Chapter 20

Continuation of Collaborative Curriculum Design Outcomes: Teachers' Transfer of Teaching with Technology

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Introduction

The focus of most professional development projects is on the development of effects that will continue even some years after the project's termination (Harvey & Hurworth, 2006; Zehetmeier, 2009). Informing the stakeholders that an initiative has been designed well, or has been successful, is not enough, because quite often, after funding ends or staff leave, such programs can collapse (Harvey & Hurworth, 2006). According to these authors, the question should be: is this program continued after the professional development has finished? As a response to this question, the two studies reported in this chapter were conducted to investigate the extent to which pre-service and in-service teachers continued to use technology in their teaching after the professional development arrangement had ended. We consider the long-term effectiveness of professional development arrangements in terms of the continuation of technology integration practices that use the knowledge, skills and beliefs about technology integration in teaching that were acquired during the professional development projects. The outcomes of the two studies will be presented and discussed in this chapter.

The first study pertained to teachers' involvement in technology use in mathematics teaching in Ghana. Positive effects have been reported from incorporating technology in teaching mathematics to enhance motivation and improve student achievement (Agyei & Voogt, 2011a). However, many maths teachers do not feel

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proficient in teaching mathematics lessons that take advantage of technology-rich environments. Technology simply being present in the classroom is not enough, and the use of technology is a responsibility left ultimately to mathematics teachers. Integrating technology in teaching mathematics is a very complex and difficult task for mathematics teachers. They must learn to use new technologies appropriately and to incorporate them in lesson plans and lesson enactment. Professional development is therefore critical for helping pre-service teachers to develop the proper skill set and required knowledge before such instructional change can occur. In the first study, a professional development arrangement in which pre-service teachers collaboratively designed and used technology to teach for the first time was carried out. Technology is presented as a tool for enacting a guided activity-based pedagogical approach (referred to as Activity-Based Learning) to teaching mathematical concepts in order to develop pre-service teachers' knowledge and skills for teaching with technology. In the study, Technological Pedagogical Content Knowledge (TPACK) was used as a conceptual framework guiding the preparation of pre-service teachers for ICT integration (cf. Koehler & Mishra, 2005) because it seemed an interesting and useful framework for better understanding what knowledge base teachers need to incorporate ICT in their teaching. Although TPACK is often assessed on a more generic and abstract level that measures perceived knowledge that does not reflect specific content knowledge, specific pedagogical knowledge or specific technological knowledge, the study described in this chapter particularly focused on specific spreadsheet applications in enacting a guided activity-based pedagogical approach to develop pre-service teachers' TPACK for teaching mathematics.

The second study was based on three previous studies conducted in Tanzania that showed that participants in a professional development arrangement developed technology integration knowledge and skills, as was revealed through self-report data, lesson plan evaluations, interviews, focus group discussion and observations of classroom lessons. The positive findings of these studies showed an immediate effect of the professional development arrangements. However, the aim of most professional development programs is to be effective after their termination (Harvey & Hurworth, 2006). For this reason, an impact study was conducted to investigate the long-term effects of the professional development arrangements in the three studies on teachers' continued use of technology in science and mathematics teaching. The professional development arrangements in the prior studies had aimed at developing science and mathematics pre-service teachers' and practicing teachers' technology integration knowledge and skills, and adapted TPACK as its framework for describing the knowledge required by the teachers to effectively integrate technology in science and mathematics teaching. Teachers' learning took place through a workshop in which they explored technology applications for their subjects and collaboratively designed technology-enhanced science and mathematics lessons, which they used in their teaching and reflected upon with their peers. It was hypothesized, as shown by several studies (e.g., Agyei & Voogt, 2012; Alayyar & Fisser, 2011; Jimoyiannis, 2010) that the professional development arrangements that involved teachers in the collaborative design of technology-enhanced science or mathematics

lessons would be promising for teachers' development of technology integration knowledge and skills and would have effects that were sustained over time.

Theoretical Underpinnings

Continuation and Transfer

In the studies discussed in this chapter, in particular the second study, transfer of training is assumed to be a prerequisite for continuation. Baldwin and Ford (1988) described continuation of the practices, knowledge, skills and beliefs in terms of the transfer of training, which is described as the degree to which trainees effectively apply the knowledge, skills and beliefs gained from training to a job. Baldwin and Ford presented a training transfer model with three parts; the training input factors, the training output, and the transfer conditions. According to Baldwin and Ford, there are three training input factors that determine the transfer and maintenance of knowledge, skills and beliefs over time. These factors include the training design, trainee characteristics and work environment.

