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Science and Mathematics Teachers' Professional Use of Computer-Based Technologies

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This paper is a report on a formative evaluation study of science and mathematics teachers' perceived professional development needs to support their classroom and professional use of computer-based technology. Surveys and interviews provided data on perceived needs, how program activities could best address integrating technology into professional work and perceived outcomes. This study suggests that attaining success in increasing technology use by teachers is based on at least two considerations: (a) All aspects of technology use should center first on pedagogical concerns, rather than on attending to details of technology and (b) Teachers and staff should accept learning as a collaborative endeavor; staff guidance is necessary to facilitate all phases of learning, as teacher participants advance from novice inquirers toward becoming confident, autonomous users.
Keywords: *professional development, high school teachers, computers*

This paper is a report on a formative study of perceived professional development (PD) needs of mathematics and science teachers in their use of computer-based technologies. The PD program focused on content knowledge and pedagogy, and involved supporting teachers' classroom activities (in high-needs schools) and implementation of computer-based technologies. The researchers briefly review the literature surrounding issues that arose in this research, describe the PD program and methodologies used in the study, report results, and discuss their implications.

LITERATURE REVIEW

Technology often influences the mathematics that is taught, extends the range of problems accessible to students, and enhances students' learning (NCTM, 2000). A variety of technologies can be implemented in mathematics and science classrooms to enhance investigations and communications (NCTM, 2000; NRC, 1996). Fisher (1998) identified instructional technology as essential support for teaching that extends beyond building computational skills to building conceptual understanding. It can and should be used to support basic mathematical and scientific understandings and to hone intuition, as teachers focus on facilitating student decision making, reflection, reasoning, and problem solving.

Charischak (2000) identified two important domains of technological knowledge in

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mathematics teaching: (a) how to use technological resources and (b) how to create and use technology-based environments. Adams, Brower, Hill, and Marshall (2000) found that within middle- and high-school mathematics and science classes, using technology was identified by teacher participants as the third most effective instructional method, with hands-on and problem-solving activities as the two most effective teaching strategies; however, using technology was the instructional strategy least practiced by the same teachers. This suggests that teachers need support in learning to implement technology. Insufficient technology PD is a barrier to successful integration of technology into schools (Mann & Shafer, 1997). Wozney, Venkatesh and Abrami (2006) investigated computer technology practices and teacher attitudes, and concluded that computer use outside of teaching activities was the most salient predictor of classroom use; the most important factors in computer use were perceived value and success expectancy by teachers. According to the review of literature, the essential conditions for teachers to implement technology successfully included access, technical assistance, and support policies, in addition to PD, where teachers had steady access to technology staff that support technology use in classrooms (ISTE, 2000).

Technology-related training plays a critical role in developing teachers' competencies with computer applications (Gilmore, 1995). Appropriate and adequate PD is crucial for effective technology support for student learning (Heinecke, Blasi, Milman, & Washington, 1999; Sivin-Kachala & Bialo, 2000). PD must move beyond merely training teachers how to use hardware and software to establishing practices that are useful to support instruction (Judson, 2006). Longitudinal research examining teachers' technology uses shows that their needs evolve as they become better able to navigate and more proficient in integrating technology into their teaching; some teachers do not believe they have sufficient knowledge to be certain about what barriers they face (White, Ringstaff, & Kelley, 2002). Teachers should feel familiar with the technology before they effectively integrate it into their teaching (Coghlan, 2004; Dunlap, 2002). Ongoing support is especially crucial, given that technology changes so rapidly that teachers are often asked to keep up with and to integrate new ideas at break-neck speeds (Heinecke et al., 1999).

CONTEXT

In collaboration with tribal colleges and public school systems, a consortium of five universities in northwest U.S. established the *Center for Learning and Teaching in the West* (CLTW). Teacher PD programs were housed within each of three states where CLTW partner universities were located. Each state provided in-depth PD for mathematics and science teachers in identified high-need schools through a combination of on-site and distance education activities. This paper addresses only the joint PD program implemented by the two institutions located in the Rocky Mountain (RM) region, separated by only an hour's drive. The program focused on teachers from high-need schools in the Rocky Mountain area and adjoining Eastern Plains, including rural, urban, and suburban schools. During initial years of implementation, the PD program integrated

science, mathematics, and technology content, in addition to pedagogical and assessment techniques, into graduate courses for teacher participants. In most classrooms, equipment and manipulatives were used by these teachers; however, their use of instructional technology was minimal. Technology skill development became a focus, since participants were expected to participate in distance-education activities and deliver their classroom activities through web pages.

