' technology skills for graphing calculators and other software programs, and increased their overall confidence in teaching different math topics. But technology in schools being a new frontier in Kenya, there is limited research revealing the extent technology training influence teachers to apply technology in school mathematics, the challenges they face, and how they cope with such challenges. This study applied Rogers' (2003) diffusion of innovations theory to understand the research problem.

Theoretical Framework

The diffusion of innovations theory describes a process in which an innovation is communicated through certain channels over time among members of a social system (Rogers, 2003). Rogers stated that diffusion is a special type of communication about an idea that might work or not work. Rogers argued that adoption or rejection of new ideas lead to a social change—a "process by which alteration and functioning occur in a social system" (p. 6). Most of the new ideas that have been investigated in diffusion studies are technological innovations and therefore Rogers (2003) used "innovation" and "technology" synonymously. According to Rogers, any diffusion process is influenced by four elements: (1) innovation, (2) communication channels, (3) time, and (4) a social system.

Innovation

An innovation, according to Rogers, is an "idea, practice or object that is perceived to be new by an individual or other unit of adoption" (p. 12). An innovation may have been invented many years before, but if it is new to an individual then it is an innovation. The newness of an innovation is related in terms of the knowledge, persuasion, and decision stages of an innovation-decision process.

Communication channels

The adoption rate of an innovation depends on how individuals communicate among themselves. Elaborating how the process of communication between individuals occurs, Rogers (2003) introduced the concepts of *homophily* and *heterophily*. On one hand, Rogers described homophily as "the degree to which two or more individuals who interact are similar in certain attributes, such as beliefs, education, socioeconomic status, and the like" (Rogers, 2003, p. 19). Rogers observed that homophily is more effective when similar individuals live closely and share similar goals. On the other hand, Rogers described heterophily, the opposite of homophily, as the degree to which two or more individuals differ in certain attributes. Rogers argued that diffusion of innovation does not occur between individuals with similar skills levels because there is no information to exchange between them. However, diffusion of innovation occurs when there is some degree of heterophily between two individuals in a communication process.

Time

Time is an important variable in the diffusion of innovations process (Rogers, 2003). Rogers elaborated that there are three ways in which time is involved in the diffusion of innovation process: (1) the innovation-decision process—the time an individual progresses from the initial knowledge acquisition through the adoption or rejection of an innovation, (2) the innovativeness and adopter categories—how early or late an individual adopts an innovation compared to other individuals in a system, (3) the rate of adoption—the speed an innovation is adopted by individuals in a social system.

A social system

Rogers (2003) defined a social system as a "set of interrelated units that are engaged in joint problem solving to accomplish a common goal" (p. 23). These units of a social system may be individuals, groups, or organizations. According to Rogers, all the members "cooperate at least to the extent of seeking to solve a common problem in order to reach a mutual goal" (p. 24). The bond of working together is strengthened by the common problem. In organizations, for instance individuals work together to achieve common goals through ranks and division of labor (Rogers, 2003).

In sum, the diffusion of innovations theory might be particularly useful to study technological innovations in a developing country like Kenya. Therefore, Rogers' diffusion of innovations theory was particularly useful in understanding the (1) technological innovations in the training programs; (2) the innovation-decision processes for teachers and the stages involved; (3) technological needs of different adopter categories (the early adopters and late adopters); (4) communication channels used by individuals to share information related to technology adoption; and (5) organizational unit of the social system and how it influences technology adoption. Thus, I found Rogers' (2003) diffusion of innovations useful in answering the research questions for this study.

Research Methodology

Research Design

This study followed a qualitative case study design to examine the extent technology training influences mathematics teachers' decisions to adopt or not to adopt technology in teaching.

Participants

Using maximal variation sampling (Creswell, 2008) I selected three early and three late adopters of technology based on mathematics teachers' (1) willingness to participate in the study, (2) school having substantial technology resources and infrastructure, and (3) demographic characteristics such as gender. According to Rogers (2003) it is more efficient to classify members of a system on either being early or late adopters because each category consists of individuals with a similar degree of innovativeness (Rogers, 2003). For instance, he noted that characteristics of innovators and early adopters are similar to the characteristics of early knowers of technology in terms of education and social economic status, while late adopters may join the innovation decision process a little later.

The early and late adopters of technology came from five different public secondary schools. The early adopter category consisted of three participants who had adopted technology in their teaching – Mr. Hamisi, Mr. Gatimu, and Mr. Musyoka. I changed their real names to protect their identity. In sum, (1) all three teachers had graduate degrees; (2) their teaching experience averaged 18 years; (3) they were leaders at their schools either as head of mathematics or examination department; (4) their age averaged between 40 and 50 years; and (5) likely to be male teachers. The late adopter category consisted of three mathematics teachers who had not adopted technology in their mathematics classroom practice – Ms. Shiro, Mr. Awiti, and Ms. Amina. In sum, (1) all teachers except one had no graduate degrees; (2) their teaching experience averaged 13 years; (3) all teachers except two had leadership roles at schools either as head of mathematics or examination departments; (4) their average age was between 30-40 years; and (5) both genders.