The factors presented by Baldwin and Ford (1988) as determinant of the transfer of the training are presented in this study as key factors determining the continued use of technology in teaching and are categorized as follows: the training design is presented as *professional development factors*, which are comprised of the teachers' perceived valuing of the professional development arrangement (PDA), and the opportunity for continued learning (Pritchard & McDiarmid, 2005; Todorova & Osburg, 2010). Trainee characteristics are presented as *personal factors*, comprised of teacher beliefs, knowledge and skills, time and engagement (Buabeng-Andoh, 2012). The environment is presented as *institutional factors*, comprised of access to technology, support from the management, and environment (Almekhlafi & Almeqdadi, 2010; Eickelmann, 2011). Since the focus of the professional development arrangement in our studies was about technology integration in science and mathematics teaching, *technological factors* (cf. Buabeng-Andoh, 2012) were investigated in addition to the three factors presented by Baldwin and Ford (1988).

Professional development factors: Baldwin and Ford (1988) described these as training design factors, which include the incorporation of the learning principles, the sequence of training materials and the job relevance of the training content. Studies by Putman and Borko (2000), Todorova and Osburg (2010), and Voogt et al. (2011) reported that, for a successful professional development arrangement, teachers need to be involved in determining their learning needs and need to participate in the learning opportunities, which should be school-based, continuously supported, information-rich, and facilitate theoretical understanding and collaborative problem solving.

Personal factors are related to the individual teacher, such as knowledge and skills, beliefs, time availability and engagement in the use of technology in teaching

(cf. Agyei, 2012; Baldwin & Ford, 1988). According to Fullan (2007), “educational change depends on what teachers do and think: it’s as simple and as complex as that” (p. 129). Collis and Moonen (2001) argued that, if the teachers’ first experience of working with technology fits with their experience and belief about the learning process, they will build up self-confidence towards technology and will engage in the use of technology in teaching. In addition, Guskey (2002) argued that teachers can accept a professional development program if they believe that it will expand their knowledge and skills, contribute to their growth and enhance their effectiveness in teaching.

The primary *institutional factor* influencing the continued use of technology after the professional development arrangement has ended is the value and belief system of the school, driven mainly by the school administration through motivation: rewards, incentives and financial support to teachers (Harvey & Hurworth, 2006; Pritchard & McDiarmid, 2005). Eickelmann (2011) described the institutional factors in terms of the support for individuals in schools, support from peers, participation in decision making and availability of technological tools (cf. Almekhlafi & Almeqdadi, 2010). Agyei (2012) and Almekhlafi and Almeqdadi (2010) reported that the limited technological resources in schools are one of the great impediments to the up-take of technology in schools.

Collis and Moonen (2001) mentioned two *technological factors* that affect continued use of technology: ease of use and effectiveness. Ease of use refers to the convenience, adequacy, reliability and user-friendliness of the technology, whereas effectiveness refers to the likelihood of long-term tangible benefits for the institution, improved learning and communication.

Based on the literature (Buabeng-Andoh, 2012; Eickelmann, 2011; Harvey & Hurworth, 2006), a conceptual model of the relationship between different factors that contribute to teachers’ continued use of technology in their teaching is proposed (Fig. 20.1). In this model, the professional development arrangement is presented as the initiator of teachers’ technology use in teaching, personal factors as the new

Fig. 20.1 A conceptual model of the factors determining teachers’ continued use of technology in teaching

knowledge and skills, beliefs, motivation and time commitment that teachers developed through the professional development arrangement. This also represents the initial use of technology, which was described in Baldwin and Ford (1988) as learning and retention. For teachers to continue using technology in their teaching, the institutional factors and technological factors need to be taken into account. Unlike the training transfer model (Baldwin & Ford, 1988), which considers the design of the training, environment and trainees characteristics as all inputs, which lead to learning and retention (initial uses of technology) and transfer of training, the conceptual model presented in Fig. 20.1 interprets the relationships between each of the factors as influencing the teachers' continued use of technology in teaching.

The model represents the factors contributing to the continued use of technology in teaching after the termination of the professional development arrangement. While every type of factor (professional development, personal, institutional and technological) has a direct influence on the teachers' continued use of technology in teaching, through this model we can also indicate the relationships among factors.

