Technology Learning Principles for Preservice and In-service Teacher Education

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Abstract

This essay presents a vision for technology integration in teacher education that develops teachers into "technology integrationists," or teachers who thoughtfully choose to integrate technology when it supports students' subject matter learning. Four principles guide the design of technology learning experiences for preservice and in-service teachers to increase the likelihood that they will become technology integrationists. The principles are (a) connecting technology learning to professional knowledge; (b) privileging subject matter and pedagogical content connections; (c) using technology learning to challenge professional knowledge; and (d) teaching many technologies. The advantages and limitations of using these principles with preservice and in-service teachers are discussed. Future innovations in technology learning approaches in teacher education are outlined.

In the last decade, K-12 schools have begun to accumulate sufficient resources to enable technology-supported teaching and learning. For example, in the United States, the ratio of nine students per instructional computer in K-12 schools reported in 1997 (CEO Forum, 1997) has been reduced to 4.2 students per instructional computer in 2002 (Skinner, 2002). As the public desires and supports technology instruction in schools (Starkweather, 2002), many K-12 schools currently promote the use of technology (e.g., computers, software, and peripherals) in teaching and learning. Toward achieving that goal, professional development targeting the mastery of technology, such as opportunities to learn new computer programs or technological devices, is offered to teachers and staff in schools. In addition, most schools/colleges/departments of education (SCDE) now offer educational technology courses within the teacher preparation program to prepare future teachers and to renew in-service teachers. Despite the availability of resources and increased emphasis on the use of technology, many teachers, whether preservice (Doering, Hughes, & Huffman, 2003; Willis & Sujo de Montes, 2002), novice (Web-Based Education Commission, 2000) or experienced (National Center for Education Statistics, 2000), currently feel ill-prepared to use technological tools and resources for the teaching of content.

Two factors may be contributing to preservice, novice, and veteran teachers' struggles with integrating technology into their teaching in innovative and effective ways. First, school leaders call for technology integration without actually defining their vision for integration (Perry & Aregaldo, 2001). Likewise, many SCDEs do not possess a clear vision of technology integration within their own institution or for K-12 schools (Mehlinger & Powers, 2002). Second, opportunities to learn technology (i.e., initial licensure course, graduate courses, school-based inservices) are developed without a theoretical framework to guide the nature of technology integration into teacher learning. Teachers' learning opportunities, in turn, are predominantly skill-based when schools offer short-term technology skill workshops (McKenzie, 2001; Zhao, Pugh, & Sheldon, 2002) and SCDEs offer a single course in information technology (Moursund & Bielefeldt, 1999), and this implementation of short-term skill training is not increasing the effectiveness of technology-supported content area teaching, a goal in our nation (Riley, Holleman, & Roberts, 2000). A more coordinated vision for technology integration and productive learning principles may provide needed guidance for both preservice and in-service technology education. This article aims to meet this goal by presenting a foundational vision for technology integration and four guiding principles for technology learning.

Vision for Technology Integration

A focus on technology skill development in technology training initiatives (e.g., McKenzie, 2001; Solmon, 1999) lacks an overall vision for what teachers will do with these technologies once they are learned. A more productive goal may be to develop teachers into "technology integrationists," a term I used in this paper to describe teachers possessing the unique ability to understand, consider, and choose to use technologies *only* when they uniquely enhance the curriculum, instruction, and students' learning – a position that empowers appropriate technology decision-making in schools (Bradshaw, 2002a). Teachers who are technology integrationists are not necessarily "techies" nor have they necessarily taken many formal courses about computers, computer science, or technology. What distinguishes teachers who are technology integrationists is their ability to interpret new technology concepts through their professional knowledge – the knowledge that both consciously and subconsciously directs their daily teaching activities. Most notably, technology integrationists use their general pedagogical knowledge, subject matter knowledge, and pedagogical c ontent knowledge (Shulman, 1987) to identify promising, innovative ways technologies may be used to teach their subject area discipline to K-12 students (Drier, 2001; Dun, Feldman, & Rearick, 2000; Hughes, in press; Margerum-Leys & Marx, 2002).

Descriptive portrayals of technology integrationists' accomplishments in the classroom reveal innovative and creative uses of technology that enable students to learn subject matter more deeply and with more curiosity than without the technology. Chen and Armstrong (2002) described a myriad of project-based learning activities in which teachers used technologies to engage students as scientists in collecting data on stars for NASA, as explorers in wide-ranging expeditions around the world, as writers publishing poems or even literary magazines, and in a range of other innovative roles engaging in relevant projects. Mills (2003) described how she used calculator-based laboratory and calculator-based ranger for students to "gather, investigate, and make deductions about the physical evidence," as well as graphing devices and handhelds during a mock trial in her secondary -level Crime and Justice class. Portrayals such as these demonstrate that technology integrationists exist and that technology is being used in subject matter learning, yet the process through which teachers learn to accomplish and sustain these practices is less clear.