Orientation into the PD program consisted of consecutive one-week Summer Institutes for science teachers and mathematics teachers, respectively. The interactive institutes focused on academic content, inquiry-driven instruction, alternate assessment, diversity and equity issues, and technology-infused instruction. At that time, teachers checked out laptop computers if they could not access a computer at home or school to participate in year-long, on-line discussions and communicate with staff and their colleagues via email. Arrangements were made for home Internet access, personal email accounts, and web pages. Knowledge building occurred as the teachers interacted in the PD sessions and online.

During the academic year, teacher participants met in university classrooms for six Saturdays over the academic year. The Saturday sessions provided opportunities to investigate computer-based technology, while learning mathematics and science content and enhancing their pedagogical content knowledge (Shulman, 1986). These PD activities allowed participants to learn more about Microsoft Office tools, web page development, instructional content software, and navigating on-line course management tools. The goal of the PD technology component was to provide practicing teachers technical tools and skills that would support and sustain technology's implementation in classrooms.

AN INFORMAL EVALUATION

During fall semester of the program's second year, the researchers observed teachers' use of technology during activities and discussed with participants integration of technology in their teaching activities. It was quite apparent that teachers were neither completely comfortable with using computer-based technology nor how to use computer technology effectively for preparing lessons, integrating it into instruction, or for managerial tasks. Time was often identified as a need—time to become familiar with technology and its applications, to gain hands-on experience, and to collaborate and problem solve with colleagues. The anecdotal data collected by the researchers during PD interactions became the impetus to better understand the impact of PD upon computer-based technology classroom use. With this information, barriers that prevented them from maximizing teachers' use of computer technology in their classrooms were defined.

DESIGN & METHODS

Two pencil-paper surveys were administered in the Spring semester of the second academic year of PD, while teachers attended face-to-face sessions. The first survey was administered at the start of the January session; a second survey was given at

the close of the last academic-year PD session in April. That is, data gathering did not occur until after a full semester of PD work with teacher participants had been completed. The surveys sought this information: (a) what teachers wanted to learn regarding computer use, (b) what teachers knew and were comfortable using, (c) what barriers teachers saw that prevented them from maximizing use of computer-based technology in their classroom, (d) how and when teachers used computer technology in their preparations for teaching, (e) how teachers viewed their proficiency with technology, and, (f) how and when teachers used technology during instruction. Furthermore, to gain understanding of the extent of perceived effectiveness of the technology PD, this question was posed: *Overall, how do you view your proficiency (knowledge and skills) with technology in general?*

After data analysis from the first survey, telephone interviews were completed. These were conducted with three teachers who were randomly chosen from sub-groups emerging according to teacher participants' experiences with computer-based technology. In the analysis, the researchers used the pseudonyms "Pat," "Terry" and "Robbie." Pat had participated in the program for two years, initially starting as an inexperienced user of technology. Terry, considered a novice, had no prior experience working with technology. Robbie entered the technology PD program already successfully integrating technology into teaching.

As mentioned earlier, the second survey was administered at the end of the semester, in April. Additional questions were added to the original survey to determine the extent that technology PD activities developed new skills, especially regarding completion of their technology-oriented CLT-W course assignments. In particular, teachers estimated the level of skill acquisition as they used E-mail, Blackboard, web page development tools, Microsoft Office tools, supplementary curriculum software, and the Internet to locate web-based resources.

RESULTS

FIRST SURVEY RESULTS

Twenty-four teachers responded to the pre-semester survey. Table 1 summarizes first survey results related to the extent that teacher participants perceived that class size, administrative support, and access to resources (i.e., hardware, software, Internet, technology staff, and PD) created barriers to their effective implementation of technology. Lack of access to technology hardware, professional development, and technical assistance were primarily perceived as barriers to computer technology use.

Two-thirds of teachers, in response to the first survey, commented that lack of personal comfort was a moderate or important barrier to their use of technology. Thus, optional Saturday workshops focused on technology use and facilitated by the staff were added, at the suggestion of participants. This enabled teachers to choose and explore technical areas that they were unfamiliar with at that time. The teachers also requested more one-on-one and side-by-side time with staff to learn how to use laptops and Website-development software. Website development was one of their areas of concern, since this was a PD

requirement of course completion. As teachers gained knowledge and skill in developing their web sites, they became eager to design and add new, engaging web pages.

