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## Mathematics Preservice Teachers' Beliefs and Conceptions of Appropriate Technology Use

PATRICK WACHIRA  
*Cleveland State University*  
*Cleveland, OH USA*  
p.wachira@csuohio.edu

JARED KEENGWE AND GRACE ONCHWARI  
*University of North Dakota*  
*Grand Forks, ND USA*  
jared.keengwe@und.edu  
grace.onchwari@und.edu

Many preservice teachers report having had little exposure on the use of technology in the teaching and learning of mathematics. Without guidance on the appropriate use of technology, prospective teachers are left to form their own beliefs about what is appropriate technology use. This study assessed preservice teacher beliefs and conceptions of appropriate use of technology in mathematics teaching and learning. Findings indicate that preservice teachers generally did not share the vision of appropriate use of technology in Mathematics (as provided in the National Council of Teachers of Mathematics [NCTM] Standards) to support and facilitate conceptual development, exploration, reasoning and problem solving. Preservice teachers' beliefs and conceptions of appropriate technology use were limited to the use of technology as computational tools and for checking accuracy of these computations. Evidence from this study suggests a lack of understanding of technology as powerful tools to help students gain knowledge, skills, and appreciation of mathematics.

Technology pervades the world outside school. It is now part of our culture and, outside school settings, students are undoubtedly required to use technology in diverse social and business environments. The rapid advancement and accessibility of technology have opened up literally worlds of possibilities for mathematics education. The availability of technology means that students no longer have the same need to perform procedures with large numbers or lengthy expressions that they might have had in the past without ready access to technology. In fact, 81% of the American states that require exit exams now allow calculators to be used on at least some test items (National Council of Teachers of Mathematics [NCTM], 2003a).

The NCTM (2000) recommended increased attention to curricula that genuinely embraces conceptual understanding, mathematical reasoning and problem solving, and that takes advantage of available technology resources and tools by incorporating appropriate technology in instructional objectives, lessons, and assessment of learning outcomes. Students can learn mathematics more deeply with the appropriate and responsible use of education technology. The No Child Left Behind Act (NCLB, 2001) emphasized the importance of leveraging the power of technology in all areas of K-12 education. For these goals to be attained, it is imperative that mathematics teachers possess the knowledge and skills to determine when and how their students can use these tools appropriately and effectively. Regrettably, few teachers are reported to integrate technology into their teaching (Cuban, 2001) to enhance student learning. Consequently, it is imperative that, with the advances in educational technology and its increasing availability in K-12 schools, colleges of education look critically at how technology is integrated into their teacher preparation programs.

### APPROPRIATE TECHNOLOGY USE

Appropriate use of technology is one in which technology is used to support and facilitate conceptual development, exploration, reasoning and problem solving (NCTM, 1998, 2000). Technology is a tool; a tool can not function alone, it must be used properly. According to NCTM, technology is essential in teaching and learning mathematics and enhances students' learning. Technology helps students extend the range and quality of their mathematical investigations and to encounter mathematical ideas in more realistic settings. In addition, the powerful capabilities of technology for computation, construction, and visual representation offer students access to mathematical

content and contexts that would otherwise be too complex for them to explore thus removing computational constraints. Technology provides students with opportunities to create and test conjectures as well as to work at higher levels of generalization or abstraction (NCTM, 2000). Calculators, computer software tools, and other technologies assist in the collection, recording, organization, and analysis of data. They also provide convenient, accurate, and dynamic drawing, graphing, and computational tools.

Walmsley (2003) defined an “appropriate” calculator activity as an activity in which a mathematics topic is investigated with aspects of the calculator and without using the calculator for basic operations or as a type of “crutch” for solving problems. Garofalo, Drier, Harper, Timmerman, and Shockey (2000) identified as appropriate use of technology, content specific activities in which preservice teachers are learning how to guide their students to use technologies such as spreadsheets, graphing calculators, dynamic geometry programs, and playable websites to explore mathematics concepts and use mathematics to solve problems in applied contexts.