To facilitate teacher learning, research indicates that teachers need to reflect on their own beliefs (Borko & Putnam, 1995, 1996; Bransfo rd & Schwartz, 1999), have access to alternative practices and beliefs that are reflective of their subject and grade level and observe the positive impact these practices have on students' learning (Richardson & Placier, 2001; Sandholtz, Ringstaff, & Dwyer, 1997), yet these activities cannot be accomplished within the limited time constraints of short-term learning experiences (McKenzie, 2001; Moursund & Bielefeldt, 1999). Recently a shift toward content-based technology preparation has begun to occur in preservice preparation (e.g., Niess, 2001) and in-service education, (e.g., Crohen, 2001), and there is evidence that school districts are moving away from the short-term approach and building in long-term, ongoing professional development (Bradshaw, 2002b). However, it is unclear how widespread these trends are, as well as to what extent the ongoing activities target teacher reflection, observation, and experimentation. This paper offers a set of guiding principles that can be considered when evaluating, constructing, or redeveloping technology learning opportunities at the preservice and in-service levels that, if implemented strategically, may facilitate teacher reflection, observation, and experimentation and, ultimately, develop teachers into technology integrationists.

Principles for Technology Learning

In this section, four technology learning principles, grounded in emergent empirical and theoretical literature related to in-service and preservice technology professional development, are described. Ex tensive examples from literature are used to illustrate each principle and to discuss how the principle's transformation into practice impacts different teacher-learners. Other teacher educators have enumerated technology principles for preservice education that vary according to subject matter, including English language arts (Pope & Golub, 2000), science (Flick & Bell, 2000), mathematics (Garofalo, Drier, Harper, Timmerman, & Shockey, 2000) and social studies (Mason et al., 2000). An important contributio n to the field, the principles set forth in this collection of articles provided subject-specific, conceptual frameworks for teacher educators interested in creating "technology -based activities" (Garofalo et al., 2000) or "technology infusion" (Pope & Golub, 2000) in preservice education. This current article extends and strengthens this past work by identifying principles that apply across subject matter and teacher experience (preservice/in-service) and, most important, establishing the notion that imple mentation of these principles hold unique advantages and limitations for certain populations of preservice and in-service teachers.

Principle 1: Connect Technology Learning to Professional Knowledge

Technology learning should be closely connected to teachers' professional knowledge, that which directs their professional activities. The explicitness of the connection cannot be understated, for it is crucial in enabling teachers to understand conceptually the potential for technology in their daily professional lives. A contemporary perspective emphasizes the need for teachers to learn about technology "in context," that is, in the context of their subject matter and pedagogy, as opposed to a decontextualized technology tool. Instructional technologists (e.g., Molebash, 2002; Shoffner, Dias, & Thomas, 2001), as well as subject specific methods instructors (e.g., Flick & Bell, 2000; Flores, Knaupp, Middleton, & Staley, 2002; Garofalo et al., 2000; Jacobsen, Clifford, & Friesen, 2002; Mason et al., 2000; Pope & Golub, 2000), concur on this perspective. Based on research described in Hughes, 2003, there are two ways for teachers to develop and understand these connections. They include (a) a scaffolded connection occurring when another person (such as an instructor, in-service facilitator, or curriculum coordinator) offers preliminary connections for teacher-learners and (b) a self-identified

connection occurring when a teacher independently identifies the technology-teaching connection through reflection and learning.

Scaffolded Connections. In learning situations, an instructor may make explicit connections between technologies and professional knowledge as technologies, methods, or subject matter topics are introduced. When such connections are made during learning activities, teachers may place the technology learned in the context of their professional knowledge. For example, in the context of learning writers workshop method, teachers can simultaneously learn technological tools and strategies that support such an approach to writing, such as portable writing hardware like AlphaSmarts or handheld PDAs, word processing software, or software features like tracking changes (Microsoft Word). Due to the immediacy and explicitness of the connection, the teacher may categorize and connect these technologies with concepts like writing instruction and writers workshop method – concepts likely to be part of an English teacher's pedagogical content knowledge.