Activity-Based Learning (ABL) in Mathematics

The learning that takes place in the studies in this chapter, particularly in study 1, is conceptualized by ABL, which describes a range of pedagogical approaches to teaching mathematics. Its core premises include the requirement that learning should be based on doing hands-on experiments and activities. The idea of ABL is rooted in the common notion that students are active learners rather than passive recipients of information and that learning, especially meaningful learning, requires engagement in activity (Churchill & Wong, 2002). Churchill (2004) argued that an active interaction with a learning object enables construction of learners' knowledge. Accordingly, he believed that the goal of ABL is for learners to construct mental models that allow for 'higher-order' performance such as applied problem solving and transfer of information and skills. This suggests that in ABL approaches, learners are actively involved, the environment is dynamic, the activities are interactive and student-centred and much emphasis is placed on collaboration and exchange of ideas. Mayer (2004) explained that a basic premise in constructivism is that meaningful learning occurs when the learner strives to make sense of the presented material (or activities) by selecting relevant incoming information, organizing it into a coherent structure, and integrating it with other organized knowledge. Thus, Mayer placed much emphasis on cognitive activity and learning by thinking instead of depending solely on learning by doing or learning by discussion. He emphasised guidance, structure, and focused goals when using an activity-based learning approach and recommended using guided discovery, a mix of direct instruction and hands-on activity, rather than pure discovery. Hmelo-Silver, Duncan and Chinn (2008) indicated that such guided inquiry approaches do not substitute content for practices; rather, they advocated that content and practices are central learning goals. Hmelo-Silver et al. (2008), argued that although it is challenging to develop

instruction that fosters the learning of both theoretical frameworks and investigative practices through the development of guided learning environments, such approaches provide the learner with opportunities to engage in the scientific practices of questioning, investigation, and argumentation as well as learning content in a relevant and motivating context. Furthermore, they indicated that guided inquiry approaches with appropriate scaffolding involve the learner in the practices and conceptualizations of the discipline in a way that promotes construction of knowledge. This implies that the teachers' role is critical in designing and enacting an activity-based lesson in mathematics. Their roles should include prompting and facilitating discussion, focusing on guiding students by asking questions and designing activities that will lead learners to develop their own conclusions about mathematical concepts.

TPACK and Mathematics

According to Niess, van Zee, and Gillow-Wilese (2010–2011), most teachers learned mathematics using paper and pencil, which limited the use of data for exploration and required time to calculate averages and create charts for every change in the variables. With the potential use of technologies in maths education, however, there is a need for teachers to create innovative learning experiences that truly engage the power of technology to involve students in higher-order thinking tasks. Thus, mathematics teachers are still confronted with challenges and questions about how and when to incorporate such technologies for teaching and learning various subject matter topics (Niess, 2011). For this reason, teachers' knowledge and skills for teaching with technology need to be developed (Niess, 2008). Mishra and Koehler outlined the Technological Pedagogical Content Knowledge (TPACK) framework (Koehler & Mishra, 2005; Mishra & Koehler, 2006) in an effort to explain the types of knowledge teachers need in order to integrate technology into their teaching. TPACK emphasizes the comprehensive set of knowledge and skills teachers need to successfully integrate technology in their instructional practice (Koehler & Mishra, 2005).

Niess (2011) indicated that TPACK-related strategic thinking includes knowing when, where and how to use domain-specific knowledge and strategies for guiding students' learning with appropriate information and communication technologies. Considering the goal of engaging students in mathematical problem solving, for example, a mathematics teacher's TPACK must focus on thinking strategically about planning, organizing, implementing, critiquing results and plans for specific mathematics content and diverse student needs (Niess, Sadri, & Lee, 2007). This framework explicitly acknowledges that effective pedagogical uses of technology are deeply influenced by the content domain in which they are situated. Thus, the TPACK framework for using technology strategically in classroom instruction does not encourage technology use as a "stand-alone" support in mathematics teacher education but as a tool specifically and uniquely applied to mathematics instruction.

Subject-specific technological software such as spreadsheets have been used as a pedagogical tool for teaching and learning and have potentials that effective teachers can maximise to develop students' understanding and increased proficiency in mathematics. Niess et al. (2010–2011) indicated that spreadsheets contain features for modelling and analysing change, providing teachers with tools that rely on mathematics concepts and processes for accurate analysis. According to Niess et al. (2007), teachers who are able to design and enact spreadsheet lessons experience elementary concepts of mathematical modelling, expand their own conceptions of teaching mathematics with spreadsheets, investigate and expand their knowledge of instructional strategies for integrating spreadsheet learning activities, develop their own knowledge and skills regarding spreadsheets as tools for exploring and learning mathematics, and explore curricular materials that support learning with and about spreadsheets over an extended period of time. This redirection exposes the importance of teachers' strategic thinking and actions with respect to integrating technologies as learning tools in mathematics instruction. In our studies, TPACK was used as a conceptual framework to examine the knowledge and skills pre-service maths teachers developed about technology, pedagogy, and content as they designed and enacted activity-based lessons supported with spreadsheets. As shown in Fig. 20.2, the pedagogical knowledge examined in this study concerned ABL (PK_{ABL}).