Table 1. *Teacher-Perceived Barriers to Their Use of Technology (n = 27)*

Barriers	% perceived as moderate or important
Access to software	89%
Access to technology in the classroom	74%
Access to PD on technology skills	74%
Access to PD on technology integration	74%
Access to technology support	70%
Access to computer labs	69%
Class size	66%
Administrative support	51%
Access to Internet	39%

Regarding what teachers wanted to learn, teachers indicated in the first survey that they wanted to become proficient with Web search tools, in addition to instructional software and Microsoft Office tools. Furthermore, many of these mathematics and science teachers expressed the desire to integrate Web-based resources found on the Web into their instruction. With this information, program staff aligned these items within CLT-W mathematics and science programs and workshop objectives. Subsequently, the staff devised technology-focused PD activities and held workshop sessions, such as *Searching the Web Effectively*, which provided teachers with strategies for classroom integration of these technologies. This information suggests a strong desire for technology PD when teachers reflect on reasons they do not use technology.

SECOND SURVEY RESULTS

In the second survey, teacher participants reflected on perceived barriers they noted in the first survey and described how and to what extent these perceived barriers and obstacles for using technology in their classrooms changed as a result of participating in PD activities. Twenty teacher participants responded to the post-semester survey. The outcome of participation in the technology PD yielded interesting comments ranging from, "I learned to experience technology without being afraid of results or lack of results" to "I am not a computer person but I feel like I can now get information off the Web and use it to help my class." Their comments implied that attitudinal changes were positive and that participants were motivated to continue using technology and to seek further PD.

Table 2, responses to a multiple-choice item on the second survey, shows the percent of teachers who reported acquiring new skills due to the technology PD activities. They reported becoming more proficient with using E-mail and Word, and in navigating with the distance-learning tool, Blackboard. Furthermore, teacher participants reported that they were able to develop Web pages, locate teaching resources on the Web, and effectively use supplementary curriculum software. Fewer teachers perceived an increase in their skills regarding the graphical presentation tool, PowerPoint, and the spreadsheet tool, Excel. These data suggest that by listening and responding to teacher participants' perceived needs and beliefs, technical support provided teachers appropriate experiences to gain proficiency

with computer-based technologies, specifically in areas of their interest.

Table 2. *Teachers' Self-Reported Skills Acquisition (n = 20)*

Skills Regarding . . .	Some New Skills Reported	No New Skills Reported	No Response
Web Page Development	100%	-	-
Find Teaching Resources on Web	85%	10%	5%
Navigate Blackboard	85%	10%	5%
Instructional Software	70%	20%	10%
Word	40%	25%	35%
E-mail	40%	35%	25%
Excel	20%	30%	50%
PowerPoint	15%	45%	40%

Comparison Of Survey Results

To document perceived teacher changes, pre-semester survey results were compared to post-semester survey results. In their initial survey, teachers typically reported that the "biggest problem is that 99% of my students use no technology in the home and my class is their first academic exposure" and "I want to learn more in a 'safe' environment." By contrast, post-semester comments focused more positively on their own learning and, consequently, enabled them to support their students' learning in a technological environment. Teachers typically noted that "Students need a technology background. I need to be a resource for them" and that "I know I need to keep learning." Forty-five percent of teachers offered comments similar to these: "CLT-W has helped me fill in a few blanks on Web page design" so that "I love incorporating technology and really would like to learn more."

Table 3. *Self-Reported View of Teachers' Technology Proficiency (n = 20)*

Response Selected	Pre-Semester Survey	Post-Semester Survey
Sufficient for my work as a teacher.	8	12
Ok, but I'd like to learn more.	6	4
Not really as good as I would like.	6	4

According to the results in Table 3 of the multiple-choice question, *Overall, how do you view your proficiency (knowledge and skills) with technology in general?*, the proportion of teachers who perceived their *technology proficiency was sufficient* increased by 50%. That is, 8 of 20 teachers regarded their technology proficiency as sufficient on the pre-semester survey, while, on the post-semester survey, 12 of 20 teachers reported that their technology proficiency was sufficient. Among the 12 teachers, all 8 teachers who expressed pre-proficiency *still* expressed proficiency or better at the end, and the remaining 4 came to that expressed view for the post-semester survey. Additionally, one teacher reported improvement to perceive proficiency as "OK." The remaining teachers reported the same level of proficiency in the post-semester survey as they reported in the pre-semester survey. Throughout the PD program, staff offered technical support and facilitated communications between teachers and technical-support personnel, with the goal of enhancing sustainability. The teacher participants reported that they became more proficient with interactions associated with the

Web, in addition to integrating supplementary curriculum software in their teaching.

