International Journal of Education Learning and Development
Vol.3,No.3, Pp.55-67, April 2015
Published By European Centre For Research Training And Development UK (www.eajournals.org)

ISSUES AND OPTIONS FOR USING MULTIMEDIA TO IMPROVE PRE-SERVICE MATHEMATICS TEACHER EDUCATION IN GHANA

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ABSTRACT: *It is well documented that the overly theoretical coursework in conventional mathematics teacher education programs does not effectively challenge pre-service mathematics teachers' preconceived ideas about the teaching of mathematics. In addition, field experiences provided for pre-service teachers have been shown to have inherent limitations. Consequently, several mathematics educators have drawn attention to the need to engage pre-service mathematics teachers in experiences that present actual teaching practices and make it possible for them to study or critique those practices reflectively. In the developed countries like the US there appears to be a growing interest in the potential of multimedia systems to bring this type of reflective and critical thinking about the teaching of mathematics. In the developing countries such as Ghana, very little of such efforts, if any, is being done to improve mathematics teacher education. This paper looks at the potential of these multimedia environments to improve education of prospective mathematics teachers in Ghana. It focuses on how multimedia programs fit into contemporary theories of teacher learning and supports this with a discussion of empirical research efforts at using multimedia programs to facilitate education of prospective mathematics teachers. Implications for pre-service mathematics teacher education in Ghana are also presented.*

KEYWORDS: Pre-service mathematics teacher education, Use of multimedia technology, improving teachers Education

BACKGROUND TO THE STUDY

In conventional teacher education programs, pre-service mathematics teachers learn about the teaching of mathematics as a form of "school knowledge" (Lampert & Ball, 1990). In addition, the courses are offered in isolated circumstances and mostly in a theoretical manner that many pre-service teachers do not easily establish the linkage (see for example, Ball, 1988b). At the University of Cape Coast in Ghana, for instance, pre-service mathematics teachers are exposed to college-based mathematics courses, foundations of education courses and a number of mathematics education courses are offered theoretically and in isolated circumstances. In addition, micro-teaching sessions, under the guidance of experienced professors, are provided during the third year of the undergraduate teacher education program to help pre-service mathematics teachers put into practice the theories of mathematics teaching and learning they have previously been exposed to. Thereafter, pre-service teachers are attached to schools for one semester for supervised internships (Off-Campus Teaching Practice), with the help of experienced mentors. During the internship, pre-service teachers observe lessons and take lead roles in teaching under the mentorship of experienced teachers in their subject areas while faculty from the University occasionally visit to assess their performance and progress. What

ISSN 2054-6297(Print), ISSN 2054-6300(Online)

conventional teacher education at the University of Cape Coast in Ghana offers, as in many conventional teacher education programs, can therefore be likened to a process of initially exposing pre-service teachers to 'maps' of the classroom situations under which they would later be working and later, testing their ability to reproduce the maps through the micro-teaching and off-campus teaching practice arrangement (Lampert & Ball, 1990). Lampert & Ball (1990) have argued that due to the largely theoretical nature of these maps, many newly trained teachers are left with very few guideposts, if any, to guide them when they arrive at the work situation. New teachers are therefore compelled to invent their own maps; hence the argument sometimes that no matter how much teachers learn during preparation, learning to teach inevitably occurs on the job.

The abovementioned arrangement of taking courses in isolated circumstances makes it difficult to effectively challenge the preconceived ideas about mathematics and the teaching of the subject that pre-service teachers bring with them to the college of education. Lortie (1975) has estimated that on average, students spend about 13, 000 hours in direct contact with classroom teachers by the time they graduate from high school. During this period, many pre-service teachers would have been exposed to mathematics teaching that transmits mathematics content and procedures in a prescriptive and repetitive manner and this makes it possible for them to develop the thinking that mathematics should be taught in a procedural manner emphasizing the explanation of algorithms and how they could be applied (Eisenhart, Borko, Underhill, Brown, Jones & Agard, 1993). Even in situations where they are exposed to exemplary teaching, students are not equipped with sufficient theory and ability with which to analyze the actions of their teachers. Consequently, instead of preconceiving the teaching of mathematics in an explicit and analytic manner based on pedagogical principles, there is the tendency for students to preconceive of it (i.e. mathematics teaching) in an intuitive and imaginative manner. Thus, before they enter colleges of education, pre-service teachers are likely to have formed subjective understanding of what it means to teach a subject like mathematics by imagining why their teachers pursue certain agendas in their classrooms. Research is replete with the findings that these preconceived ideas and thinking about mathematics and the teaching of mathematics affect what pre-service teachers learn from their courses and field experiences (see Lortie, 1975; Fieman-Nemser, & Buchmann, 1986; Ball, 1988a, 1988b). Ball (1988b) for instance, has argued that due to the lack of connection between the overly theoretical coursework in traditional teacher education courses and the realities of classroom life, the experiences and preconceived assumptions of pre-service mathematics teachers, for the most part, remain unchallenged by conventional teacher education programs; and beginning teachers are likely to teach using the same unproductive methods they are so familiar with.