Some of the technologies that can be incorporated into the teaching and learning of mathematics are online discussion boards and Java tools. Applets on the Internet can also allow students to interact with mathematics problems. Other technologies include dynamic software such as those used in geometry and data analysis that allow for interactivity, graphing calculators, handheld devices such as palm pilots that allow for real time data collection, analysis and representations, and some applications software such as spreadsheets that allow for data analysis.

## REVIEW OF THE LITERATURE

While there are a number of studies examining the integration of technology into teaching, few have specific focus on mathematics preservice teacher education and on the use of technology consistent with the guidelines set by NCTM. In a study to assess what beliefs preservice teachers held about the use of calculators—the beliefs about the use of calculators and the uses they foresee for their future students, Walen, Williams, and Garner (2003) reported that many of the preservice teachers viewed calculators largely as tools for speeding up arithmetic computations or for ascertaining the accuracy of those computations. A related study by Fleener (1995) reported

that teachers had similar beliefs about the motivational effects of calculators for mathematics instruction but had differing views on the cognitive benefits of calculators. Fleener reported that teachers believed that calculators should not be used until students have achieved conceptual mastery.

In a study to uncover how secondary preservice teachers' beliefs about teaching and learning influence their understanding of the role of the computer for teaching and learning, Mullen (2001) found that definition of computer literate teacher (as given by all the participants) lacked maturity as it was skill-based and reflected no understanding of a computer as a shaper, reflector, and transformer of knowledge and information. In a different study, teachers were reported to have increased confidence in their ability when they were taught not only about technologies but also how to integrate specific technologies in teaching (Pope, Hare, & Howard, 2002). The preservice teachers were taught by instructors who modeled the use of technology by using PowerPoint presentations, Internet lessons, multimedia, and word processing software.

Other studies have documented the lack of technology preparedness for preservice teachers (Albee, 2003; Gado, 2004; NCATE, 2001; Quinn, 1998). Gado noted that while the course descriptions of middle childhood education courses in many teacher preparation programs stress the extensive integration of technology, the processes and strategies of integrating technology are not clearly stated. The introductory technology course that preservice teachers are usually exposed to, prior to their practicum and methods courses, does not prepare them to effectively integrate technology into their teaching (Pope et al., 2002). A different study (Quinn, 1998) found that three-fourths of the respondents had reservations about using technology in mathematics classrooms. Quinn concluded that preservice teachers leave their mathematics methods course with a feeling that they need to learn more about the use of technological aids in the teaching of mathematics. Consequently, there is need to conduct studies related to preservice teachers' beliefs about technology when its use is modeled to develop and facilitate students' conceptual understanding in the context of exploration, reasoning, and problem solving.

## PURPOSE OF STUDY

While the use of technology has been found to be an effective means to produce growth in students' understanding of mathematics content (Cradler, McNabb, Freeman, 2002), research findings indicate that technology is not being used widely by classroom teachers (Huang & Waxman, 1996; Milou, 1999). What prevents teachers from implementing changes in classroom practices that incorporate the use of technology? An important reason for the limited technology usage in the classroom is the teachers' beliefs about the nature of mathematics and the goals of mathematics education which works against the full inclusion of technology (Fleener, 1995; Norton, McRobbie, & Cooper, 2000). Generally, the relationship between what teachers believe about mathematics and about teaching mathematics and the way they teach is very important (Thomson, 1992). In mathematics, for instance, Battista (1994) noted that when teachers possess beliefs that are totally inconsistent with those of the current reform movement these beliefs causes them to block their understanding and acceptance of the philosophy of the reform movement, thereby precluding the possibility of substantive curricular change.

Since many teachers report having little exposure on the use of technology in the learning of mathematics, it is expected that, future use of technology in mathematics classrooms will be based on their beliefs and past experiences. In addition, without appropriate discipline-specific training, many teachers may leave college not knowing how to appropriately use technology in their classrooms. This study sought to explore mathematics preservice teachers' beliefs and conceptions about "appropriate" use of technology and to compare these with recommendations of NCTM. The article seeks to provide further direction to the phrase "appropriate use of technology," a phrase that is constantly used but not well defined.