Data collection

Data collection involved classroom observation sessions and semi-structured interviews**.** I observed at least two lessons for each of the six participant teachers. The purpose of the classroom observation sessions was to provide supplemental data for the study, in addition to generating interview questions and probes. I audiotaped each participant for a period not exceeding 60 minutes to gather data on participants' experiences about training.

Data Analysis

I coded the text data to identify themes using the Creswell (2008) criteria of coding data, which involved identifying code words from the text data, then grouping similar codes, and looking for redundant codes with the intention of reducing the codes to a smaller, more manageable set. Using this refined list, I went back to the data to find if there were any emerging codes, and then reduced the codes to common themes supported by evidence.

The Early Adopters

The early adopters of technology consisted of three mathematics teachers. These teachers were Gatimu, Hamisi, and Musyoka.

Gatimu

When I asked Gatimu whether he had acquired technology skills, first he told me that he had taken some computer courses during his postgraduate diploma studies but, according to him, the courses were meant to meet the program requirements and not necessarily for improving technology skills for teaching. Then he told me he had attended the Centre for Mathematics, Science and Technology Education in Africa (CEMASTEA) training program. However, he felt he did not benefit because "you were crowding in one computer; ten people in one computer so there is only one who had the touch and it is those who know" (Gatimu, Interview Data, line 98-99). According to Gatimu, because of the lack of computers for training at the center he felt that he did not benefit during the training.

He told me that the technology skills he had were self-taught from the Internet. He stated, "I have trained myself. You just go to the Internet, for example, if you have something you want to check, you go to the Internet, you Google. You check." (Gatimu, Interview Data, line 105-106). When I asked him if he was knowledgeable in mathematical software for teaching he told me he was not. He reported, "I use Excel but I cannot say that I am very good. I am not very good because I keep on consulting … I am trying to, but I have forgotten something" (Gatimu, Interview Data, lines 357-360). In one of our post-conference interviews, he was not sure there was a graphing tool on the smart board. After checking with him we found a graphing tool on the left hand side of the KAMAU that he had not used before. He was glad we found it.

Emphasizing how limited technology skills had affected his teaching, he told me about how the Internet had supported him in accessing instructional resources. However, he was scared he could get accused of plagiarism. To overcome such challenges, he told me that he would like to be trained in using mathematical software. He said, for instance, "if I am talking on reflection, I would like to have a way, if I am talking inflective rectangle, through line $y = x$, I have a way of reflecting it. Maybe it is software developer or something like that" (Gatimu, Interview Data, lines 112-114). He implied that training would make him effective because he would be able to develop his own instructional materials and students would see him make and correct mistakes, as opposed to the readily available materials from the Internet that he cannot edit. He told me how the videos from the Internet played fast and the students could barely visualize what was happening. As a result, the students were not able to draw graphs on their own because they never observed the teacher drawing.

According to Gatimu, technology training should be made mandatory for teachers, and certification issued as evidence of training. He also told me that teachers need to be reimbursed when they spend money on technology training: "If you used KES 50,000 and you bring a certificate, we reimburse back. That way, teachers will be encouraged in training. Again, it should be from a recognized university or a college. That way after capacity building, ICT integration will become very easy" (Gatimu, Interview Data, Lines 334-337). He gave me examples where other government ministries sponsored their employees to go to the university to study, and books and tuition fees were paid for them. But in the teaching profession, "there is none like that. You go for masters, you pay for yourself and you support yourself. There should be incentives" (Gatimu, Interview Data, lines 366-368). According to him, supporting teachers with funds during the training could encourage them to seek more skills that are required to adopt technology in the teaching and learning of mathematics.

Gatimu told me that time is a hindrance for technology training for mathematics teachers. During the holidays, he told me that teachers would want to relax after working for three months. He suggested that training should be made flexible so that "if they also want to train over the holiday, like those who are doing their master's degree during their holiday programs. Then those who want to train in the evening should do like that" (Gatimu, Interview Data, line 349-352). According to Gatimu, teachers would be free to get training at a convenient time. Additionally, he suggested that starting many training centers across the country would ensure that teachers attend training any time of the year when they want.

Hamisi

When I asked Hamisi how he had learned about technology, he told me that he received some training during his undergraduate and graduate studies after he completed computing courses like SPSS and Spectrum as program requirements. In addition, he told me he had attended training through teacher training programs: "I have also taken several initiatives by attending some empowerment courses in terms of technology, in two weeks, three weeks during the holiday, some courses entirely on ICT and integration in schools" (Hamisi, Interview Data, Lines 77-80). According to Hamisi, he felt he had benefited from the technology training provided through these programs.