While it is true that field experiences and supervised internships help pre-service teachers construct practical knowledge that is detailed, concrete, and integrated around problems of practice, it has been argued that such field experiences could have inherent weaknesses in terms of their effectiveness (Buchmann & Schwille, 1982; Shulman, 1987; Masingila & Doerr, 2002). First, in attaching students to schools for field experience or internship purposes pre-service teachers are usually attached individually to particular teachers in their field placements and never together, as a cohort, in the same teacher's classroom. Their individual experiences in this arrangement are, therefore, never the same. Masingila & Doerr (2002), for instance have argued

ISSN 2054-6297(Print), ISSN 2054-6300(Online)

that pre-service teachers' lack of common experience limits their ability to reflect and analyze the teaching and learning process generally with their classmates in a meaningful manner. Second, it is documented that expert teachers have the ability to deviate from their "curriculum scripts" (e.g. Putnam, 1987) and engage in "actions associated with teaching quickly, accurately, flexibly and inventively under several types of constraints" (Leinhardt, 1988, p.120). Unfortunately, even when individual pre-service teachers are placed in the classroom of exemplary teachers, it is doubtful whether they (the pre-service teachers) possess the ability and experience to completely and meaningfully deconstruct what is "good" from simply observing the rapidly changing and complex interactions (both spoken and unspoken) that take place in the classroom (Shulman, 1987). In addition, it is quite difficult, if not completely impossible, for pre-service mathematics teachers to interrupt the classes they are observing and pose questions to their mentors in order to fully understand the actions of their mentors. Their learning in these arrangements could therefore be intuitive, imaginative and in some cases unreflective in nature. Consequently, it is possible that pre-service mathematics teachers draw faulty inferences from their field experiences and internships (Buchmann & Schwille, 1982). Furthermore, in reality, because the number of exemplary reform-based classrooms is few, it is difficult to get sufficient mentors who can help pre-service teachers deal with the disparity between the theoretical courses they take in college and the reality they face in their field placements (see for instance, Masingila & Doerr, 2002).

The foregoing suggests that neither the university-based theoretical study of teaching nor learning to teach through unreflective apprenticeship, either separately or together, are likely to produce a career-long orientation of professional learning. These issues, namely; the lack of connection between the overly theoretical college-based courses for pre-service teachers, the problems inherent with the type of learning pre-service mathematics teachers engage in during their field placements, have led several mathematics educators to draw attention to the need for intensive practical orientation through the presentation (to pre-service teachers) of experiences that present actual teaching practices and make it possible for them to study or critique those practices (Lampert & Ball, 1990; Merseth & Lacey, 1993; Mousley & Sullivan, 1997; Sullivan, 2002). Currently, many mathematics educators seem to suggest that exposing pre-service mathematics teachers to teaching in a reflective manner has the potential of effectively challenging the initial ideas pre-service mathematics teachers' formed from their apprenticeship of observation and helping to learn about the teaching of mathematics practically. Sullivan (2002), for instance, has observed that, "studying teaching in simulated or real situations offers considerable potential for stimulating thinking not only about the application of theory to practice but also for creating personal theories for the study of [teaching] practice" (p. 291). To achieve the type of reflective practical orientation suggested here, many mathematics educators have began to investigate and advocate for the use of multimedia systems to support pre-service teacher education (e.g. Lampert & Ball, 1990; Merseth & Lacey, 1993; Mousley & Sullivan, 1997; Herrington, Sparrow & Oliver, 1998; Masingila & Doerr, 2002; Sullivan, 2002). It is suggested that multimedia systems that capture the complexities of an exemplary "can become sites for investigation, reflection and study by pre-service teachers in ways that are not easily accomplished with actual classroom experience" (Masingila & Doerr, 2002, pp. 236-237).