## RESEARCH QUESTION

This article reports on the initial phase of an ongoing study aimed at exploring how preservice teachers' beliefs about appropriate use of technology in mathematics evolve during a methods course instruction that brings technology to the forefront in an investigative and problem solving context. Prior to taking the methods course preservice teachers' preexisting beliefs

were assessed. These beliefs were compared for possible alignment with the NCTM recommendations about appropriate use of technology. In this article, the authors argue that preservice teachers do come to the methods class with existing beliefs on technology use that they may consider ‘appropriate’ based on their past and current experiences. The following question guided the study for this article:

What are preservice teachers’ preexisting beliefs and conceptions about “appropriate” technology use and how do these beliefs align with recommendations about appropriate technology use?

## METHODS AND PROCEDURES

### Research Design

A mixed method combining qualitative and quantitative elements was used (Creswell, 2002) to assess preservice teacher initial beliefs and conceptions about “appropriate” technology use.

### Participants

The participants in this study were 20 preservice middle school teachers enrolled in a large midwestern university’s undergraduate mathematics methods course. The methods course was chosen for this study because as noted by Ball (1990), it can be an intervention that changes preservice teachers’ knowledge, assumptions, and feelings about mathematics as well as beliefs concerning the role of the teacher in the classroom. The sample consisted of 15 female and 5 male students. The students were informed that participation in the study would not affect their grade in any way nor the instructor’s attitude towards them. In this initial phase of data collection, two researchers, the classroom instructor and his colleague, were involved in data collection over the course of the semester. A third researcher was involved as an outside consultant.

## Data Collection and Analysis

Data was drawn from the teachers' personal philosophies of teaching mathematics which they wrote at the beginning of the semester and was included in their teaching portfolio—a requirement for graduation. In their personal philosophy statement, the prospective teachers were asked to specifically address their beliefs about the use of technology in teaching and learning mathematics. The researchers' notes from classroom discussions on the use of technology provided additional qualitative data. Quantitative data, meant to clarify and enhance the qualitative data, was drawn from the teachers' responses to two questions designed to assess their past experiences with technology. These questions asked the teachers (a) to indicate their experiences with instructional technology use in mathematics, and (b) to provide compelling arguments for the use of technology in mathematics learning

Qualitative data was analyzed by thematic analysis, “a process for encoding qualitative information” (Boyatzis, 1998, p. vi). Each data source was analyzed independently by the researchers for patterns, which were coded inductively and sorted for emerging themes. Collected data was coded as belonging to one theme (category) only. The final two questions were examined using descriptive analysis methods. Triangulation was accomplished through the use of multiple data sources (philosophy statements, survey, and researchers' notes from classroom discussions), double-checking findings, and checking for relationships that converge. Triangulation was also conducted by cross checking and comparing findings among the three researchers. The themes were examined and compared with NCTM and others researchers' (Garofalo et al., 2000) recommendations for appropriate technology use.

## RESULTS

Two broad themes emerged from the qualitative data. These were (a) use of technology as a cognitive tool and, (b) the use of technology for affective reasons.

## Use of Technology as a Cognitive Tool

The teachers' personal philosophies and notes from classroom discussions revealed that many teachers believed that technology should only be used as a supplement—to reinforce concepts and procedures that have already been learned—after students have mastered the basic facts and thus have a mathematical understanding of what is happening “behind the scenes” when using technology. The teachers were concerned that students used technology, such as the calculator, for basic operations or as a type of “crutch” for solving problems. The teachers expressed fear that their students heavily relied on technology at the expense of learning basic facts.

To determine whether these beliefs were based on teachers' past experiences, we examined the quantitative data from which 15 out of the 20 teachers reported having used computers with software for practicing and reinforcing already learned math skills or the Internet for searching information in their schooling and practicum experiences. None of the teachers viewed technology as a tool that could be used to develop these same basic facts through exploration of numbers and operations patterns. Only five of the teachers stated that they had used calculator technology in their schooling.