I asked him about the technology applications he learned during the training that were related to mathematics and he stated:

> What they wanted people to learn is the use of email, and e-learning topics from the Internet. They were also exposing teachers to the new curriculum that KIE [Kenya Institute of Education] is developing about the e-material and use them in the classroom. There was an element of the Kamau and how to use it, projector, using the LCD, those are the things we learned there and we felt it was very useful. (Hamisi, Interview Data, lines 199-200)

I observed Hamisi teach one of his classes where he used a LCD projector and CD-ROMs to teach a topic in optimization, latitude and longitude. He observed that, "when the teacher used technology, initially he asked the students if anyone was willing to come forward and operate the projector" (Hamisi, Observation Notes, lines 42-45). Hamisi appeared to not be confident. I attributed his lack of confidence to limited technology skills. I observed that there were no worksheets for the students and the teacher depended on the video from a CD-ROM to teach the class. I concluded that technology was used for illustration purposes only.

That aside, Hamisi alleged that although he had experienced good technology training at the Strengthening of Mathematics and Science in Secondary Education (SMASSE) project, many teachers had negative attitudes towards the training during the initial training sessions. He noted that, "the people, who are teaching you, are the same people you are with in the field. Why should I be taught by my colleague whom I think I am even more competent than, in that angle?" (Hamisi, Interview Data, lines 206-209). Hamisi implied that the technology instructors were not qualified to train teachers on technology adoption because the trainers were their fellow teachers in the schools and their qualifications were known by these teachers. Secondly, he told me that the teachers were feeling abused because the teachers were not compensated the cost of attending the training. He stated that the teachers knew the Ministry of Education officials were getting compensated, but they were not. Therefore, some teachers withdrew from the training. However, that changed "when the cry was heard, the ministry changed, they were able to foot maybe your out-of-pocket services – the issue of transport – people now cooled down" (Hamisi, Interview Data, lines 217-219). After this time, the training was open to teachers and they could train when they wanted to. Thirdly, he told me that certification after the training was not recognized by the teacher employer for promotion despite teachers dedicating a lot of time during the training, and for that reason teachers lacked the self-drive to attend technology training offered to them. Thus, the initial negative perceptions towards SMASSE still persist, although currently there is more technology being incorporated into the training, unlike before.

Hamisi told me that he felt his colleagues across the country were not well prepared to use technology. He stated, “but I know my colleagues have a problem and not one not two, so even across the country, that training of teachers to be ICT compliant is important. That is what I need to say” (Hamisi, Interview Data, lines 295-298). Hamisi noted that because of the dynamic nature of knowledge, there is a need for teachers to embrace technology, to be trained about the use of other technologies they are not knowledgeable about. He gave me an example from when he bought his mobile phone and he realized that he could download information for personal use. He stated, “if I can be able to download the whole physics syllabus content, then I will be able to teach my boys even more effectively than the way I am doing today” (Hamisi, Interview Data, lines 302-304). Hamisi implied that teachers need to be enlightened on the need to adopt technology in their classroom practices so that they would appreciate a changing world.

Hamisi told me that even as the debate to train teachers on technology skills rages on, “the very first people who should be trained I think are the managers so that they can appreciate the usefulness of the same” (Hamisi, Interview Data, lines 242-243). He implied that some school managers lack adequate technology skills and therefore they are not aware the about the priority technology knowledge that teachers need.

Musyoka

Related to the training of teachers and how CEMASTEA had handled the training of mathematics and science teachers, Musyoka told me that he was dissatisfied with how the training program had been carried out. He told me that teachers developed negative attitudes towards technology because “the employer used strong words ‘if you don’t attend, it is equivalent to forsaking your job’. So people went there, but grudgingly” (Musyoka, Interview Data, lines 188-193). According to Musyoka, that statement angered teachers and when these trainings were started, teachers were coerced to attend the training sessions. Thus, even though the teachers would go for the training, they were demoralized and they developed negative attitudes towards the training.

Musyoka noted that teachers were not paid well and therefore they found the need to take extra responsibilities that did not come with compensation. He stated, “teachers want to see what monetary benefit ‘will I gain from this training’ and when they discover there is none, they forget anything in the training. But the training is intended that it will make the teacher better pedagogically” (Musyoka, Interview Data, lines 194-198). According to Musyoka, despite the good intentions of equipping the teachers with classroom skills back at the schools, teachers refused to implement the skills they had learned and they continued with the traditional ways of teaching mathematics. He noted that teachers would say, “after all, everybody is going on with their business as they have known how to, so why am I to do things a little different? Let me continue with my normal life” (Musyoka, Interview Data, lines 202-204). Musyoka saw this rigidity of not wanting to adjust to something new and different as the reason that the training of mathematics teachers had lagged behind. In fact, he lamented that during the trainings that he had conducted as an ICT champion teacher, “fewer attended the training and so forth ... some have, some have done nothing after the training and so forth … but those were the people” (Musyoka, Interview Data, lines 23-25) from about 10 to 20 schools. From Musyoka’s experiences as an ICT champion teacher, there was evidence that despite teachers getting trained on technology skills, they most likely were not implementing technology in the classroom.

