

Teacher Pedagogical Beliefs: The Final Frontier in Our Quest for Technology Integration?

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Although the conditions for successful technology integration finally appear to be in place, including ready access to technology, increased training for teachers, and a favorable policy environment, high-level technology use is still surprisingly low. This suggests that additional barriers, specifically related to teachers' pedagogical beliefs, may be at work. Previous researchers have noted the influence of teachers' beliefs on classroom instruction specifically in math, reading, and science, yet little research has been done to establish a similar link to teachers' classroom uses of technology. In this article, I argue for the importance of such research and present a conceptual overview of teacher pedagogical beliefs as a vital first step. After defining and describing the nature of teacher beliefs, including how they are likely to impact teachers' classroom practice, I describe important implications for teacher professional development and offer suggestions for future research.

□ According to Becker (2000), computers serve as a "valuable and well-functioning instructional tool" (p. 29) in schools and classrooms in which teachers: (a) have convenient access, (b) are adequately prepared, (c) have some freedom in the curriculum, and (d) hold personal beliefs aligned with a constructivist pedagogy. Although many teachers do not work in schools in which *all* of these variables are present, a number of recent reports suggest that this is starting to change. For example, according to Market Data Retrieval (MDR, 2002) students across the United States now enjoy an average student-computer ratio of 4:1, with 98% of schools and 77% of classrooms connected to the Internet. Recent demographic data from the Integrated Studies of Educational Technology (ISET; U.S. Department of Education [DOE], 2003) revealed that 81% of teachers have either moderate or high levels of access to instructional computers. Furthermore, no significant differences were found in computer availability by school type (elementary vs. secondary) or poverty level.

Along with increased access have come increased opportunities for teachers to gain technology skills. The majority of teachers (85%) now report feeling "somewhat well-prepared" to use technology for classroom instruction (U.S. DOE, 2003), a notable increase since the 2000 report of the National Center for Education Statistics (NCES) in which 53% of teachers reported feeling somewhat prepared. Furthermore, in the 2003 study, only 37% of teachers expressed interest in learning basic computer skills while over 80% expressed interest in learning how to integrate computer technology into curricular areas, suggesting that the majority of current

teachers have obtained (or at least *perceive* they have obtained) minimum levels of technical competency.

Although progress in the third area (e.g., freedom in the curriculum) is harder to measure, recent legislation and policy statements indicate a strong commitment by education authorities to support the expansion and use of computers in K-12 classrooms (U.S. DOE, 1996, 2001, 2003). Evidence of this commitment includes the adoption of standards for technology use by administrators, teachers, and students (International Society for Technology in Education, 2003); the increasing prevalence of block scheduling (which allows for longer class periods) at the high school level (American Federation of Teachers, 1999; North Carolina Department of Public Instruction, 1998); and provisions within the No Child Left Behind Act to ensure that teachers can integrate technology into the curriculum for the purposes of improving student achievement (U.S. DOE, 2001). Simply stated: "Technology is now considered by most educators and parents to be an integral part of providing a high-quality education" (U.S. DOE, 2003, p. 3).

Although the first three conditions identified by Becker (2000) appear to have been nearly met, the fourth (teachers' beliefs) is much less understood and, consequently, less readily resolved. This may be due, at least in part, to the fact that the first three conditions have required changes that might best be described as first order (Waters, Marzano, & McNulty, 2003); that is, changes that adjust current practice in an incremental fashion without changing existing structures or beliefs. However, the fourth component comprises a second-order change—change that confronts teachers' fundamental beliefs and, thus, requires new ways of both seeing and doing things. While first-order changes are, in effect, reversible, second-order changes are seen as irreversible: Once you begin, it is impossible to return to your previous routines and habits (Brownlee, 2000). As such, these types of changes are riskier for teachers, as well as more difficult to achieve. Furthermore, knowing how to facilitate and support these types of changes is much less familiar to staff developers who typically have been concerned with facilitating first-

order change (Garet, Porter, Desimone, Birman, & Yoon, 2001).