ISSN 2054-6297(Print), ISSN 2054-6300(Online)

In the developed countries, many mathematics educators have already started using multimedia systems to improve mathematics teacher education, both in pre-service and continuous teacher education (see for example, Putnam & Borko, 2000; Derry & the STEP Team, 2002; Krainer, 2002; Oonk, Goffree & Verloop, 2003). Unfortunately, developing countries like Ghana have not made any strides on the use of multimedia systems as tools for reflective teaching in mathematics education yet. It is in the light of this that this paper recommends the use of multimedia systems in pre-service mathematics teacher education in Ghana.

CRITICAL FEATURES OF MULTIMEDIA PROGRAMS

This paper relies on the definition of the term multimedia provided by Herrington, Herrington, Sparrow & Oliver (1998) who see "multimedia simply [as] a combination of media, such as text, video, graphics, sound and animation in a computer-based learning environment which enables users to interact with a wide variety of resources and activities" (p.92). By their design, multimedia systems, whether web-based or produced on CD-ROMs, have the potential to expose pre-service mathematics teachers directly to the terrain of teaching to enable them learn about the teaching of mathematics. This is essential in pre-service mathematics teacher education because learning to become a mathematics teacher involves both learning what mathematics teachers know, do, and how they think (Lampert & Ball, 1990).

A key feature of multimedia systems is the multiplicity and non-linearity of the learning opportunities it provides to users. It is important to bear in mind that multimedia systems allow teacher educators to provide genuine or authentic examples of classroom teaching and learning environments in their classes. Authentic here is used to mean that the lessons videotaped are not staged but can be said to mirror real classroom experience as much as possible. In addition, the videotaped lessons can be presented in the raw form without any editing to perfect them. As a result, it is possible to retrieve both good practices and mistakes from multimedia systems. Though, in some cases, the multimedia developers are able to select 'best' teachers and at times develop the lesson plans with them, it is reasonable to consider such cases as cases of expert teachers rather than a form of Hollywood-scripted and staged lessons. These videotaped lessons together with accompanying transcripts of the lessons, teachers' and students' thinking as well as textual representations of the mathematics content provide flexible links that allow pre-service mathematics teachers multiple paths through a non-linear network of information (Lampert & Ball, 1990) for cognitive flexibility in their learning.

Also, in traditional mathematics teacher education programs, pre-service teachers learn the content of what to teach and how to teach it often in separate sessions. Multimedia systems open a new approach to teacher education as it helps to bridge this gap between the content and theory Dolk (2000). And this is facilitated by the wider range of teaching practice provided to pre-service teachers.

Another crucial aspect of multimedia programs is their interactivity (i.e., the interactive environments they are able to generate) (Sudzina, 1999). This idea of interactivity can better be appreciated if we are willing to take an ecology view of pre-service mathematics teacher education classes (Nardi & O'Day, 1999). By taking an ecology view of our classes the spotlight

ISSN 2054-6297(Print), ISSN 2054-6300(Online)

is not put on technology but on human activities that are served by technology (which in this case is the multimedia programs). In applying this view, pre-service mathematics teacher education classes could be perceived as information ecologies with a collection of people (students and their instructors), in a network of relationships, and technologies (including multimedia systems), all focused on the activity of helping students to construct their own knowledge of teaching. In field experiences traditionally provided for pre-service teachers to engage first hand with teachers, it is impossible to pause the teaching and learning process and pose questions, reflect on particular aspects of classroom practice, share ideas and challenge each others' thinking about what is happening in the classroom. Multimedia systems permit these to be done in ways that help learners interact among themselves and the classrooms interactions they are presented with (i.e., they provide situated learning opportunities to pre-service teachers). This helps to engage learners in critical thinking about the videotaped teachers' and students' actions and thinking while they (pre-service mathematics teachers) take responsibility for their own learning (Brunner and Tally, 1999). Herrington et al. (1998) have referred to multimedia this way as "vehicle for the situated learning environment" (p. 93).