One interesting point that was also mentioned by the other teachers interviewed was the limited skills for the trainers. He told me that:

> Most of the fellows who do the training are fellow teachers who are known by some of these teachers and if they are known, some of them are known, even their grades are known, their qualifications are known by their peers and their peers wonder which authority these fellows or expertise these fellows carry to come and tell us what they are telling us. (Musyoka, Interview Data, lines 207-212)

These trainers, according to Musyoka, had no idea what technology was about: “they think that training teachers on Excel, Word – that will be sufficient for integrating technology in the classroom” (Musyoka, Interview Data, lines 226-228). Musyoka saw that the technology skills needed for adopting technology must be above skills in using Microsoft Office. When trainers teach limited technology integration skills to teachers, then teachers would not find any benefits of training. The technology trainers, according to Musyoka, were their fellow teachers who had little or no qualifications to train mathematics teachers in technology. In fact, Musyoka stated that the trainers had not carried themselves as exemplary teachers because during the discussions with teachers, "they tell teachers something and when they have their normal discussion, they would tell them 'these things we were saying just for saying' [laughs]. But they don't themselves practice what they are talking about" (Musyoka, Interview Data, lines 213-216). Thus, these trainings, according to Musyoka, had remained a theoretical venture, whereas that was not what they were intended to be.

Lastly, Musyoka noted that after the training the teachers were not mentored to ensure they overcame the challenges that come with technology. He stated:

> If the teachers are engaged further in class, in school, so that they have someone they are walking with towards a particular pedagogical concept, which they need to work on, it will enhance the program. But since that seems not to be there, follow-up seems not to be there it disappears. (Musyoka, Interview Data, lines 218-222)

He implied that the technology implementation programs in schools were not pulling through because teachers were not mentored after the training. According to Musyoka, the training sessions are very short, often during school holidays, and teachers had no time to reflect on the skills they had learned.

Conclusion

The early adopters of technology had mostly acquired their technology training during their undergraduate or graduate studies and through the government training programs (e.g., through CEMASTEA). However, they mentioned that despite the technology skills they had acquired, they still felt unprepared to adopt technology in their teaching. They noted that the type of government training they had acquired was below their expectations because technology trainers were not qualified, and teachers were trained on technology skills they already knew or they could learn by themselves like Microsoft Office, email, and the Internet. None of the three teachers had been trained on technology skills for mathematical software such as Geometer's Sketchpad™ or computer algebra systems; however, if they used it then it was learned from the Internet. Regarding technology training, these teachers had learned technology by themselves. Gatimu stated, "I have trained myself. You just go to the Internet, for example, if you have something you want to check, you go to the Internet, you Google. You check" (Gatimu, Interview Data, line, line 105-106). To cope with the lack of training, the early adopters had taught themselves the skills they needed to use technology for mathematics teaching by asking colleagues or through the Internet.

The Late Adopters

The late adopters of technology consisted of three mathematics teachers. These teachers were Shiro, Awiti, and Amina.

Shiro

Shiro told me that she had received one in-service training session on the use of technology at the CEMASTEA. She described the training as not very helpful: "It was not that …, let me say it was not that, really expansive, but ..., let me say quite a number of things I had already known even before" (Shiro, Interview Data, lines 29-30). According to Shiro, the in-service training session was not different from the technology skills she had acquired during her master's degree program. She told me the training at CEMASTEA was not initially intended for technology training because the training was dealing with teaching methodologies and strategies to teach high school mathematics. However, she noted, "they actually gave us those websites, but it is not like we really used them, but they just gave us. You can go to this site and download this and that. But I did not use it actually" (Shiro, Interview Data, lines 50-52). According to Shiro, despite the training she received she did not implement the skills in the classroom.

When I asked who does the technology training sessions at the CEMASTEA, she told me that "the training is done by other teachers who are like us, who were trained early. Now who trained them? Actually, I cannot tell because the people who also trained them are also teachers and some of them are heads of departments" (Shiro, Interview Data, line 148-151). Regarding this, she told me that one of the senior teachers at her school was also a trainer. This teacher, according to her, did not qualify to train teachers on technology skills. Shiro felt that the training on technology was not as successful when compared to other in-service training sessions that did not involve technology. Shiro did not think the trainers were qualified to train the teachers considering they are fellow colleagues. Other participants in this study expressed these same sentiments.

When I asked her about her technology skills and how she used in them in the classroom, she told me that "unless Excel to add and subtract, what else? Or maybe PowerPoint to present. But Word … unless typing and also typing the mathematical equations signs and all that" (Shiro, Interview Data, line 162-163). Shiro felt that she did not have sufficient technology skills for classroom use and thus does not use technology in her classes.