The technological knowledge (TK_{ss}) learned by the pre-service teachers was spreadsheet applications for mathematics, because these were readily available in senior high schools and in teacher education colleges (Agyei & Voogt, 2011a, 2011b), user-friendly and had the potential to support students' higher-order thinking in mathematics (Niess et al. 2007). Content knowledge (CK_{maths}) was mathematics, which was the pre-service teachers' teaching subject area.

Fig. 20.2 TPACK framework for this study

Pre-service teachers' knowledge and skills that are needed to teach spreadsheet-supported ABL lessons in mathematics (first study) were operationalised as their TPACK, consisting of the following specific knowledge and skills:

- Content knowledge (CK_{maths}): knowledge about mathematical concepts.
- Pedagogical knowledge (PK_{ABL}): knowledge and skills about applying ABL teaching strategies.
- Technological knowledge (TK_{ss}): knowledge and skills about the affordances and constraints of spreadsheet use.
- Pedagogical content knowledge (PCK_{ABL}): knowledge and skills regarding how to apply ABL to teach particular mathematics content.
- Technological content knowledge (TCK_{ss}): knowledge and skills related to representing mathematical concepts in a spreadsheet.
- Technological pedagogical knowledge (TPK_{ABL}): knowledge and skills regarding how to use spreadsheets in ABL.
- Technological pedagogical content knowledge ($TPCK_{\text{maths}}$): knowledge and skills related to representing mathematical concepts with spreadsheets using ABL.

The Professional Development Arrangement

The professional development arrangement (PD) was based on 'learning technology by design' (Mishra & Koehler, 2006). The PD consisted of three stages: an introductory workshop for Design Teams (DTs), design of lessons in DTs and implementation of lessons by DT members. The workshop lasted for 2 weeks and prepared the pre-service teachers by giving them the theoretical foundation/concepts as well as practical skills. Exemplary materials consisting of two models of activity-based lessons supported with a spreadsheet that were prepared by the researcher and appraised by an expert with ample experience in the use of technology in teaching mathematics were a necessary component of the PD arrangement. Based on their level of experience, the teachers worked in teams of two during the design stage (6 weeks) and were challenged to select mathematics topics suitable for teaching with spreadsheets, and to make use of the affordances of the technology to design learning activities that would foster higher order thinking in mathematics. It was expected that the combination of a specific pedagogy (ABL) and a specific technology (spreadsheets) would encourage the pre-service teachers to apply their knowledge and skills in designing and enacting ABL lessons by employing a mix of direct instruction and hands-on activity to guide students through activities with spreadsheets to enhance student learning. Six activity-based lessons supported with spreadsheet were developed and enacted two times each at different stages of implementation. In the implementation stage (5 weeks), each lesson was enacted by teaching it to their peer pre-service teachers and in three secondary high schools. In the second study, the 'learning technology by design' approach was adopted. However, unlike other design research in which the identification of the problem is

done through conducting a feasibility study or situational analysis study (cf. Agyei, 2012; Bakah, 2011; Nihuka, 2011), this research began with a *proof of concept study* in which the problem identification was based on the previous research and an in-depth review of the literature. According to Plomp (2009), “informed by prior researches and review of relevant literature, researchers in collaboration with practitioners can design and develop workable and effective interventions by carefully studying successive versions (or prototypes) of interventions in their target contexts, ...” (p. 13). From the literature, it was revealed that, although technology was available in schools in Tanzania and teacher training colleges were training teachers to integrate technology in teaching, technology uptake in schools was low. Thus, a proof of concept study was conducted with the preservice teachers to find out if the professional development approach that had been successful in Ghana (Agyei, 2012) and Kuwait (Alayyar & Fisser, 2011) could also be applied successfully in Tanzania to develop teachers’ technology integration knowledge and skills.

The professional development arrangement presented in this study adopted the “plan, teach, evaluate, re-plan” approach proposed by Peker (2009) for pre-service teachers. This approach was implemented by Jimoyiannis (2010) for in-service teachers as “planning, development, evaluation and rethinking”. Unlike Peker (2009) and Jimoyiannis (2010), who began their programs with planning, the professional development arrangement presented in this study began with an introductory workshop to introduce the concept of technology integration in science and mathematics teaching, followed by collaborative designing in teams (planning), lesson implementation (teaching), reflection (evaluation) and re-designing (re-plan). During the collaborative design of technology-enhanced lessons in teams, teachers were provided with support from a facilitator and/or an experienced science and educational technology expert, collaboration guidelines, exemplary lessons, and online learning materials. The availability of such materials provided a useful opportunity for teachers to share knowledge, skills, experiences and challenges related to technology integration in science and mathematics teaching, and thus, to learn from each other (cf. Agyei, 2012; Jimoyiannis, 2010).