On the use of technology as a cognitive tool, 15 teachers indicated that technology is beneficial for arithmetic computations or for checking answers to computations. From the qualitative data, Racha's comment reflects the beliefs of many of the other teachers: “...calculators should only be used to speed up the calculation process or to check answers. Calculators should not be used to introduce primary skills such as whole number operations.”

Sixteen teachers also stated that technology was a great representational tool. They indicated that technology was a great tool for visual learning; that technology could provide a variety of ways in which concepts and procedures could be presented for better understanding concepts thus accommodating diverse learners. Fifteen participants named calculators as the dominant tool that could be integrated into mathematics teaching and learning. Thirteen participants reported that computers were mainly used for presentations, drill and practice exercises, while the Internet was used for searching for information. Only one participant mentioned the use of dynamic or interactive software such as those used in geometry, yet this technology application is required to support sound mathematical curricular goals of exploration and investigative learning.

## Use of Technology for Affective Reasons

Many participants expressed the opinion that technology should be used for affective as well as for practical reasons. One participant pointed out: "...to leave computers and calculators behind would only hinder the ability of students to succeed in the real world..."

Quantitative data revealed that 16 participants reported that technology was appealing to students, and that students enjoyed learning with technology. They stated that students were motivated because they found technology fun to learn with. Five participants also believed that using technology was trendy in a digital world and that technology use in the classroom represented the real world of their students after graduation. Further, they believed that students who did not get the right exposure to modern technology use would suffer in the future workplaces that relied heavily on technology.

Table 1 shows how preservice teachers' responses aligned with recommendations from NCTM and others (Garofalo et al., 2000) about appropriate use of technology.

**Table 1**  
Alignment of Teachers' Responses About Appropriate Technology Use

Teachers responses	Recommendations for appropriate use of technology
Cognitive; <ul style="list-style-type: none"> <li>• Reinforcing concepts</li> <li>• Speedy Computation</li> <li>• Checking answers</li> <li>• Multiple representation—visual learning</li> </ul> Affective; <ul style="list-style-type: none"> <li>• Motivational tool—trendy, real life</li> </ul>	Cognitive; <ul style="list-style-type: none"> <li>• In depth exploration of patterns and concepts.</li> <li>• Investigate mathematical relationships</li> <li>• Make and test conjectures</li> <li>• Multiple representations</li> <li>• Used in context—encounter math in more realistic setting—collect real life data.</li> <li>• Provide convenient dynamic graphing and drawing</li> <li>• Convenient and speedy computation—remove computational constraints</li> <li>• Checking answers</li> </ul>

## DISCUSSION

According to the NCTM (2003b), technology should be used not only for ease of computation but to support and facilitate conceptual development, exploration, investigations, reasoning, and problem solving. Preservice teachers' beliefs about appropriate technology use was limited to using

technology as a motivational tool, for speeding up the computations, and for checking answers to those computations. While these beliefs held by the teachers are some of the ways that technology can be used, they are not sufficient to justify the use of technology. Mathematics activities facilitated by technology should support sound curricular goals and should not be developed merely because the technology is available.

The preservice teachers did not provide specific ways on how technology could be used to promote learning. None of the preservice teachers indicated that technology could be used to explore patterns, discover more about mathematics concepts or to investigate mathematical relationships, for instance. This suggests that the teachers lacked understanding on how technology could be used appropriately to develop concepts. Consequently, their beliefs and conceptions of appropriate technology use did not appear to be significantly aligned with NCTM and others (Garofalo et al., 2000) recommendations in which technology is used to facilitate meaningful learning.

The results from the quantitative data that assessed preservice experiences and benefits of technology use in mathematics classroom indicated that the teachers lacked appropriate and meaningful technology experiences both in the school and college which could lead to their beliefs about not using technology until students had mastered basic mathematics skills. Technology, when used appropriately, can help students to develop the basic mathematical facts. In addition, only one participant mentioned the use of dynamic or interactive software such as those used in geometry and data analysis, yet these technologies can support sound mathematical curricular goals of exploration and investigative learning.