Awiti

By the time of this interview, Awiti had not yet received technology training on using technology related to mathematics teaching. However, he told me that when an interactive white board was installed at his school, he was trained on how to use it, in addition to getting some training on digital literacy. When I asked him why he had not yet trained at the CEMASTEA, he told me that his school had not been invited to participate in the training. He stated that there is a conflict about the location of the school in terms of the county government, and the educational officers had not resolved this conflict. That aside, in his opinion, Awiti believed that the government had done minimal technology training for secondary school teachers. He stated, "basically, I doubt if they [CEMASTEA] use [technology]. Basically, they encourage the use of models – use of pyramid models, especially the use of three-dimensional geography" (Awiti, Interview Data, line 70-72). I observed that Awiti had some teaching models lying on the table in his office. When I asked him if he used the models, he noted, "they help students to visualize more of the content. You can imagine you are trying to draw on the blackboard and you are telling the students perpendicular height; it is a bit difficult for us. They are for the teacher to demonstrate" (Awiti, Interview Data, lines 77-82).

Following up on this, Awiti told me that one reason that technology had not been embraced in the Kenyan secondary schools is because most of the Kenyan government employees were not conversant with technology. He stated, "we have just moved from our government offices doing [things] manually and [with] analogue where you have a secretary and an old typewriter and therefore, being agents of the government, very few people understand computers" (Awiti, Interview Data, lines 235-238). Likewise, Awiti felt that the Kenyan teachers were not ready to take up technology in the classroom because they had inadequate technological skills. To address this problem, he said he would challenge the government to consider:

> A top-down approach – train, integrate it in teacher curriculum. When you are training the teachers, can you integrate [technology] in teaching mathematics so that mathematics teachers, as they leave the school they can be able to, one, develop the content themselves; two, they can be able to use technology themselves, so first of all they would start with university, and they impart knowledge into them. Those who are in the field, they should roll out the in-service training" (Awiti, Interview Data, lines 300-305).

Building on this, Awiti felt that the teachers graduating from the universities to teach mathematics in secondary schools were not well equipped to use technology in the classroom. As such, technology training could start at the universities. Reflecting on how teachers are prepared at the universities, he noted:

> Most of our presentations, we do manually, from the university. In the math curriculum they just put one or two units; computer, but basically the content that they give is for a computer science student and mostly it is very oral in form of a lecture. So that you never dealt with a computer unless you have yours. Most of the young people who are coming from the university are not equipped, mathematically they are not. They can use [technology], yes, but mathematically they cannot. (Awiti, Interview Data, lines 357-363)

Awiti insisted that technology training for mathematics teachers should start during teacher training programs and lecturers should also use technology. He stated that it is very difficult for pre-service teachers to adopt technology in mathematics teaching coming from the universities with limited technological skills. According to him, a pre-service teacher may have technological skills but those skills are not related to mathematics teaching. Additionally, these teachers when they go to the schools are already struggling with other pedagogical issues. He noted:

> [a pre-service teacher has] been taught how to plan for a lesson, but practically it is on paper. He has been trying here and there managing these times, following the schemes of work, covering [the syllabus]; that requires a lot of time, [and] is a bit of a challenge. So he does not know how to balance all that. Again, if you introduce a new concept in [technology], I think it will be a struggle for him. (Awiti, Interview Data, lines 407-412)

That is what he called the balancing act. These challenges further complicate younger teachers' decisions to use technology in mathematics teaching at the secondary schools. When I asked Awiti how he had grown as a mathematics teacher since he started teaching, he noted:

> You know at the university we would do advanced calculus, complex analysis – most of which we do not apply here. Mostly you don't use it in daily life, and also you don't teach it. So that all that disappears, but this guy has gone so advanced, very fast knowledge, but now that fast content that he knows here (points to head), areas of difficulty to this young learner – he does not have that. (Awiti, Interview data, lines 382-395)

Awiti felt that the advanced content courses in undergraduate mathematics courses do not matter so much. According to him, the most important thing is for teachers to understand the mathematics that students learn at high school and the areas of difficulty that students encounter. He stated that a pre-service teacher would need at least two years of teaching experience to become a better teacher, and introducing technology during this "trial" period would be a struggle for the teacher.

Amina

Amina has attended and received professional training at CEMASTEA since the time of her first teaching job, over 10 years ago. She noted, "There is this government project, Strengthening of Mathematics and Science in Secondary Education (SMASSE), that is trying to teach others how to teach math and using computer. It has been there for a while; sometimes we go during the holidays" (Amina, Interview Data, lines 124-127). Amina stated that she had received training on technology during the school holidays, where she has trained to use "PowerPoint, how to use YouTube, to get some questions, drawing of graphs" (Amina, Interview Data, lines 128-129). Despite having been trained, I did not see her using technology during the lessons that I observed.