Research Questions

The main research question of the first study was: *To what extent did pre-service teachers’ knowledge and skill in designing and enacting spreadsheet-supported ABL lessons develop and impact secondary school students’ learning outcomes?* This study was an in-depth investigation of the knowledge and skill needed by pre-service mathematics teachers to design and enact spreadsheet-supported ABL lessons, in which both quantitative and qualitative data were used. To investigate the impact of the spreadsheet-supported ABL lessons on their students’ outcomes, a pre-posttest experimental control group design was used.

The second study was conducted to determine the likelihood of the pre-service and in-service teachers’ continued use of technology in their science and mathematics

teaching after the termination of the professional development arrangement. The main research question addressed in this study was “*What factors affect the continued use of technology in science and mathematics teaching among pre-service and in-service teachers who attended the professional development arrangements?*”

Methods

Participants

Twelve pre-service mathematics teachers participated in the first study. The pre-service teachers were in their final year of the mathematics teacher education programme at University of Cape Coast (UCC) in Ghana. The 4-year teacher training programme allows pre-service teachers to teach at junior and senior high schools when they graduate. The average age of these pre-service teachers was 26 years. The senior high school students ($n = 297$) who participated in the study were from three different high schools. These high school students (from years 1, 2 and 3) were taught lessons by the pre-service teachers. Two hundred and twenty-five of them participated in the activity-based lessons supported with a spreadsheet, while 72 of them were taught with the traditional approach and served as a control group.

Participants in the second study were 13 teachers who had participated in the professional development arrangement as pre-service teachers from a teacher training college, and are currently working as school teachers or college tutors. In this study, they are referred to as the pre-service science and mathematics teachers. The study also included 29 in-service teachers from three secondary schools, which are presented anonymously as Schools A, B, and C. Schools A and B were government schools, each with one computer lab and approximately 30 computers, of which only one computer at school A and two at school B were working. School C was a private school with three computer labs and approximately 20 working computers in each lab.

Instruments

In the first study, data collection addressed how pre-service teachers perceive as well as demonstrate their knowledge and skill, and the impact on students of the activity-based lessons supported with spreadsheet is presented. Multiple data sources were used.

A TPACK lesson plan rubric was adapted from the Technology Integration Assessment Rubric (TIAR), which Harris, Grandgenett, and Hofer (2010) created and tested and found to be a valid and reliable instrument to assess TPACK evident in teachers' written lesson plans. While TIAR is a general rubric to determine TPACK in lesson plans, adaptations were made to fit it to TPACK for spreadsheet-supported ABL in mathematics. The rubric consisted of seven different criteria and

was scored as: not at all (1), minimal (2) and strong (3). Interrater reliability (Cohen's $\kappa = 0.91$) was calculated, using a sample of three lesson plans scored by two raters. The lessons were first coded (based on the TPACK constructs) and then assessed using the rubric.

An observation rubric adapted from a valid and reliable TPACK-based Technology Integration Observation Instrument (Hofer, Grandgenett, Harris, & Swan, 2011) was developed and used to assess TPACK in observed instruction. Adaptations were made to be able to observe TPACK for spreadsheet-supported ABL in mathematics. The observation instrument consisted of 20 items, which could be scored as: not at all (1), partly observed (2) and observed (3). The interrater reliability (Cohen's κ) for assessments of two observed lessons was $\kappa = 0.94$.

The pre-service-teachers' TPACK questionnaire, which was also used, included items that addressed the pre-service teachers' self-efficacy regarding their TPACK, adapted from Schmidt, Baran, Thompson, Mishra, Koehler and Shin (2009); responses used a five-point Likert scale format (from strongly agree (1) to strongly disagree(5)). Cronbach's alpha reliability estimates got this instrument range from 0.75 to 0.93 (Schmidt et al., 2009). The instrument was adapted and administered twice, before and after the intervention.

Teachers' responses in the pre-post survey indicated their own development in the perceived knowledge and skills needed to design and enact spreadsheet-supported ABL lessons. To explore pre-service teachers' knowledge and skills needed to design and enact spreadsheet-supported ABL lessons, interviews were conducted after each teaching session. Two raters coded the interview data using a sample of 5 interviews (from 5 teachers). The interrater reliability (Cohen's κ) was $\kappa = 0.92$.

The researchers' logbook was used to maintain a record of activities and events occurring during the design and enactment of the ABL lessons supported with a spreadsheet. The logbook entries complemented findings from the other data collection instruments. Information recorded in the logbook was analysed qualitatively using data reduction techniques in which major themes (students' participation; teachers' role; use of lesson materials and challenges in enacting ABL lessons supported with a spreadsheet) were identified and clustered (Miles & Huberman, 1994).