MULTIMEDIA SYSTEMS AND CONTEMPORARY THEORIES OF LEARNING

Ideas about effective ways of teaching and learning have changed from the didactic teacher-centered models in which students are perceived as passive recipients of knowledge to student-centered models, which require teachers to engage students in activity-based settings for learners to construct knowledge themselves (Cuban, 1984). These changes demand that the way teachers are prepared must change. Prospective teachers, in general, and those hoping to teach mathematics, in particular, therefore need to be provided with experiences that help them to think deeply about teaching and students' learning (Hatfield, 1996). Conceptualizing pre-service mathematics teachers as learners (who are in the process of learning to teach) then makes it imperative for teacher education to ensure that experiences provided for pre-service mathematics teachers' learning are consistent with contemporary theories of teaching and learning.

One of such theories of teaching and learning is constructivism. Constructivist teaching is difficult to characterize because constructivist learning is conceptualized differently by various groups of theorists, depending on whether the emphasis is on individual cognitive processes or the social co-construction of knowledge. In this paper the view of constructivism is that, which encompasses both the individual cognitive processes and the social co-construction of knowledge so as to emphasize the interaction between learners and environments in the learning process (Vygotsky, 1962, 1978; Bruner, 1962, 1979; and Piaget, 1970). As Bereiter (1994) puts it, "constructivism tells us to pay close attention to the mental activities of learners, [as they interact among themselves and the environment provided to support their learning]" (p. 21). In other words, for the principles of constructivism to be effectively followed there is the for the creation of appropriate learning environment. And multimedia systems have the potential of providing the environments needed to facilitate the education of prospective mathematics teachers.

Also, child centered approaches emphasized in constructivist paradigms demand adherence to *inquiry approaches* in teaching mathematics. The process of thinking needed to be elicited from

ISSN 2054-6297(Print), ISSN 2054-6300(Online)

learners in this type of teaching requires mathematics teachers to be able to help learners to explore deeper into content and context; a form of higher order thinking (Black and McClintock, 1995; Manzo, 1998; Swain and Pearson, 2001). One way of preparing prospective mathematics teachers to engage in this type of teaching is to expose them to a learning situation or context that encourages broader thinking about teaching (Hatfield, 1996). This is possible with the use of multimedia environments because they can be used to present vignettes that offer prospective teachers valuable teaching contexts that encourage questions to be asked, and permit analysis and contextualization of teaching real practices.

Another type of activity encouraged by constructivists in learning is *reflective thinking* (Swain and Pearson, 2001). Multimedia programs allow people to 'chunk' or break information apart in a way that puts less pressure on their short-term memories and possibly aids retention (Roblyer, 1999). When used in the education of pre-service mathematics teachers, multimedia systems permit authentic teaching practices to be chunked into segments and deliberated on and even returned to where necessary to aid reflective thinking of the users. Thus, multimedia systems have the potential to enhance pre-service mathematics teachers' reflective thinking skills.

Another way to think about how multimedia programs fit into existing theories of learning is to look as socio-constructivists notions of situated cognition, promoted by the works of Brown, Collins and Duguid (1989), as well as Lave and Wenger (1991). They emphasize the social and situated nature of learning and shifted the discussion of learning away from an emphasis on individual learning to participation in a community of practice. Socio-constructivism emphasize the "kinds of social engagements provide the proper context for learning to take place" (Lave and Wenger, 1991, p14). Thus, to Lave & Wenger (1991), learning takes place through participation in social settings and is aided by the cultural artifacts provided to support, extend and reorganize mental functioning. Adding to this view of the social nature of learning, Wenger (1998) would later purport that "a central aspect of learning is that people are social beings; . . . [and that] knowing is about active engagement in the world" (p.40-41). Pre-service teachers, as the name implies, are students who are learning to teach. Therefore, engaging them together in a critical reflection and analysis of teaching practices fit Lave and Wenger (1991) social nature of learning. This is where multimedia systems fit in. Multimedia systems, whether on CD-ROMs or hypermedia format, can be used to make the practice of experienced teachers available to pre-service teachers for discussion, analysis, and to stimulate reflection.. In other words, interactive multimedia systems fit into this notion of situated learning because they can be used as resources to provide authentic activities and contexts for the learning process in general.