Likewise, teachers may experience learning that explicitly connects technologies with subject matter or general pedagogy. For example, in a rhetoric course, a teacher learns about hypertext and writes hypertexts through HTML-authored webpages. This teacher categorizes the notion of "hypertext" as a potential new subject matter to be taught in her English courses. On the other hand, a teacher may learn about alternative assessments as a general pedagogical strategy to be used across subject areas. The handheld PDAs and assessment software may be demonstrated as flexible tools that can be adopted by teachers to facilitate the use of alternative assessments in their classes.

In the research literature, there are other examples of these types of scaffolded connections. Garofalo et al. (2000) and Flores et al. (2002) described scaffolded mathematics content learning, in which preservice teachers were assigned mathematics problems to solve using technologies such as parametric graphing with graphing calculators or exploring Pythagorean theorem using The Geometer's SketchPad. In addition, Henriques (2002) acknowledged this type of scaffolded connection in her science methods course when stating, "The examples I give employ technology as a means of teaching pedagogical knowledge and pedagogical content knowledge." Wiske (2001) described an online environment and tools that supported practicing teachers' "talking about subject matter and learning," as well as exploring, developing, and discussing technology-supported lessons in a collaborative environment. The environment, resources, and guided workshops used a Teaching for Understanding framework to guide teachers' examination and to develop technology-supported curriculum. It is crucial that the instructor or facilitator of the learning – whether an educational technologist, a methods expert, or subject area instructor – use technology only when it supports subject matter content and instruction – thus, emphasizing technology's connection to the professional knowledge of teachers.

Self-Identified Connections. Certainly teachers are not reliant on instructors or facilitators to identify all or the only possible uses for technology. Frequently, teachers identify for themselves the ways technology can serve their professional activities. A very natural path to self-identified connections between technology and professional knowledge emerges when teachers have identified a problem-of-practice within their teaching or their students' learning (Hiebert, Gallimore, & Stigler, 2002). A problem-of-practice, as such, is identified when teachers possess depth of knowledge about teaching and learning and also have time to reflect and consider their teaching practice. As teachers participate in learning opportunities, they may discover a technology that may offer possible solutions for their identified educational problem-of-practice. The technology can become conceptually associated with the unique nature of the problem – related to subject matter, pedagogy, or pedagogical content methods. For example, a

teacher was interested in placing current events as a more prominent theme throughout his humanities curriculum. Yet, his students needed adequate access to current event periodicals to enable this focused change in his curriculum. When full-text articles became available through CD-ROM and online databases, this teacher initiated his own learning of these technologies in order to fulfill the subject matter and pedagogical changes in the classroom.

Jacobsen et al. (2002) described preservice teachers engaging in self-identified technology connections in a redeveloped initial licensure program. This unique preservice opportunity situated learning in "professional seminars [that] offer students an opportunity to reflect critically on themselves as teachers-in-the-making, to pursue topics and skills of particular interest, and to engage in the many debates that surround the nature of education and teaching." They used "digitally rich, inquiry-based learning environments on campus and in their field placements" to support preservice teachers' development of thinking and teaching with technologies. Similarly, Hunter (2001) described Team Action Projects (TAP), a process for innovative practices and professional development for in-service teachers that "legitimizes the creative work of the teachers, drawing upon their knowledge and insights about their students' needs and potential" (p. 490). Working in small teacher groups, an innovation or student learning issue was identified, such as writing conferences or project-based learning, after which the teachers identified technology tools that could support their innovations.

Advantages. Explicitly making connections between technology and professional knowledge enables teachers to conceptualize technology's role in education in ways that potentially will make the biggest impact on students' learning. A significant advantage lies in offering teachers preliminary ideas concerning the connection between technology and their daily teaching responsibilities. These preliminary ideas offer a way for teachers to conceptualize the role for technology in education. These connections offer at least one way they could imagine using the technology, if not immediately, at some future time. It was this principle in action when Garofalo et al. (2000) decided to introduce graphing calculator features in the context of mathematics use, and they discovered that through this approach, preservice teachers could "see its direct applicability and usefulness." In learning situations without such connections, the responsibility falls to the teacher learners to develop such connections. This can be a formidable task especially for preservice or novice teachers who have less experience and, thus, less professional knowledge with which to understand technology's potential roles. Some experienced teachers, unless they are intrinsically interested in a technology or already have identified a problem of practice, may not be willing or able to spend additional time to identify ways to use the technology unless they have a starting point, as scaffolded connections provide.