For each of the designed lessons, a test was developed by the pre-service teachers, and reviewed by the researcher, to determine student learning outcomes. The same test was administered pre- and post-instruction to ascertain the impact of the ABL lessons supported with a spreadsheet, for each of the six lessons enacted. Furthermore, two pre-service teachers developed the same lessons and taught them in a teacher-centred approach without using the spreadsheet-supported ABL pedagogical approach in the same school for comparison purposes.

Data for the second study were collected by using two kinds of instruments: a questionnaire and an interview. A questionnaire was used to assess the extent to which teachers continued to use technology in their science and mathematics teaching, as well as the factors (if any) that determined the teachers' continued use of technology in their teaching. The questionnaire was modified from Agyei (2012) and new items were included. The scale for this questionnaire was divided into two

sub-scales: questions related to the continued use of technology and personal factors used a five-point Likert scale: strongly disagree (1) and strongly agree (5). Items related to professional development, institutional, and technological factors used a four-point Likert scale: not at all (1), a little (2), somewhat (3) and a lot (4).

A semi-structured interview guide was developed by the second author to assess the continuation of the use of technology in teaching and the professional development, institutional, personal and technological factors that affected the teachers' continued use of technology in teaching. Three teachers from each group in the study: pre-service, school A, school B, and school C teachers, were randomly selected to participate in the interview. Pre-service teachers participated in the interview through a phone call, while teachers from schools A, B and C, participated in a face-to-face interview. Examples of interview questions were: (1) How often do you use technology in your teaching? (2) What are the factors determining technology integration in teaching at your school? A random sample of 4 interviews was coded by a second person. The inter-coder reliability κ was 0.84.

The data from the questionnaire were analyzed to compute means and standard deviations. An ANOVA was carried out to test the difference in the means between the participant groups. The qualitative data from the interviews were transcribed and coded by using the codes that were generated from the study's theoretical framework (deductive coding) (Miles & Huberman, 1994).

Main Findings

In the first study, pre-service mathematics teachers collaboratively designed and used spreadsheet teaching materials to enact an ABL lesson within a mathematics classroom context. In particular, the study sought to measure the extent to which the pre-service teachers were able to develop and demonstrate the knowledge and skill needed to design and enact spreadsheet-supported ABL lessons and the impact of pre-service teachers' enactment of the lessons on secondary school students' learning outcomes. The lesson documents and lesson enactment showed that the pre-service teachers employed a mix of direct instruction and hands-on activity to guide students through activities in which the students explored, conjectured, verified, generalized, and applied results to other settings and realistic mathematical problems, consistent with other studies (Hmelo-Silver et al., 2008; Mayer, 2004). The teachers used the spreadsheet extensively to give greater opportunity to verify results and consider general rules, make links between spreadsheet formulae, algebraic functions and graphs, analyse and explore number patterns and graphs within a briefer time and allow for many numerical calculations simultaneously, to help their students explore mathematics concepts and perform authentic tasks. The findings support arguments that a spreadsheet-supported ABL approach fostered learner-centred classroom practices and has potential for improving mathematics achievement in senior high schools.

This confirms similar studies (Özgün-Koca, Meagher, & Edwards 2010) that have found that pre-service teachers' understanding of technology shifted from viewing technology as a tool for reinforcement to viewing technology as a tool for developing student understanding of mathematical concepts.

The findings of the first study also indicated that teachers demonstrated knowledge and skills in designing and enacting ABL lessons supported with a spreadsheet in their lesson plan products and observed instruction. Thus, as novice teachers, the new experience with spreadsheet and ABL impacted their knowledge and skills regarding all of the TPACK constructs. This was confirmed by their perceived development in the knowledge and skill needed to design and enact spreadsheet-supported ABL lessons, as observed by significant gains in all the TPACK components of the teachers' self-reported data.

The first study also showed that ABL pedagogy can play a vital role in enhancing pre-service teachers' skill and their experience with integrating technology in their future classes. The ABL approach prompted clearly defined roles for both students and teachers. Students worked collaboratively in groups, had the opportunity to evaluate their own work and that of others by sharing their evaluations. The role of the teachers, on the other hand, was more as facilitators than dispensers of knowledge; they managed the context and setting and assisted students in developing mathematical concepts through activities.

Findings from the second study revealed that, while the pre-service teachers and teachers from school B used technology for teaching, teachers from schools A and school C used technology mostly for administrative purposes. Earlier findings by Hare (2007) and Swarts and Wachira (2010) reported the frequency of teachers' use of technology for administrative rather than instructional purposes. However, the findings presented for pre-service teachers and teachers at school B are in line with those from study 1 who reported successful transfer of training to the job, after a similar professional development arrangement.

Several factors contributed to the continued use of technology in their teaching by the teachers who attended the professional development arrangement.