INTERVIEW RESULTS

Interview questions sought to identify teacher perspectives regarding their confidence in their use of technology in teaching. The teachers were asked, *with regard to computer-based technology, do you feel you have the knowledge and skills necessary for your work? If no, what knowledge do you need and why do you need it? During PD thus far, what new knowledge and skills have you acquired? How have you used them?* In addition to those queries, Pat was asked to *compare your experiences during the first and second years with regard to: (1) technology support and professional development and (2) your growth.*

Pat had enrolled in the second year of the technology PD component, excited to continue work with technology, and soon started to develop strategies to incorporate PowerPoint slides in instruction. Terry had collected Websites over the previous year and continued to use the Web for planning and locating needed information. Terry also entered the PD program possessing minimal experience with technology, at both personal and professional levels. By contrast, Robbie began the PD with prior technology skills and a knowledge base to become an independent learner.

After a full academic year of PD participation, Terry gained sufficient knowledge of technology to develop Web pages conveying classroom information for students, parents, and colleagues. Terry commented that

> "Well . . . actually I would like to use this web page as kind of a portfolio, but my goal was for parents and different things like that; even putting my background and qualifications on there and for kids developing different fun math web pages and so I hope to use it quite a bit. I have been actually cranking it out this past week."

Pat noted that it had taken two years of participation in the PD program to finally "get it" and feel comfortable with how to begin using technology effectively in the classroom. Pat said that

> "[In] the first [year of PD], my web page never really did get anywhere or turned out very good, but I think it was that I had it again and I had already had some background, so I built on that background. I needed both [years] to get it done."

Robbie, felt less adequate in understanding how to maximize technology use, given needed knowledge and skills become more challenging.

> "I actually do a lot with the little knowledge that I do have but I have always felt that I am really pretty far behind the eight ball as far as my own personal skills [sic]. I have taken some of the district offerings and some of the basic classes but I don't feel like I have a real good command for them. I mean I know how to use it, but I don't have real good skill—for example, in Excel in creating graphs and how to instruct kids how to make graphs, and charts, a lot of things that could be really useful in science. I don't have real good background in some of the programs; that could be more useful."

The two teachers' perceptions share a common element—they recognized that numerous hands-on PD workshop opportunities to

investigate computer-based technologies had supported their progress regarding implementation and professional use.

DISCUSSION

Based on post-semester results of self-Based on post-semester results of self-reported growth in teachers' proficiencies with technology use, the researchers are confident that teachers built a solid foundation to consider alternate ways to integrate technology into their classrooms. According to survey results and participant interviews, teacher participants reported that they had acquired important Blackboard navigation and Web-page development skills. Teachers' use of these skills was demonstrated through their on-line discussions and their development and presentation of Web pages that conveyed how they implemented technology-based content and pedagogical activities into their classrooms.

Given the results of this study, secondary mathematics and science teachers, regardless of their level of initial technological skills, generally struggle with integrating technology into their instruction. Thus, PD must support teachers in developing an orientation toward technological tools and then assist them in transitioning from a personal-use perspective toward managerial use of technological tools to enhance their teaching (Manoucherhri, 1999).

The researchers found that teachers need to feel comfortable with their personal use of technology before they can successfully integrate it into their classrooms; conversely, having technologically competent teachers does not guarantee they will invite their students to use it (Nelson, Kosiak, Ericson, Gerretson, Farmer, Reinsvold, Chambers, & Rectanus, 2004). Nor does technological competence guarantee that teachers can address/surmount local barriers (i.e. access to classroom technology tools and awareness of creative ways to use limited resources). Further attempts to support technology integration must address such issues. To support educators on overcoming the challenge of access, a year-long lending program of multimedia laptop computers to ensure continuous classroom use was awarded through a competitive process and became an integral part of sustaining the efforts of this PD program.

A remarkable outgrowth of the implemented PD was noted during the third Summer Institute, as the previous (second-year) teacher cohort interacted with the incoming (third-year) teacher cohort. The encouragement conveyed to new participants by those completing the previous PD year helped allay incoming teachers' fears and apprehensions toward considering and using technology. This was particularly evident when new (third-year) teacher participants learned that they were expected to design and create Web pages. Most of the incoming cohort was overwhelmed by that expectation. However, experienced PD participants eased these concerns by affirming that the PD needs survey would gather their expressed concerns and subsequently inform the design and delivery of appropriate PD activities.