She told me that the kind of training Kenyan teachers get from the government had been received with disapproval by the teachers:

> We have told them that it cannot work. They know. Can I speak the truth? Because some people are eating [benefitting financially] from SMASSE, the project would rather go on but not achieve its objectives. We have told them the mean of mathematics [of students' exam scores] before SMASSE was 2.0; 10 years after SMASSE is still at 2.0. The project has failed. Why continue and there is no improvement. It is because it is funded and there is ... money! So that it continues even with very negative teachers. They have not won us in their project and therefore cannot be implemented. (Amina, Interview Data, lines 206-213)

She added that during these training sessions, she sometimes would go to sign-in, or walk out of the training sessions to talk to a friend. Amina appeared visibly irritated when she described her training experiences. According to her, these sessions were held during the holidays when she wanted to be with her family or tutoring struggling students in mathematics to gain extra income. She stated that many Kenyan students have difficulties in mathematics and sciences and it is during the holiday sessions that teachers help these students and the parents pay them some stipend:

> So when you call us for an in-service where we are not earning, and we are also underpaid, we are about to go on a strike again [Kenyan teachers went on strike June through July 2013], then you are telling me to go for an in-service when I can teach there and get KES 10,000 per day, I will be negative. So, I would rather be left alone [laughs]. That is a way of taking the money away from me and the salary I get; I deserve a holiday. I don't want projects; we don't earn a single cent and they are being forced on us. (Amina, Interview Data, lines 221-227)

She stated that teachers need to be well compensated when they attend these sessions, and take the teachers to high-end hotels (where they take everyone else), and bring qualified facilitators who are well trained. She told me the facilitators who had trained them before were selected through nepotism and they had no clue about technology. When I asked her whether the facilitators she was referring to were technology trainers, Amina stated, "Yes, they are not trained themselves; some are total blackouts. So when they come, they don't know what to do. They start depending on the same teacher to tell them what to do, so we don't take it seriously" (Amina, Interview Data, lines 236-238). According to Amina, because the trainers were not well equipped with technology skills, they depended on the teachers attending the training for support. She added, "At the same time, we have the challenges of the principals and the head teachers who are also not computer literate. Then the chairman of the district committee, they have no idea what we are talking – math taught using computers" (Amina, Interview Data, lines 260-263). Amina stated that a senior teacher in her school was among the trainers at CEMASTEA during the school holidays and she was aware the teacher did not have adequate technological skills to qualify to be a trainer. Shiro had discussed a concern about the qualifications of the trainers also. For these reasons, Amina stated that she did not have any motivation for going to the trainings, and if she went it was only for appearance.

Conclusion

Regarding the issue of technology training, Awiti was the least experienced teacher among the three late adopters. He had not attended technology training as opposed to Shiro and Amina who had been trained at the CEMASTEA. Speaking from the perspective of a pre-service teacher, Awiti thought technology training should start at the university level going downward to primary schools. Shiro and Amina had interesting perspectives on the kind of technology training they both had received at the CEMASTEA. According to Shiro, the training she had received was not different from what she already knew. She noted that the teachers at the training were given some websites that she ended up never using. In addition, she stated, "the training is done by other teachers who are like us, who were trained early. They are trained trainers" (Shiro, Interview Data, line 148-149). According to Amina, these trainers are "total blackouts", implying they did not have the knowledge to train teachers. Therefore, Amina and Shiro were demotivated and did not have interest to participate in training. These teachers only had Microsoft Office and the Internet skills. Of interest is the large number of graphing calculators at Shiro's and Amina's school they had not used because they did not know how to use them. Similarly at Awiti's school, there was a time that he had not used technology because he thought it would take too much time to type in mathematics equations and formulas, and again he was not familiar on how to paste graphs on word document. Thus, technology training was very low for these teachers.

Findings and Discussion

In a study conducted by Muller and colleagues' (2008), the findings revealed that in-service training and the continuing support of good practice were among the greatest determinants of successful technology adoption. In my study, the qualitative findings revealed that early adopters and late adopters lacked adequate skills to adopt technology, and the findings agree that technology training would be needed to enable teachers to adopt technology in mathematics teaching. These findings mirror those of Forgasz (2002) who found that the teachers in her study indicated the desire to participate in technology training to gain knowledge of mathematics-related software. Consequently, early adopters in my study used technology to support teacher-directed instruction and presentation (Peeraer & Petegem, 2011) as opposed to applying technology to support students' conceptual understanding. Similarly, the late adopters of technology developed negative perceptions of technology related to supporting students' learning, which was a reflection of their lack of knowledge on the usefulness of technology to students' learning (Manouchehri, 1999). According to Ertmer and Ottoenbreit-Leftwich (2010), technology training may support teachers in gaining knowledge, skills and confidence for technology adoption in their classrooms.

The findings also suggest that both early adopters and late adopters had not been trained adequately on mathematical software for teaching mathematics. Instead, my study revealed spreadsheets and word processing were the most widely used computer software by teachers, more so than mathematics-specific software. Similarly, a study by Gulbahar (2007) in Turkey found that most teachers were competent with word processing applications and the Internet, with very few teachers having skills in using educational software. Other studies revealed similar findings (Demiraslan & Usluel, 2008; Keong, Horani & Daniel, 2005).