Yet, when teachers self-identify the potential benefits technology offers to their professional responsibilities, informed decision-making concerning technology integration might occur more easily. Indeed, Jacobson et al. (2002) found that

> They [preservice teachers] moved beyond being mere proponents of ICT usage, or already-hardened skeptics, and became thoughtful professionals who choose tools appropriate for the tasks they needed to accomplish. Students developed an informed personal position on ICT use in education and articulated and defended that position with each other.

These students developed personal visions, the ability to explain and defend their vision, and experience in choosing and using technologies in line with their vision, all of which provides the foundation of technology integrationists. The teachers in the TAP groups (Hunter, 2001), uplifted by "the living innovation, invented by the teachers" (p. 490),

accomplished technology-supported innovations when school conditions for change were less than ideal.

Limitations. The major limitation to this principle's success is the teacher's professional knowledge base. When offering scaffolded connections, the instructor or facilitator should choose ideas that match the professional maturity level of the participants. The connections need to be understood by the participants. If a group of preservice teachers begin learning about technology prior to taking methods courses or subject-specific courses, the instructor may need to spend much more time describing the subject matter or pedagogical aspects in order for the preservice teachers to truly understand the educational concepts with which the technology connects.

At the same time, this strategy's scaffolding also may hinder teachers' abilities to independently develop connections between technology and their professional knowledge. The scaffold is not meant to serve as a permanent crutch; therefore, guidance and opportunity to reflect and self-identify these connections should be encouraged during learning experiences.

Doering et al. (2003) examined how preservice teachers who received scaffolded connections like these throughout their teacher preparation program envisioned the use of technology within their future classrooms. Three interviews during their licensure program indicated a shift in participants' perspectives about technology in education from skepticism to an awareness of its assistance in student learning. However, when asked for examples of integrating technology in education, the students repeated the examples (the scaffold) provided in their classes. After the student teaching experience, only one participant was able to generate a new technology integration idea. Preservice teachers need to be enabled to identify connections as they leave initial licensure programs and enter the teaching profession, much like what Jacobsen et al. (2002) accomplished. To accomplish this, a program might build a field-based activity in which preservice teachers either (a) identify how technologies they have learned in coursework might serve specific educational aims in the field context or (b) identify specific educational goals that can be supported by new technologies they have learned about in the field. Given the rate of technological innovation, these novice teachers will need the experience to self-identify connections as they learn new technologies.

Experienced teachers may also be susceptible to a lack of facility to self-identify connections after learning experiences. Due to time constraints, practicing teachers may rely on the connections offered during in-service or by colleagues as their main source of ideas for using technology. Again, due to innovation, practicing teachers also need the experience of identifying connections for themselves. Alternatively, experienced teachers may feel limited, constrained, or distracted by the scaffolded connections presented in learning situations. Experienced teachers' diversity of experience and knowledge situates them to interpret and reflect on technologies in ways that novice teachers may not be able to do. Scaffolded connections are still an important aspect of the learning experience in order to provide a foundation, but the instructors or facilitators should encourage all teachers to identify connections between a technology and their own professional knowledge.

Principle 2: Privilege Subject Matter and Pedagogical Content Connections

Technology will have limited impact on education, as Cuban (2001) described in cases at the primary, high school, and collegiate levels, unless technology plays a role in students' subject matter learning. To achieve integration into subject matter learning, the "context"

must involve specific connections between technology and subject matter and/or pedagogical content knowledge.

Teachers know a lot about how technology can support general pedagogy. For example, they may use grading programs that allow students and parents access to up-to-date information; they use PowerPoint or other presentatio n tools to provide visual supports for lectures; they use word processors to write tests or create handouts. Pedagogical uses of technology have been well-established because general pedagogical knowledge is accessible to preservice, novice, and practicing teachers. Therefore, in learning experiences that cluster diverse teachers together, the only common knowledge shared by these teachers is general pedagogy. Thus, technologies taught have been connected with general pedagogical knowledge, and subsequent pedagogical technology use has not dramatically changed our schools (Cuban, 2001). However, Hargrave and Hsu (2000) noted a shift in instructional technology courses that focus less on the general pedagogy like teacher productivity and more on curriculum integration and content emphasis. Subject-specific, preservice principles also illustrate this shift. Mason et al. (2000) connected technology with development of citizens in democratic societies; Pope and Golub (2000) promoted technology as a literacy tool; Garofalo et al. (2000) and Flick and Bell (2000), respectively, focused on worthwhile mathematics and science in their technology use principles.