Flores, Knaupp, Middleton, and Staley (2002) posit that science and mathematics teachers should have PD experiences similar to those expected of them, related to both content and how students learn science and mathematics, especially in light of integrating

technology. "Perceived needs" evolved as teachers advanced from "How do I begin?" to "I want to build a better Web page," while others progressed to "I want to learn more about the use of Palms and Probes." This study suggests that attaining success in increasing teachers' technology use is based on at least two considerations: (a) all aspects of technology use should center first on pedagogical concerns rather than on attending to details of technology. As someone once wryly observed, "Thinking about *computers in education* means initially thinking about *education* rather than thinking about *computers*." (b) Teachers and staff should accept learning as a collaborative endeavor; staff guidance is necessary to facilitate all phases of learning, as teacher participants advance from novice inquirers toward becoming confident, autonomous users.

REFERENCES

Adams, K., Brower, S., Hill, D., & Marshall, I. (2000). *The components of an effective mathematics and science middle school: Standards, teaching practices and professional development.* (Report). Kingsville, TX: South Texas Research and Development Center. ERIC Document Reproduction Service No. ED449 342.

Charischak, I. (2000). A look at technology's role in professional development of mathematics teachers at the middle school level. *School Science and Mathematics, 100*(7), 349-354.

Coghlan, B. (2004). Addressing the barriers to technology integration: A case study of a rural school. Unpublished doctoral dissertation, Mississippi State University, Mississippi State, MS.

Dunlap, C. (2002). Effective technology Integration: A plan for professional development. Unpublished master's thesis, Cedarville University, Cedarville, OH.

Fisher, A. (1998). Fragile future. *Popular Science, 235*(6), 92-98. Retrieved on February 15, 2005, from http://www.youngstown.k12.oh.us/chaney/teachers/neff/Mag_Art/Fragile.htm.

Flores, A., Knaupp, J., Middleton, J., & Staley, F. (2002). Integration of technology, science, and mathematics in the middle grades: A teacher preparation program [Electronic version]. *Contemporary Issues in Technology and Teacher Education*, *2*(1).

Gilmore, A. (1995). Turning teachers on to computers: Evaluation of a teacher development program. *Journal of Research on Computing in Education. 27*(3), 251-269.

Heinecke, W., Blasi, L., Milman, N., & Washington, L. (1999). New directions in the evolution of the effectiveness of educational technology. The Secretary's Conference on Educational Technology. Retrieved on February 16, 2006, from http://www.ed.gov/rschstat/eval/tech/techconf99/whitepapers/paper8.html.

International Society for Technology in Education (ISTE). (2000). *National educational technology standards for teachers.* Eugene, OR: ISTE.

Judson, E. (2006). How teachers integrate technology and their beliefs about learning: Is there a connection? *Journal of Technology and Teacher Education, 14*(3), 581-597.

Mann, D., & Shafer, E. (1997, July). Technology and achievement. *The American School Board Journal*. Retrieved on February 15, 2006, from http://www.asbj.com/199707/asbj0797.html.

Manoucherhri, A. (1999). Computers and school mathematics reform: Implications for mathematics teacher education. *Journal of Computers in Mathematics and Science Teaching, 18*(1), 31-48.

National Council of Teachers of Mathematics (NCTM). (2000). *Principles and standards for school mathematics.* Reston, VA: NCTM.

National Research Council (NRC). (1996). *National science education standards*. Washington, DC: National Academy Press.

Nelson, K., J. Kosiak, D. Ericson, H. Gerretson, J. Farmer, L. Reinsvold, R. Chambers, & C. Rectanus. (2004, April). Improving student achievement in mathematics in low-income, high-minority schools through teacher learning and access to computer technology. Research Presession to the NCTM Annual Meeting. Philadelphia.

Shulman, L.S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4-14.

Sivin-Kachala, J., & Bialo, E. (2000). *2000 Research report on the effectiveness of technology in schools* (7th Ed.). Washington, DC: Software and Industry Information Association.

White, N., Ringstaff, C., & Kelley, L. (2002). Getting the most from technology in schools. Retrieved on January 20, 2006, from http://www.wested.org/online_pubs/kn-02-01.pdf.

Wozney, L., Venkatesh, V., & Abrami, P. (2006). Implementing computer technologies: Teachers' perceptions and practices. *Journal of Technology and Teacher Education. 14*(1), 173-207.

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