The findings in my study suggest that in-service training of teachers on technology may be related to teachers' early decisions for adopters during the technology adoption process. According to Rogers (2003), the innovation-decision-process begins when an individual becomes aware of an innovation's existence and gains understanding of how it functions. Thus, the innovation-decision process is "essentially an information-seeking and information-processing activity in which an individual is motivated to reduce uncertainty … of an innovation" (p. 172). During this process, an individual encounters such questions as what, how, and why about an innovation. The findings from my study suggest that mathematics teachers had not been made aware to a great depth about the technology available to them to teach mathematics. This may have been due to the role of the technology trainers (change agents) who, according to Rogers, play a significant role in bringing knowledge and awareness about the existence of an innovation to clients (in this case, teachers). Rogers argued this happens when change agents fail to understand how an innovation works, which is most important to the clients, as they make decisions about adopting an innovation.

Consistently, the early and late adopters in my study alleged that the type of technology training they had experienced at the CEMASTEA had something to do with the trainers designated to train them. The teachers said that trainers of technology were their fellow colleagues who also taught at their schools. This is what Rogers called *homophily* – the degree to which individuals are similar in certain attributes such as education. According to Rogers' (2003) *homophily* "occurs when similar individuals belong to the same groups, live and work together and share similar interests … [C]ommunication of new ideas is likely to have greater effects in terms of knowledge gain, attitude formation and change, and overt behavior change" (p. 19). But according to Rogers homophily can be a barrier to the flow of innovations within a system. He implied that "homophilous could cause diffusion of an innovation to spread horizontally rather than vertically, within a system" (p.307). When the diffusion does not occur vertically the adoption of an innovation may significantly slow down. Rogers suggested that an ideal change agent can be homophilous with his or her clients in social characteristics but heterophilous (the degree to which two individuals are different) with regard to technical competence about the innovation being diffused. In my study the participants indicated that technology trainers had less technology expertise to influence mathematics teachers' innovation-decision processes.

According to Rogers (2003), change agents should be aware of their clients' needs and adapt their change programs to them. He wrote, "change projects that ignore clients' felt needs often go awry or produce unexpected consequences" (p. 375). When adequate levels of knowledge to use innovation are not obtained prior to the trial and adoption of an innovation, rejection of the innovation is likely to occur (Rogers, 2003). However, Rogers insisted that clients should never be allowed to pursue their needs completely on their own since they might commit errors and dismiss priorities. This implies that the change agents should not relinquish their roles on shaping the needs of the clients. In addition, Rogers, "personal acceptability of the change agent is as important as, or more important than, technical expertise" (p. 384). Thus, teachers in my study suggested that technology training should be handled by people who understand technology as opposed to fellow teachers who likely do not know significantly more about technology than the teachers they are training.

My participants suggested that more training centers need to be established in their localities so that they have options to decide on their training needs and to attend training events at more convenient times and places. This is what Rogers (2003) called a decentralized diffusion system. According to Rogers, "centralization has usually been found to be negatively associated with innovativeness … top leaders are poorly positioned to identify operational-level problems or to suggest relevant innovations to meet these needs" (p. 412). Under a decentralized diffusion system, users feel a sense of control in making key decisions such as the problems to be addressed, the innovations that best meet these needs, how to seek information about an innovation and from what source, as well as how much to modify an innovation as they implement it to meet their local needs (Rogers, 2003), including time management.

The participants indicated that incentives and recognition of their efforts to learn technology would significantly motivate them to attend technology training. According to Rogers (2003) one way to increase the degree of relative advantage of new ideas is to offer incentives in terms of cash or other forms of incentives. Rogers suggests that "while innovations are often in form of financial payments, they may also take the form of some commodity or object that is desired by the recipient" (p. 237). Such rewards are likely to change behavior and enhance adoption of innovation. In my study, the participants suggested that such incentives can be in the form of compensation to cover technology training expenses, certification and recognition after training, tuition credits for higher education, or grants to purchase technology.

Rogers (2003) pointed that some incentives are designed to secure adoption of a new idea by early adopters and after a certain period when diffusion process becomes spontaneous, the incentive may be withdrawn. On one hand, the findings of my study indicated that to overcome inadequate technology skills the early adopters of technology had embarked on "self-training" strategies, using personal technology tools such as laptops, the Internet modems, projectors, and smart phones. Using these tools the early were able to access online instructional resources such as exams, videos, and worksheets and to collaborate with teachers from other schools. Consistent with Rogers's suggestion, such early adopters can be recognized through incentives so that they continuously participate in the diffusion process. On the other hand, the late adopters had not embraced technology despite having access to technology resources at their schools for lack of understanding regarding how technology could be used as an alternative instructional strategy. Withholding of incentives may eventually change manifested behavior towards a new idea and lead to significant positive outcomes on technology adoption process (Rogers, 2003).