Teachers know much less about how technology can support subject matter learning and instruction of students in learning subject matter (pedagogical content knowledge). Yet, it is this kind of activity that will potentially strengthen educational technology uses in schools. Therefore, connections between technology and subject matter and pedagogical content knowledge must be prioritized and privileged during learning experiences for teachers, which requires focused discussion of subject matter and instructional approaches to teaching that subject matter. As Harper, Schirack, Stohl, and Garofalo (2001) demonstrated, even teachers who possess depth in their mathematics content knowledge may lack conceptual knowledge of some mathematical topics, and learning these topics with technology may lead to many "ah ha!" moments. Further, they noted that these moments facilitate opportunities to discuss and contrast different teaching and learning methods.

Browning and Klespis (2000) emphasized that preservice teachers may need more than simulated technology -supported K-12 content and instruction. They explained that "activities that are designed for *their* level of understanding, present *new* mathematics, and are facilitated by the use of technology in their *initial* constructions" (emphasis in original) may enable preservice teachers to determine technology's role in their own personal learning. Warburton and Campbell (2001) similarly leveraged integrated language arts-technology activities that "focused on the student teachers' own appreciation and understanding of poetry, and the possibilities offered by computer technology to provide a medium for the expression of poetic sentiments" (p. 588). Subject matter focused technology learning experiences such as these may be crucial, for many practicing and some preservice teachers have not personally experienced technology -supported content learning during precollegiate and collegiate schooling. Understanding the roles that technology plays in their own learning may provide a useful backdrop for understanding technology's potential role for their own students' learning.

Advantages. Privileging subject matter and pedagogical content connections is essential during initial licensure and undergraduate education in order to enable preservice teachers to see and use technologies for more than general pedagogical purposes. Preservice teachers' professional knowledge and practical teaching experience are not as robust as is practicing teachers'; therefore, their immediate concerns channel their

thoughts to pedagogy. Yet, practicing teachers, even with years of experience teaching their subject area, also need these focused subject matter and pedagogical content connections, because the immediate and easy implementation of the technology is likely to be pedagogical. It does not necessitate changing the content or approach to teaching that content. By prioritizing and privileging connections between technology and subject matter and pedagogical content, preservice, novice, and experienced teachers will be better prepared to identify technological uses across their profession, including use of technology by the children they are teaching. For example, Warburton and Campbell's (2001) study indicated that preservice teachers began to understand poetic language, developed more confidence in teaching poetry to children, and observed how popular culture and technologies could serve their instructional aims after participating in three integrated projects that immersed them in appreciating and understanding figurative language and poetic forms and communicating an original poem through text and computer-based illustrations.

Limitation. To privilege these kinds of connections, the most productive learning situation is a subject-specific learning opportunity. Preservice teachers need subject-specific educational technology courses and/or content methods and content courses that acknowledge the role of technology. Novice and practicing teachers need subject-specific educational technology in-service opportunities. The need for subject-specificity may introduce significant additional expense, especially at the in-service level. Large initial licensure programs may have enough students to create subject-specific educational technology courses. However, most P-12 schools do not have enough duplicative grades to create groups of subject-specific teachers by grade levels. A solution could be to group schools together for in-service training to share resources and create groups of subject-specific teachers at certain grade levels. Another solution could be to create subject-specificity but broaden the grade levels of a group. In any case, facilitating the subject-specific consideration of technology, as described in this section, will require some expense and certainly some creativity in design of the learning experience.

The first two principles emphasize the need to connect technologies with the professional knowledge of teachers. Put into practice, these principles would decrease the likelihood of teachers learning – and then forgetting – isolated technology skills and would increase teachers' use of technology in support of instruction and student learning. The two principles aim to increase the likelihood of technology integration by helping teachers become aware of ways technology connects with their professional activities and knowledge, but these connections may not necessarily represent advancements in pedagogy and subject matter. For example, a teacher may learn about word processing, becoming convinced of its potential assistance in students' writing habits. In practice, the students may merely type up their final writing assignments in the computer lab after they have written them by hand during or outside of class. In this case, the teacher's instructional approach to writing is not truly process oriented; therefore, the advantages the technology might offer for writing instruction vanish. The goal of the next principle is to leverage teachers' reflection about their own professional beliefs concerning instruction and learning through technology learning.