Teachers' perceived valuing of the professional development was a significant predictor of teachers' continued use of technology in their teaching. Teachers reported satisfaction with the content, sequence and relevance of the professional development arrangement they attended. They further reported that collaborative design of technology-enhanced science lessons in teams, implementation of the designed lessons and reflection with peers, were necessary components for developing their understanding of various technological tools that can support learning, and of how they can improve learning of difficult science topics through the use of technology. According to Jimoyiannis (2010), teachers' collaborative design of technology-enhanced science lessons is a promising professional development arrangement for developing teachers' technology integration knowledge and skills.

Analysis of personal factors showed that knowledge and skills was the only significant predictor of the teachers' continued use of technology in their teaching. Although these findings agree with those of Eickelmann (2011) and Todorova and

Osburg (2010), who reported that knowledge and skills was an important determinant of technology integration, they differed from those of Agyei (2012), who reported that perceptions (belief) was a significant predictor of the continued use of technology in teaching. The findings in this study showed that belief negatively predicted the continued use of technology in teaching. This implies that although some teachers did not use technology in their teaching, they had a positive belief about the use of technology in teaching.

Findings on the institutional factors showed that access to technology and support were significant predictors of the teachers' continued use of technology in their teaching. Of the three measures of institutional factors assessed in this study, access, support and environment, only environment was an insignificant predictor. Most of the teachers who did not integrate technology in teaching reported the lack of access to technology and support as factors that hindered their integration of technology. However, both the teachers who continued using technology and those who did not experienced similar problems related to the environment (lack of electricity, cables, etc.).

Further, the analysis of technological factors revealed that ease of use of technology was a significant predictor of the teachers' continued use of technology in their teaching. Although the majority of teachers reported that technology was effective in science and mathematics teaching, they differed on the ease of use. Some teachers reported that technology use is easy, while others said that it depends on the choice of technology or found it difficult in lesson preparation but easy in teaching. The combination of all significant factors (perceived value of the professional development, knowledge and skills, access to technology, support and ease of use of technology) showed that knowledge and skills, access to technology and ease of use of technology were significant predictors of the teachers' continued use of technology in their teaching. The perceived value of professional development and support from the management were not significant.

The findings of the second study led to the conclusion that a long-term impact of a professional development arrangement in the context of Tanzania depends on teachers' technology integration knowledge and skills, access to technology and the ease of use of the available technology. Although Baldwin and Ford (1988) indicated that the professional development factor can directly lead to transfer of training, the findings in this study showed that the professional development factor does not necessarily lead to the continued use of technology in teaching; instead it is an important aspect for the change in teachers' knowledge and skills regarding integrating technology in their teaching, which in turn has an effect on their use of the technology available at the school, provided that it is easy to use. Moreover, Eickelmann (2011) quoted several studies indicating that management support is the most important and supportive factor for teachers' continued use of technology (cf. Hennessy, Harrison, & Wamakote, 2010). However, our study showed that management support was not a significant predictor of the teachers' continued use of technology in their teaching. The findings from interviews indicated that teachers were more likely to continue using technology in teaching in schools in which they were supported by the management than in those in which teachers were not supported.

Since the analysis of the institutional factors determining the continued use of technology in teaching showed that support from the management was a significant predictor, it is possible that management support acts as a catalyst, rather than having a direct impact on the continued use of technology in teaching. The teachers' continued use of technology can take place if the management can provide incentives to motivate teachers to use technology in their teaching (cf. Hennessy et al., 2010): (1) ensure that the technological tools are available and maintained for ease of use; (2) encourage teachers to use technology in their teaching; and (3) offer opportunities for teacher training to enhance their technology integration knowledge and skills.

Discussion

In spite of the advantages of the pedagogical approach used in the first study, the teachers reported some difficulties in applying their knowledge and skill in designing and enacting activity-based lessons supported with spreadsheet. The areas they identified to be particularly challenging and difficult included: selecting and integrating appropriate spreadsheet tools and relevant spreadsheet applications in designing authentic learning activities for selected topics. It is apparent that the range of spreadsheet capabilities is limited and that for many mathematics concepts spreadsheet applications are not relevant. As a result, most teachers might have experienced difficulty in making spreadsheet application choices and in matching the learning activities that they employed in their instructional plans. The context-sensitive factor related to how pre-service teachers have been deep-rooted in a teacher-centred learning approach could have influenced their thinking and practices. A concern regarding time was reiterated by the teachers, indicating that conducting spreadsheet-supported ABL lessons involved a lot of time and required a type of subject-specific training with technology. These drawbacks notwithstanding, the spreadsheet-supported ABL lessons impacted their secondary students' learning outcomes. The pre-post test scores for the lessons showed significant improvement after all the lessons. The mean gains in the spreadsheet-supported ABL approach compared to the traditionally taught lessons showed a significance difference, with a medium to high effect size, which confirms the findings of previous studies (cf. Keong, Horani, & Daniel, 2005) that technology use improves the way mathematics is taught and enhances students' understanding of basic concepts, and has a positive effect on student achievement in mathematics (cf. Beauchamp & Parkinson, 2008; Bottino & Robotti, 2007). Thus, the spreadsheet environment appeared useful for engaging pre-service teachers in the design of learning activities to support the mathematics learning of students, such as: discussing presentations, collecting data (e.g., on the co-ordinates of an object), working in teams, making predictions. This variety of learning activities allowed the pre-service teachers to orchestrate student learning in various ways (cf. Drijvers, Doorman, Boon, Reed, & Gravemeijer, 2010). This is the kind of pedagogical reasoning (cf. Heitink, Voogt,