A number of large-scale studies (e.g., Barron, Kemker, Harmes, & Kalaydjian, 2003) have verified that teacher technology use has increased in classrooms across the nation, undoubtedly because of these increased levels of access and skill, as well as the current favorable policy environment. However, although many teachers are using technology for numerous low-level tasks (word processing, Internet research), higher level uses are still very much in the minority. For example, results of a survey conducted by Michigan Virtual University (Newman, 2002) as part of a program to give every Michigan teacher a laptop computer (completed by more than 90,000 teachers) indicated that whereas most teachers reported knowing how to get information from the Web and send e-mail, only a small proportion of the teachers (sometimes only 1 in 9) knew how to use high-tech tools such as spreadsheets, presentation software, or digital imaging to enhance their lessons. Results from ISET (U.S. DOE, 2003) were similar: The computer-related activities in which teachers most often engaged their students included expressing themselves in writing, improving their computer skills, doing research using the Internet, using computers as a free-time or reward activity, and doing practice drills.

Thus, while instructional computer use appears to be increasing (at least as measured by self-report data), the most common and frequent uses have resulted in only incremental, or first-order, changes in teaching style and remain far removed from the best practices advocated in the literature (Becker, 1994; Berg, Benz, Lasley, & Raisch, 1998; Dede, 1998; Dexter, Anderson, & Becker, 1999). For example, Becker (1994) classified exemplary technology users based on standards that "suggest a classroom environment in which computers were both prominent in the experience of students and employed in order that students grow intellectually and not merely develop isolated skills" (p. 294). In general, low-level technology uses tend to be associated with teacher-centered practices while high-level uses tend to be associated with student-centered, or constructivist, practices (Becker, 1994; Becker & Riel, 1999).

The predominance of low-level uses may be due simply to the fact that low-level uses precede high-level uses, and that not enough time has passed for high-level uses to emerge. Based on developmental models of technology integration proposed by researchers for the Apple Classrooms of Tomorrow (e.g., Sandholtz, Ringstaff, & Dwyer, 1997) and others (Becker, 1994; Hooper & Rieber, 1995; Marcinkiewicz, 1993), it takes five to six years for teachers to accumulate enough expertise to use technology in ways advocated by constructivist reform efforts. The assumption, then, is that increased or prolonged technology use will actually prompt teachers to change their practices toward more constructivist approaches. While this may be true, it has yet to be verified by empirical research (e.g., Barron et al., 2003; Newman, 2002). For example, based on the results of their work in two high-tech high schools in California, Cuban, Kirkpatrick, and Peck (2001) noted that "Few fundamental changes in the dominant mode of teacher-centered instruction had occurred. . . . Even in computer-based classes, teacher-centered instruction was the norm" (p. 825). Cuban and his colleagues postulated that these results might have been because of the "deeply entrenched structures of the self-contained classroom, departments, time schedules, and teachers' disciplinary training" (p. 83).

Still, one has to wonder whether changes in these structures would be sufficient to facilitate the type of fundamental changes required for teachers to use technology in constructivist ways. Although changes in these structures might create more opportunities for teachers to use student-centered approaches, other second-order barriers (i.e., barriers that are intrinsic to teachers and that challenge their beliefs about current practice) may limit their efforts (Ertmer, 1999). As noted by Dexter et al. (1999), "Although culture and context create norms of teaching practice . . . teachers can choose, within these limits, the approach that works for them. This autonomy provides teachers with choices to adopt, adapt, or reject an instructional reform" (p. 224).

Ultimately, the decision regarding *whether* and *how* to use technology for instruction rests

on the shoulders of classroom teachers. If educators are to achieve fundamental, or second-order, changes in classroom teaching practices, we need to examine teachers themselves and the beliefs they hold about teaching, learning, and technology. As Marcinkiewicz (1993) noted, "Full integration of computers into the educational system is a distant goal unless there is reconciliation between teachers and computers. To understand how to achieve integration, we need to study teachers and what makes them use computers" (p. 234). Cuban's observation (1997) supports this: "It's not a problem of resources, but a struggle over core values" (online).