Principle 3: Use Technology Learning to Challenge Current Professional Knowledge

In the literature, educational technology is touted as a change agent (e.g., Holland, 2001; King, 2002; Means, 1994), in which learning new technology leverages teachers' reflections on the nature of teaching and learning during which they access, consider, question, and eventually change their professional knowledge and practice. Yet, the addition of technology into a classroom or school does not inherently nor naturally

reform teaching or learning (Dede, 2001; Wiske, 2001). If and how teachers adopt technology determines if change in teaching or learning occurs. An outcome of change seems less likely than the many claims in the literature might make it appear, for "teacher cognitions have taken years to take shape and are, consequently, not easily changed" (Verloop, Driel, & Meijer, 2001, p. 454). Although learning technology does not inherently change teaching, instructors or facilitators can use technology to leverage teacher reflection that may possibly lead to reform over time. Although the essence of this third principle was not explicitly mentioned in the subject-specific preservice principles (Flick & Bell, 2000; Garofalo et al., 2000; Mason et al., 2000; Pope & Golub, 2000), challenging students' professional knowledge is perhaps implicit in their guidelines. For example, Mason et al.'s (2000) fourth principle, "Foster the development of the skills, knowledge, and participation as good citizens in a democratic society" (p. 111), holds the potential to challenge or change preservice teachers' subject matter knowledge by exposing them to new subject matter or new combinations of subject matter. In addition, implementing Pope and Golub's (2000) fourth principle, "Evaluate critically when and how to use technology in English language arts classroom" (p. 93), should lead preservice teachers' to deeply consider and develop their pedagogical content knowledge.

Cullin and Crawford (2003) used this principle when preparing an intervention for preservice science teachers. First, they recognized that in-service and preservice teachers' pedagogical content knowledge and scientific knowledge concerning the role of models and modeling in science was not adequate. Subsequently, they designed a technology-based intervention that used dynamic systems modeling software, Model-It (HI-CE, http://www.hi-ce.org/), to augment students' knowledge of modeling in science, especially the role for modeling in scientific inquiry and the critical advantage of teaching about and with scientific models. In addition to challenging subject matter knowledge, technology-supported activities also can challenge teachers' assumptions about the role that technology plays in learning and instruction. Mason et al. (2000) described lessons that engaged preservice teachers in "learning beyond what could be done without technology." Similarly, Howard, McGee, Schwartz, and Purcell (2000) targeted epistemological changes related to constructivist philosophies through "communication packages, multimedia tools, authoring software, and computer-based curriculum supplements that use constructivist methodologies" (p. 456-457). Introducing new technologies – especially those that are reflective of current curriculum and instructional goals – has the potential to challenge teachers' beliefs. This principle acknowledges the role that teachers' knowledge of instruction, subject matter, and their familiarity with their students' needs has on examining new technologies but also acknowledges that teachers may benefit from an expanded awareness of advancements in educational theory and subject matter.

Advantages. This principle's main advantage is the challenge or "cognitive conflict" (Pressley & McCormick, 1995) that preservice, novice, and experienced teachers may experience when introduced to new technologies that inherently reflect new subject matter, epistemology, and/or pedagogy in the field. This principle seems applicable for preservice or novice teachers who are just beginning to learn about current approaches to curriculum, instruction, and student learning. Many novice teachers have developed assumptions about teaching and learning based on their own experiences as learners that do not reflect the current practices in the field (Lortie, 1975). Technological innovations that are used to exemplify current educational theories and practice may begin conversations and reflection that spur eventual changes in knowledge and practice. In Cullin and Crawford's (2003) intervention, the preservice teachers came to believe that, in addition to using models to represent systems and relationships, they could have students use the tool for learning. This shifted the technology from teacher to student. Likewise, Howard et al.'s (2000) month-long professional development program found

that teachers did change "from objectivist epistemological orientations to more constructivist ones" (p. 459). Activities built upon this principle also provide practicing teachers the luxury of considering new developments in instruction, learning, and subject matter that they may not have had time to explore or discover outside of their daily teaching responsibilities. Through using technology to challenge these teachers' beliefs, teachers may be exposed to new educational theories, as well as to the fact that the theories of curriculum, instruction, and learning have wide implications – including the choices about technology -supported teaching and learning.

Limitations. Implementing this principle does not guarantee change in teachers' professional knowledge. However, this principle, as the research literature indicates, has been used to reform teaching. Instructors and facilitators of learning experiences can promote the evaluation and consideration of technology's epistemological and content basis, but it is ultimately the individual teacher who determines the outcome. Established teachers may be less able or less inclined to face the challenges to their established practices and beliefs presented through this strategy. For example, Norton, McRobbie, and Cooper's (2000) study of why mathematics teachers in a technology -rich school did not use technology revealed the deep roots of teachers' beliefs about subject matter and instruction. They found that "resources were not used because the pedagogy, which was implicit in the activities contained in these resources, did not support the teacher's preferred [transmission-oriented] teaching strategies" (p. 105).