The results of this study parallel findings of other studies (Fleener, 1995; Walen et al., 2003) about beliefs and conceptions of teachers regarding technology use for teaching mathematics. The participants in this study showed a limited understanding of technology as a powerful tool to help students gain a deeper understanding and appreciation of mathematical concepts and skills. The fear that students may over-rely on technology at the expense of learning basic facts suggest that the teachers did not view or understand how technology can be used appropriately to develop concepts without the danger of students over-relying on technological tools. Sandholtz, Ringstaff, and Dwyer (2000) argued that:

Teachers enter the profession with deeply held notions about how to conduct school—they teach as they were taught. If these beliefs are commonly held and help teachers negotiate the uncertainty of work in schools, no wonder teachers are reticent to adopt practices that have not stood the test of time. (p. 257)

## IMPLICATIONS FOR TEACHER EDUCATION

Findings from this study imply the importance of establishing consistent efforts by teacher education programs to assess and examine inherent teacher beliefs regarding the use of technology. This way, educators can help teachers reflect on their beliefs especially those that may hinder appropriate technology use. This section offers some recommendations on how this could be achieved.

To begin with, mathematics educators should provide direct instruction to preservice teachers on ways to integrate technology into their instructional practices. Such instruction will require that teachers be provided with conceptual frameworks for technology integration that emphasizes use of technology to support and facilitate instruction consistent with reform goals of exploration and investigative learning. Second, preservice teachers need to see the modeling of appropriate use of technology by faculty in an inquiry-based environment, in which they see how the technology enhances mathematics learning, thus challenging their existing beliefs.

Third, mathematics educators should provide discipline-specific instruction on the appropriate technology use that include specific ways to modify assessment such that the tool is not used a “crutch” rather as a tool for exploration and facilitate further understanding of the concepts. In addition, preservice teachers should be provided with the opportunities to develop and practice, with assistance, lessons that appropriately integrate technology, which can be practiced in their field placements. This will help teachers develop competence skills in appropriate technology use, without which it will be difficult for them to know how to create mathematics learning experiences that is consistent with the goals of exploration, problem solving, and sense-making facilitated by technology as envisioned by NCTM.

Finally, given the dynamic nature of technology, it is not enough to merely model the use of one technology. In addition, it is expected that preservice

teachers will shun the active use of technology in their course if they do not see the potential benefits of these tools. Therefore, educators should strive to build in preservice teachers, positive dispositions, and the willingness to experiment with appropriate technologies. Methods courses should strive to help preservice teachers develop attitudes they need to turn potentially useful tools into sound instructional practice. This way the technology integration process becomes self-sustaining. Further, there is need to provide the teachers with opportunities to reflect, modify, or change their existing beliefs.

### SUMMARY

This study contributes to the knowledge of preservice teacher beliefs and conceptions about appropriate technology use. Teachers' beliefs about the appropriate use of technology may depend on their past training and experiences with technology among other reasons. Prospective teachers in this study, for instance, may find it difficult to see the technology tools as anything more than a means by which mathematics can be performed more quickly and easily unless they are provided with meaningful experiences that model appropriate use of technology.

This is the initial part of an ongoing study—more research questions based on the recommendations above are being examined. With more data collection, it is expected that a better understanding of teachers' evolving beliefs after instruction in which they see model lessons that appropriately integrate technology and in which they are provided with opportunities to create technology-enhanced lessons, will emerge.

### References

- Albee, J.J. (2003). A study of preservice elementary teachers' technology skill preparedness and examples of how it can be increased. *Journal of Technology and Teacher Education, 11*(1), 53-71.
- Ball, D.L. (1990). The mathematical understandings that prospective teachers bring to teacher education. *Elementary School Journal, 90*, 449-466.
- Battista, M.T. (1994). Teacher beliefs and the reform movement in mathematics education. *Phi Delta Kappan, 75*(6), 462-470.