EMPIRICAL EVIDENCE OF THE USE OF MULTIMEDIA PROGRAMS

As already mentioned, this section focuses on discussing empirical research efforts at using multimedia programs to facilitate education of prospective teachers. This has been approached in two subsections. First a number of cases are discussed showing the benefits that these provided. Next a look is taken at the constraints associated with these cases in order to help direct attention to some of the unanswered questions that might provide possible directions for future research in this area.

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Benefits observed in the use of multimedia programs

The use of multimedia systems in pre-service teacher education has not been a long experience. In spite of this, it can be seen that it has the potential of "promoting access to massive amount of data [in this case, authentic teaching practices] in their original formats, preserving their ecological validity and contextual richness, while also allowing for condensation for interpretive analysis" (Lampert & Ball,1990, p.6). A good example of this is Lampert and Ball's multimedia systems called SLATE (Space for Learning And Teaching Exploration) and School Learning Environment (SLE), which enables students to access their actions as teachers over a period of one year in two elementary school mathematics classrooms-- a third-grade class taught by Ball and a fifth-grade class taught by Lampert. SLATE, for instance, and gives users access, among other things, to digital video and transcripts of classroom sessions, copies of students' class work, student interviews, as well as copies of teachers' notes. Their effort encompasses a broad range of issues and has guided development of more interactive multimedia systems worldwide. In terms of their effectiveness, Putnam and Borko (2000) had this to say about the SLE,

"within this [Student Learning Environment] environment teachers investigate pedagogical problems that arise as they view and read about Ball's teaching of mathematics in a third-grade classroom and Lampert's in a fifth-grade classroom, simultaneously becoming familiar with new technological tools and exploring new ideas about teaching and learning. Most students saw teaching and learning through pedagogical and psychological lenses, exploring features of the classrooms such as teacher-student relationships, instructional strategies, classroom management, and student participation, rather than mathematical content or curriculum. The students' investigations in this multimedia environment sometimes pushed their thinking beyond where it was when they started" (p.11 of the online version)

One of the approaches to teaching recommended by the NCTM in their *Agenda for Action* is the problem solving approach (NCTM, 1980). Cases of the use of multimedia systems in pre-service education of mathematics teachers indicate that their use could enhance pre-service mathematic teachers' ability to initiate problem solving approaches in their teaching practice. An example of this is the *Investigations in Teaching Geometry* CD-ROMs developed at the Vanderbilt University to provide a common context within which to highlight some of the pedagogical issues that arise during mathematics lessons (Barron and Goldman, 1994). The CD-ROM portrays a three-day lesson sequence on geometry. The main features of this CD-ROM is a video, text, and graphic information that provides an authentic context in which teachers can explore issues raised in recent mathematics reform documents. These CD-ROMs have been field-tested at Vanderbilt University in mathematics methods courses for prospective elementary and middle school teachers. Evaluation results indicate that the CD-ROM resource encouraged the pre-service teachers to use a problem-solving approach to teaching, helped them plan mathematics lessons, and increased their comfort in using technology. In addition, the Vanderbilt experience has shown that multimedia systems are capable of enhancing reflective discussions among pre-service mathematics teachers (Barron and Goldman, 1994).

Another empirical effort at using multimedia programs to facilitate education of prospective mathematics teachers can be found in the Multimedia Interactive Learning Environment (MILE) created by the Freudenthal Institute (University of Utrecht) in the Netherlands. According to

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Oonk et al. (2003), initial experiences with MILE indicate that it is helping pre-service teachers to engage in reflective conversations about teaching in a way that helps them bridge theory and practice. In other words, MILE generally helps student teachers to relate theories as a means to explain the practical situations they observe from the videos and these in turn helps them to generate new questions. In terms of students' investigative processes in MILE, research has led to the observation of four levels of pre-service teachers' knowledge construction. These are a) assimilation, when pre-service teachers adopt the videotaped teachers' actions and beliefs, b) accommodation, when pre-service teachers modify the videotaped teachers' actions and beliefs to fit their own purposes c) seeing new links, when pre-service teachers establish a connection between an event on the video and aspects of their mathematics education course they are taking, and d) theorizing, when pre-service teachers design their own theories (Krainer, 2002).