For teachers who do question their teaching beliefs, any subsequent change in beliefs and practice will take time to emerge. Furthermore, to really produce change, the learning experience needs to be sustained over time. Ongoing discussions and consideration are necessary, as was illustrated in the multiyear intervention that Apple Classrooms of Tomorrow (ACOT) orchestrated and researched (Sandholtz et al., 1997). Within the Cullin and Crawford (2003) intervention's short timeframe, the preservice participants did not come to learn the importance of modeling for scientific inquiry. The researchers suggested that more exposure to these modeling concepts and experiences, such as in science content courses, might have been beneficial. Their finding of limited development of particular science and pedagogical content reflects the lengthy process required for change in knowledge, beliefs, and practice.

Principle 4: Teach Many Technologies

The final principle emphasizes the need to teach about many different technologies. The overall aim of teaching about educational technology is to help teachers understand what the technologies are and how the technologies can serve students' learning of subject matter. To do this, teachers ultimately must understand how the technology fits within their professional knowledge and activities. Because preservice, novice, and experienced teachers all have very personal and different professional knowledge that is impacted by the school context within which they work, it is unrealistic for one or two technologies to match all teachers' professional activities. Therefore, to increase the likelihood that teachers may identify technologies that fit their needs, technology-learning opportunities must include many technologies. Flores et al. (2002) and Pope and Golub (2000) acknowledged the importance of providing preservice teachers a wide, changing range of technologies that students would use in content learning. Hunter (2001) described a wide-range of technology applications put into use with students through the TAP professional development investigations.

Too many times decisions to adopt technologies are made at either the district or school-levels without consultation with teachers. The technologies chosen are usually targeted at administrative purposes, such as grading or attendance, rather than technologies that are

put into the hands of students for learning purposes. Other technologies geared toward a specific subject area, purchased without consultation with teachers, will likely not fit teachers' needs due to teachers' varied instructional techniques, familiarity with the subject matter, and students' needs. Certainly, limitations related to adoption and purchases of software and hardware exist in schools and districts. However, offering only a few technology options will reduce the number of technology-using teachers in the school, due to a lack of connection between the available technologies and the teachers' needs. Some teachers may find valuable tools in the mix, yet other teachers will not. It needs to be emphasized that teachers may not find a valuable tool – not due to lack of interest in technology but due the limited technology options. Reprimanding or penalizing these teachers is unwarranted; they actually may be extremely thoughtful about their adoption and use of technology for their students and themselves. Offering a larger pool of technology options may support these teachers in identifying tools that may fit their needs.

Advantages. Clearly, offering more technology options for teachers to investigate will increase the likelihood that they will find a tool that supports their professional activities. By examining a range of technologies, preservice, novice, and experienced teachers will understand the wide-ranging possibilities of the role for technology in education. This wider perspective may encourage teachers to examine technologies more thoroughly prior to adoption, possibly decreasing the existence of technology use for technology's sake, because teachers will have more awareness of software and hardware that have specific advantages for student learning.

Limitations. One of the main impediments to enacting this principle in technology-learning opportunities is financial constraint. The resources required to offer teachers hands-on access to a variety of technologies include both human and financial capital. A technology learning lab where demonstration or single copies of software and hardware can be compiled may benefit more than one school. A district or university learning lab such as this could serve school teachers, university students, and/or community members who may also be interested in identifying technologies for use at home. Schools, universities, community organizations, and vendors could share the cost of a learning lab. Being able to preview and examine technologies prior to adoption could reduce the expenditures toward unused technologies that exist in schools today. A disadvantage to this shared resource center is that it may be offsite for teachers. It would be valuable to be able to check out software and hardware for examination and experimentation onsite.

Another limitation to this strategy is a possible reduction in the amount of time teachers spend learning each technology. If instructors or facilitators implement this principle, they should be aware that teachers might not learn all technologies equally well. In fact, it might be counterproductive to require teachers to learn all the technologies. In line with the vision of developing technology integrationists, teachers should be encouraged to find technologies that seem particularly promising for their needs and spend as much time as needed to understand the advantages and disadvantages of the technology, ultimately deciding if the technology is worthwhile and should be sought for use in the teacher's classroom. In a university situation, instructors may need to shift their assumptions that all teacher-learners will learn all the technologies. In addition, as instructors grant teacher-learners more flexibility in focusing on certain technologies, the need for additional instructional and facilitation assistance may increase to serve all the learning needs during the learning experience.