- Boyatzis, R.E. (1998). *Transforming qualitative information: Thematic analysis and code development*. Thousand Oaks, CA: Sage.
- Cradler, J., McNabb, M., & Freeman, M. (2002). How does technology influence student learning? *Learning and Leading with Technology*, 29(8), 46-49.
- Creswell, J.W. (2002). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research*. Upper Saddle River, NJ: Merrill Prentice Hall.
- Cuban, L. (2001). *Oversold and underused: Computers in the classroom*. Cambridge, MA: Harvard University Press.
- Fleener, M. (1995). A survey of mathematics teachers' attitudes about calculators: The impact of philosophical orientation. *Journal of Computers in Mathematics and Science Teaching*, 14(4), 481-498.
- Gado, I. (2004). *Developing inquiry-based instruction through handheld-based laboratories: preservice teachers' attitude and self-efficacy*. Final Report for Gado's Technology Grant. Cleveland, OH: Cleveland State University.
- Garofalo, J., Drier, H., Harper, S., Timmerman, M.A., & Shockey, T. (2000). Promoting appropriate uses of technology in mathematics teacher preparation. *Contemporary Issues in Technology and Teacher Education*, 1(1), 66-88.
- Huang, S.Y.L., & Waxman, H.C. (1996). Classroom observations of middle school students' technology use in mathematics. *School Science and Mathematics*, 96(10), 28-34.
- Milou, E. (1999). The graphing calculator: A survey of usage. *School Science and Mathematics*, 93(3), 133-140.
- Mullen, L. (2001). Beyond infusion: Preservice students' understandings about educational technologies for teaching and learning. *Journal of Technology and Teacher Education*, 9(3), 447-466.
- National Council for Accreditation of Teacher Education (2001). *Technology and the new professional teacher: Preparing for the 21<sup>st</sup> century classroom*. Washington DC: Author.
- National Council of Teachers of Mathematics. (1998). *Calculators and the education of youth. Position Statement*. Reston, VA: Author.
- National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics*. Reston, VA: Author.
- National Council of Teachers of Mathematics. (2003a). High schools exit exams across the nation. *NCTM News Bulletin* (p. 8). Reston, VA: Author.
- National Council of Teachers of Mathematics. (2003b). *Position statement on the use of technology in the learning and teaching of mathematics*. Retrieved December 10, 2006, from <http://www.nctm.org/about/content.aspx?id=14233>
- No Child Left Behind Act of 2001, Pub. L. No. 107-110, 115 Stat. 1425 (2002). Retrieved October 31, 2006, from <http://www.ed.gov/legislation/ESEA02/>

- Norton, S., McRobbie, C.J. & Cooper, T.J. (2000). Exploring secondary mathematics teachers' reasons for not using computer in their teaching: Five case studies. *Journal of Research on Technology in Education*, 33(1).
- Pope, M., Hare, D., & Howard, E. (2002). Technology integration: Closing the gap between what preservice teachers are taught and what they can do. *Journal of Technology in Teacher Education*, 10(2), 191-203.
- Quinn, R.J. (1998). Technology: Preservice teachers' beliefs and the influence of a mathematics methods course. *The Clearing House*, 71(6), 375-377.
- Sandholtz, J.H., Ringstaff, C., & Dwyer, D.C. (2000). The evolution of instruction in technology-rich classrooms. In R.D. Pea (Ed.), *Technology and learning*. San Francisco: Jossey-Bass.
- Thomson, A. (1992). Teachers' beliefs and conceptions: A synthesis of the research. In D.A. Grouws (Ed.), *Handbook of research in mathematics teaching and learning* (pp. 127-146). New York: Macmillan.
- Walen, S.B., Williams, S.R., & Garner, B.E. (2003). Preservice teachers learning mathematics using calculators: A failure to connect current and future practice. *Teaching and Teacher Education*, 19(4), 445-62.
- Walmsley, A.L. (2003). Integrating calculator technology in an elementary and middle school preservice teacher program: A personal journey. *Contemporary Issues in Technology and Teacher Education*, 3(2), 116-127.