The potential of multimedia systems to promote critical thinking of pre-service mathematics teachers' emerging teaching practice has also been well documented. One of such cases is discussed in *Understanding pre-service teachers emerging practices through their analyses of a multimedia case study of practice,* by Masingila and Doerr (2002) in their report of an NSF (National Science Foundation) funded study. The main project used multimedia programs to facilitate education prospective seventh to twelfth grade mathematics teachers. However the Masingila and Doerr (2002) report was based on one cohort of only nine of the teachers who volunteered to participate in the study. The multimedia system used included, video overview of the school setting, a teacher's lesson plans, video recorded lessons, students' written work and a video journal of the teacher's reflections and anticipations on each lesson as well as transcripts of all videos. Study guides and specific mathematical activities for the pre-service mathematics teachers were also included. The nine pre-service teachers had early in a seminar class identified goals for themselves, which they wanted to address in their own teaching practice. Then in a different setting they were made to watch the videos on the multimedia system with an assigned journal question. The videos they watched and their own reflections of it then became the focus of their discussions in latter seminar classes. This lasted for four weeks after which they made presentations of their experiences. According to the authors, they "found that having the multimedia case study as a site to investigate, analyze, and reflect on another teacher's practice supported [these pre-service teachers] in (a) focusing on issues that were meaningful to their own teaching practice, and (b) thinking critically about another teacher's practice which in turn promoted critical thinking about their own practice" (Masingila & Doerr, 2002, p. 259).

Multimedia environments for pre-service teachers' learning have also been created on the web. One such design is the STEP (Secondary Teacher Education Project) web developed by Sharon Derry and the STEP Team at the University of Wisconsin-Madison. The goal of STEP is "to help pre-service teachers acquire useful scientific knowledge about cognitive psychology and other learning sciences that can flexibly be applied to the design and analysis of instructional environments" (Derry and the STEP Team, 2002, p.2). This project has created a complex website with resources such as videos of lessons and student learning in actual classrooms, expert commentary and case analysis in addition to commentaries that go with each lesson. There are also networks of case-related links to web pages and other resources discussing core concepts in cognitive psychology as well as a site to support online discussions of video cases. These resources are designed to support facilitated video discussions in secondary teacher

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education programs. A trial of this web in the spring of 2000 revealed that the use of STEP resources in pre-service secondary teacher education courses is capable of enhancing transfer and flexible use of course concepts. For instance, of the 18 volunteer pre-service teachers who participated in the study, only two of them continued to use teaching models in which teaching is merely a one-way transmission of information. In addition, written analyses of the video cases produced by students showed flexible application of pieces of different theories rather than application of coherent theoretical frameworks (Derry and the STEP Team, 2002). These findings are significant for two reasons. First, available literature point to difficulties in getting the initial ideas pre-service teachers effectively challenged in traditional teacher education programs (Cohen, 1998; Lampert & Ball, 1990; Ball, 1988b; Zeichner, K. M. & Tabachnik, R.B, 1981) Overcoming this problem in this study emphasizes the potential of multimedia programs in satisfying this need. Second, the flexibility with which pre-service teachers in the study used various theories point to the potential of the STEP resources in particular, and multimedia programs in general, to support the acquisition of the type of the non-linear type of learning that the Cognitive Flexibility theorist suggest as being an essential ingredient in learning complex things in ill structured domains like mathematics. In other words, pre-service teachers' ability to flexibly apply pieces of different theories in analyzing the lessons in this project is a sign of the potential of this type of resources to enhance high construction and transfer of professional teaching knowledge and skill.

Constraints, unanswered questions and future direction

The aforementioned benefits of multimedia programs notwithstanding a critical look at the various cases point to a number of constraints in their use in teacher education programs. Some of these constraints are discussed in this section. In order to broadly conceptualize the constraints associated with multimedia systems I shall discuss them under a number of broad categories. These are 1) Structural, 2) Pedagogical, 3) Practical, 5) Financial and 6) Technical Constraints.