Implementing Principles into Practice

In contrast to "ratcheting up" teachers' technology skills without clear implementation plans for the technology, this essay provided a foundational vision that seeks to develop teachers into "technology integrationists" who understand, consider, and choose to use technologies to uniquely enhance their curriculum, instruction, and students' learning. To facilitate learning situations at the preservice and in-service levels that optimize the development of teachers as technology integrationists, a set of guiding principles were described that can be considered when evaluating, constructing, or redeveloping technology learning opportunities.

The field of education needs to surpass the typical single course in information technology that is prevalent in teacher education institutions (Holland, 2001; Moursund & Bielefeldt, 1999; Rice, Wilson, & Bagley, 2001) and the short-term technology workshops available in K-12 schools for practicing teachers. Neither of these technology-learning approaches adequately implement the four principles described in this article. Single courses and workshops that involve cross-disciplinary and cross-grade level teachers, due to their diversity of participants, often focus on pedagogical issues rather than solid treatment of subject matter topics. A lack of focus on subject matter limits the enactment of Principles 1, 2 and 3, and the technologies taught would be limited to general pedagogical tools (e.g., PowerPoint, grading software). Alternative learning approaches that make more use of these technology learning principles need to be developed and established.

Some subject-specific university courses and long-term technology in-service initiatives can and do implement many of these principles. Initial licensure and professional development programs are beginning to establish cohort models in which students enroll in subject-specific instructional technology courses (e.g., Sprague & Norton, 1999). Alternatively, initial licensure programs are considering the elimination of instructional technology courses and including technology instruction within content and methods courses (e.g., Confrey, Resta, Petrosino & Tothero, 2002). Overall, these recent developments in educational technology instruction hold promise for implementing the technology learning principles and developing technology integrationists.

Another learning approach – collaborative inquiry groups, involving small groups of teachers who collectively investigate pedagogical and content issues (Crockett, 2002) – has emerged as an even more promising practice that implements all four technology learning principles simultaneously and meets the vision set forth in this paper. Subject-specific, technology inquiry groups (e.g., Hunter, 2001; Swan et al., 2002) may offer potential advantages over other instructional approaches to facilitate preservice, novice, and experienced teachers' becoming technology integrationists. For example, teachers can group themselves (along with curriculum coordinators, administrators, and/or media specialists) into subject-specific, collaborative groups that meet in an ongoing fashion. During group meetings, teachers can discuss issues within their teaching to identify problems-of-practice that determine future inquiries into technology (Principle 1 and 2). Alternatively, group members can demonstrate new technologies and propose possible integrated uses (Principle 1) or allow the technology to inspire discussion into contemporary issues within teaching and learning (Principle 3). Finally, teachers need access to technology (Principle 4) to facilitate their inquiries into problems-of-practice, to examine as possible solutions, and to spur discussion about theory and practice.

Hunter (2001) described "Team Action Projects" that were spearheaded by at least two school colleagues whose collaborative project was situated within authentic, school-based improvement goals, supported through a collaborative, vision-oriented discourse and

working group, and accessed available tools that possibly could improve the issues under study. Within two years' time, all participating teachers (of whom most began with few technology skills) were functioning at an "Invention" stage, in which technology flexibly supports new learning environments that are often collaborative, interactive, and customized. Swan et al. (2002) established the Capital Area Technology and Inquiry in Education (CATIE) initiative that placed educational technology mentors in schools (for two years) to work with teachers to develop and implement technology-supported lessons. The mentors collaboratively worked with teachers "to design computer-supported lessons that are integral parts of larger, classroom-based learning units" (p. 173). Thus, the technology learning was situated within the teachers' own classroom setting and instruction, supported by informal discourse community focused on technology integration at the school sites, and guided by constructivist approaches to teaching and learning with technologies. Teachers reported "increased knowledge of computing technologies, greater confidence in using them, and more creative teaching with computers" (p. 187).

The success demonstrated when technology inquiry groups are used with in-service teachers indicates that content-focused technology inquiry may be beneficial for preservice teachers as well, especially since the technology learning principles have been shown to be similar across preservice and in-service teachers. Partnerships among preservice and veteran teachers (e.g., Beckett, Wetzel, Buss, Marquez-Chisholm & Midobuche, 2001; Wright, Wilson, Gordon, & Stallworth 2002) could be forged to facilitate content-focused technology integration.

Future research is warranted to examine the process of establishing and supporting technology inquiry groups, the knowledge participants learn and develop, and the impact of their learning on their teaching practice and students' achievement. This field is seasoned for the development of other innovative learning approaches that integrate these principles, affording teachers engaging learning opportunities that, ultimately, will allow students to use technology for deep subject-matter learning.

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