Verplanken, van Braak & Fisser, 2016; Webb & Cox, 2004;) that pre-service teachers need to undertake in their planning and teaching of ICT-enhanced lessons.

The results in the first study indicated that exposing teachers to ABL based lessons supported with a spreadsheet is a good way to help pre-service teachers develop deeper connections between their subject matter, instructional strategy and spreadsheet application use knowledge-base of TPACK. Such a conclusion poses a question about TPACK's applicability in different contexts and with different technologies, assessing teachers at a more generic level. Therefore, the study supports the contention that for teachers to understand and develop knowledge and skills related to TPACK in a valid and reliable way, it is important for them to focus on a specific content as well as a specific pedagogical approach into which a specific technology can be integrated. This aligns with Shulman's (1986) idea of a teacher's PCK, characterized as:

knowledge of the most regularly taught topics in one's subject area, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations ... including an understanding of what makes the learning of specific concepts easy or difficult. (p. 9)

The conceptual model of influences on the continued use of technology in teaching presented in Fig. 20.1 is supported by the findings in this study, but with fewer critical variables. The model may be explained as follows: the professional development arrangement, which was mainly collaborative design in teams, initiated the teachers' learning of technology integration knowledge and skills (personal factor); the availability of supportive conditions such as access to technology (institutional factor) and ease of use of technology (technological factor) enabled teachers to use the knowledge and skills gained from the professional development for continued use of technology in their teaching (Fig. 20.3). While in this study, management support was conceptualized as one of the institutional factors, in the final model we consider that support from the management is interposed between the personal factors and the institutional and technological factors. In that way, management support becomes a catalyst for the interaction between teachers' technology integration

Fig. 20.3 A conceptual model of teachers' continued use of technology after the professional development arrangement

knowledge and skills, the technology available at school and its ease of use. The management becomes important in motivating teachers to use the knowledge and skills gained from the professional development, through providing incentives and rewards for technology uses (personal factor), ensuring availability of the technological tools at school (institutional factor), and ensuring that the technology is maintained (repaired) to make it easy for teachers to use (technological factor) (see the modified model in Fig. 20.3).

From the model (Fig. 20.3), the relationship between the professional development, support from the management and continued use of technology is represented by a dotted line, because the impact of the professional development and management support was insignificant. However, the impact of professional development was noticeable through the enhancement in teachers' knowledge and skills regarding integrating technology in their teaching. On the other hand, the impact of management support was evident in the differences in technology use between schools in which teachers were supported by the management and those which they were not.

The findings in the second study can have implications for future professional development arrangements that aim to develop technology integration knowledge and skills. First, although the professional development factor had insignificant impact, we consider it important for the teachers' continued use of technology in their teaching, because it was the initiator of the teachers' development of technology integration knowledge and skills. Second, a long-term impact of the professional development arrangement depends on the teachers' technology integration knowledge and skills, access to technology and the ease of use of the available technology. Third, although management support was not a significant predictor, we consider it essential for teachers' continued use of technology in their teaching. The findings revealed that schools that had support from the management had better implementation than those that had little support. Thus, support is considered to be an important catalyst for the teachers to put the knowledge and skills developed from the professional development into practice and to utilise the available technology at school for their teaching, provided that the technology is easy to use. Based on the findings of this study, we are confident in describing support from management as a factor that comes between institutional factors and technological factors, and personal factors.

The model presented provides key information about the factors determining the teachers' continued use of technology in their teaching (see also Niederhauser et al., 2018). Moreover, the professional development arrangement assessed in this study seemed to have a promising impact on the teachers' continued use of technology in their teaching. However, future professional development arrangements could take into account the involvement of the school management in the design, implementation and evaluation of the professional development arrangement. Moreover, future studies could also investigate whether or not the school management should be considered as among the institutional factors or should stand alone as the overseer of the whole process (i.e., teachers' learning process, availability of technology and the extent to which technology is easy to use).

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