By *structural constraints*, I mean those that are related to getting the design of multimedia systems to effectively facilitate reflective and critical thinking among its users. Lessons from MILE digitized learning environment, for instance, point to a constraint that falls into this category. From the Netherlands experimentations, Oonk et al. (2003) report that in their studies about the use of MILE systems in teacher education, some pre-service teachers engage in reflective conversations about teaching only with tutor support. This finding from the MILE trials is contrary to what has been reported in the STEP project where it is reported that reflective and critical thinking among students occurred (Cohen, 1998; Lampert & Ball, 1990; Ball, 1988b; Fieman-Nemser & Buchmann, 1986). The lack of agreement shows that using multimedia systems in pre-service mathematics teacher education classes may not automatically get students to have reflective conversations. This suggests that in terms of the design of these multimedia systems, in-depth analyses of their structure (i.e., of the various versions being used) and their benefits need to be conducted to show which aspects of the designs can facilitate reflective and critical thinking among users before they are used in teacher education (Roblyer, 1999). Findings from such studies could be useful in not only supporting future multimedia system developments but also serve as general framework for future development of effective multimedia systems for pre-service mathematics teacher education.

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Next, is the type of constraints that could be described as *pedagogical* in nature. These are constraints that are related to the mode of introduction of the systems in pre-service mathematics teacher education courses. It is well documented that pre-service teachers come into the subject specific pedagogical courses with initial ideas derived from their long experience in schools as students. The problem with these initial ideas is that they have the potential to impact the knowledge of teaching that these students construct. The question that results from this is how best to combine the use of multimedia systems with what traditional pre-service teacher education models offer for optimal outcomes (Munby, Russell, & Martin (2001) have emphasized this need). The work with SLE for example, provides an example of such pedagogical constraints. Putnam and Borko (2000) had this to say about the empirical evidence available with work with SLE,

"after carefully examining the empirical evidence . . . [it can be seen that] the investigations sometimes reinforced beliefs that the students brought with them into the teacher education program . . . strong normative assumptions such as their notions about a "good" classroom environment or "helpful" teacher . . . framed the students' inquiry and were rarely challenged by doing the investigations. Rather, the collection and interpretation of records of practice simply reinforced the students' entering assumption" (p.11 of the online version).

This raises the question of how best to organize class sessions using multimedia systems to effectively challenge students' entry assumptions about mathematics teaching. The question is relevant especially because the use of multimedia systems in teacher education is relatively new; which means that several mathematics educators now available in various colleges of education are not used to how to integrate it effectively in their classes. Research is needed in this direction.

Another type of constraint is what I call *practical constraint*. This has to do with the reality of expertise available in colleges of education to effectively implement multimedia systems for the effects discussed earlier in this paper. There are mathematics teacher educators in colleges of education who do not have the right background and expertise with technology to automatically use them. Even if these teacher educators are willing to under professional development to make them capable the reality with technology is that it takes time and effort to learn and many people do not have the luxury of abundant free time for it (Sudzina, 1999). This is a practical constraint that needs to be addressed in education schools if multimedia usage is to go to scale.

Financial constraints are those relating the supply of technology needed to support multimedia infusion in education schools. The fact is that advancement in software and hardware development is occurring so rapidly that there is the need to plan not only for getting enough computers and the right software for necessary for multimedia infusion into pre-service mathematics teacher education. There is also the need to plan for sustainability financially. This constraint is even more pronounced in education schools in developing countries and those that have limited financial resources and could affect effective implementation if not well addressed.
Finally, there are *technical constraints* involving the need for colleges of education to provide technical support to keep computers running as well as improve the design of multimedia systems as new knowledge about them get developed.

ISSN 2054-6297(Print), ISSN 2054-6300(Online)

CONCLUSION

In conclusion, it can be said that multimedia systems have the potential of improving pre-service mathematics teacher education. In spite of this, multimedia systems should not become the only focus of instruction because they cannot completely replace all the traditional experiences (e.g. field experiences) students are exposed to (Hatfield, 1996). It is also necessary to consider, prior to how best to effectively introduce the use of multimedia systems into our teacher education programs. This could involve restructuring of content, rethinking of methodology and even the way pre-service teacher learning is assessed. Until these issues are considered objectively the benefits of multimedia systems may not be derived in our pre-service mathematics teacher education.

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