Conclusion

The data from this indicates the need for technology training for Kenyan teachers to refine teachers' technology skills, technology pedagogical knowledge, perceptions, attitudes, and confidence to adopt technology. The training that I am suggesting would need to involve certified technology courses at the universities or teacher training colleges paid for by the Ministry of Education. Currently, Kenyan teachers go for training during school holidays, which I believe provides too short of a time to train teachers who have no prior encounters with technology, to understand it and know how to apply it in mathematics teaching. Thus, I suggest that training of teachers should take adequate full-time study leave. After the training, teachers can be given opportunities to practice their skills in the classrooms and to attend conferences and workshops to broaden their technology skills.

During these trainings, the technology trainers must be individuals knowledgeable on research involving students' learning in technological environments. Revolutionary thinkers and researchers in the field of mathematics education who are experts in technology adoption need to be involved in such trainings to guide teachers on the best practices to apply technology in their lessons. In such situations, the current technology trainers should act as tutors leading group discussions about the pros and cons of teaching with technology. These discussions should aim at broadening teachers' knowledge and absolve fears of technology. The discussions should also encourage sharing of technology problems and successes that are unique in other content areas, which can be replicated in mathematics teaching.

Technology training for mathematics teachers should not rely solely on Microsoft Office or Internet skills. Rather, technology training should include cutting-edge mathematical software such Geometer's Sketchpad™, computer algebra systems, Fathom©, and other mathematical dynamic software. Mathematics teachers should also be given opportunities to learn and develop technology informed lesson plans and curriculum for the mathematics taught at secondary schools.

The training of teachers should go beyond training centers and should follow the teachers in the classroom after the training. At the schools, in which they work, teachers should be assigned mentor teachers and technical support to follow up and support them during the technology implementation process. Such a training program should give teachers a sense of entitlement and accomplishment of having the opportunity to practice what they learned during the training without feeling abandoned. Progressively, through such support teachers have the opportunity to practice the skills needed to achieve the goal of engaging students in constructive learning using technology.

Experimenting with technology and campaigning for its use in schools can take a long time. To overcome such challenges, teachers should be given opportunities to showcase their technology skills through symposiums of technology lessons within the school or nearby schools. Such opportunities should reward and recognize teachers who have made improvements, especially older teachers and female teachers who could be struggling or unwilling to adopt technology. When teachers see the efficiencies of technology they may change their attitudes towards technology.

The leading personnel at the Ministry of Education involved in decision making in technology adoption must be knowledgeable individuals who are qualified through merit. Such individuals must be familiar with the global trends on technology adoption in education and teacher training models used in other developing countries. In addition, technology trainers must be individuals with university qualifications in information technology in addition to having advanced knowledge in mathematics education. I believe that education leaders across all levels of education should be individuals who understand why and how technology can benefits students' learning.

The government agencies such as TSC, CEMASTEA, NI3C, and pre-service teacher programs in public universities need to consider rewarding teachers who successfully complete technology training. Kenyan mathematics teachers need to feel valued and recognized. Government agencies need to recognize teachers who successfully complete technology training programs with a certification and a salary increment. More incentives might be offered to teachers who continue to apply technology in their lessons after the training. Such initiatives can motivate and encourage other teachers to attend training to learn technology. However, these engagements cannot be successful without adequate technology resources at the schools and the training centers.

Clearly, technology training for teachers is low and poor, and there are not adequate resources to teach mathematics. The majority of teachers have limited understanding about how technology can be used in the classroom to support students' learning. This calls for radical changes in the way technology training of mathematics teachers at both pre-service and in-service levels is being handled. The government needs to commit significant amounts of financial resources to equip schools with technology resources.

That said, the findings from this study are likely to generate heated conversations between ministry of education officials on one hand, and researchers in education on the other hand. Such conversations are not unusual in Kenyan society because many economic and social policies in Kenya are politically motivated, which is the reason why historically most educational reforms failed to achieve the goals they were intended to accomplish. However, the recommendations from this study are based on research evidence, the literature, and the Rogers (2003) theory and therefore my caution is that political ambitions should not to guide the implementation of these findings. Rather, elaborate and careful action plans should be initiated to support technology training for teachers and equipping schools with technological resources. I suggest that the National ICT Innovation and Integration Centre (NI3C) be involved in the implementation of the findings from this study because its goals are directly intended to support the success of the Kenya Vision 2030. I conclude that if elaborate measures are not taken as a matter of urgency, students' poor performance of mathematics is not likely to change soon, large class problems will continue to persist and the goal of providing quality education to all Kenyans shall thus remain a dream.

Research Recommendations

Future research should focus on in-service technology programs for mathematics teachers, particularly on technology knowledge for trainers. This investigation should focus on the role of the CEMASTEA and the NI3C in the training of mathematics teachers in Kenya. Similarly, examination is needed of technology training in the pre-service teacher education programs at the public universities and diploma teachers' colleges. This would focus on technology skills that pre-service teachers bring to the secondary school classrooms and how their skills impact technology adoption in mathematics teaching in Kenya.

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