Purpose of Article

The purpose of this article is to examine the relationship between teachers' pedagogical beliefs and their technology practices. While previous researchers have documented the influence of teachers' pedagogical beliefs on classroom practices related to teaching mathematics (Vacc & Bright, 1999), science (Czerniak & Lumpe, 1996), history (Wilson & Wineburg, 1988), and literacy (Fang, 1996), few have examined how these beliefs influence teachers' adoption and use of technology. Zhao, Pugh, Sheldon, and Byers (2002) lamented that, despite a preponderance of survey studies examining factors influencing teachers' uses of technology, "these types of studies tend to neglect the messy process through which teachers struggle to negotiate a foreign and potentially disruptive innovation into their familiar environment" (p. 483). In this review, I extend the work of these and other scholars who have examined teacher beliefs in subject-related contexts, to explicate the relationship between pedagogical beliefs and technology use. The hope is that by gaining a better understanding of this complex relationship, educators might gain a greater appreciation for why more teachers are not using technology in ways advocated in the literature. This, then, may enable us to facilitate a better alignment between research, practice, and beliefs and to provide more effective ways of supporting and documenting teacher change. Ultimately, the goal is to facilitate uses of technology that lead to

increased student learning. As noted by Pajares (1992): "Little will have been accomplished if research into educational beliefs fails to provide insights into the relationship between beliefs . . . and teacher practices, teacher knowledge, and student outcomes" (p. 327).

Definition of Teacher Beliefs

Unfortunately, there is a lot of confusion in the literature regarding both the labels and definitions used to describe teacher beliefs. Pajares, in his 1992 review, labeled teacher beliefs a "messy construct," noting that "the difficulty in studying teachers' beliefs has been caused by definitional problems, poor conceptualizations, and differing understandings of beliefs and belief structures" (p. 307). According to Calderhead (1996), teacher beliefs, as well as teacher knowledge and teacher thinking, comprise the broader concept of teacher cognition. Yet, Kagan (1990) noted that the term *teacher cognition* "is somewhat ambiguous, because researchers invoke the term to refer to different products, including teachers' interactive thoughts during instruction; thoughts during lesson planning; implicit beliefs about students, classrooms, and learning; [and] reflections about their own teaching performance . . ." (p. 420).

Part of the difficulty in defining teacher beliefs centers on determining if, and how, they differ from knowledge. In this review, I accept the distinction suggested by Calderhead (1996): Whereas beliefs generally refer to "suppositions, commitments, and ideologies," knowledge refers to "factual propositions and understandings" (p. 715). Therefore, after gaining *knowledge* of a proposition, we are still free to accept it as being either true or false (i.e., believe it, or not). For example, teachers may gain specific knowledge about how to create spreadsheets for student record keeping, and may also know that other teachers have used them successfully, yet still not believe that spreadsheets offer an effective tool for their classroom use. This might be especially true if, based on previous experiences, they have negative beliefs about their own technical capabilities. Another distinction between knowledge and beliefs, illustrated by this exam-

ple, is the stronger affective and evaluative components often associated with beliefs (Nespor, 1987). Given these distinctions, Nespor and others (Griffin & Ohlsson, 2001; Kagan, 1992; Pajares, 1992) have concluded that beliefs are far more influential than knowledge in determining how individuals organize and define tasks and problems. This, then, makes them stronger predictors of behavior.

Despite the difficulties related to sorting out this "messy construct," Pajares (1992) proposed that, "All teachers hold beliefs, however defined and labeled, about their work, their students, their subject matter, and their roles and responsibilities . . ." (p. 314). Because "humans have beliefs about everything" (p. 315), Pajares recommended that researchers make a distinction between teachers' broader, general belief systems and their educational beliefs. In addition, he recommended that educational beliefs be narrowed further to specify what those beliefs are about, for example, *educational beliefs* about the nature of knowledge, perceptions of self and feelings of self-worth, confidence to perform certain tasks, and so on. Following Pajares's recommendation, in this review I focus specifically on teachers' educational beliefs about teaching and learning (referred to here as pedagogical beliefs) and the beliefs they have about how technology enables them to translate those beliefs into classroom practice. It is my hope that establishing a clear understanding of these concepts and the relationships among them will accomplish an important first step in improving both future research and practice related to teacher change, in general, and teacher technology use, more specifically.

Link Between Beliefs and Practice

A great deal of empirical evidence has established the significance of beliefs for understanding teacher behavior (see reviews by Calderhead, 1996; Clark & Peterson, 1986; Kane, Sandretto, & Heath, 2002; Pajares, 1992). In describing this relationship, Pajares noted, "Few would argue that the beliefs teachers hold influence their perceptions and judgments, which in turn, affect their behavior in the classroom . . ."

(p. 307). Kagan (1992) cited significant evidence supporting this relationship: "Empirical studies have yielded quite consistent findings: A teacher's beliefs tend to be associated with a congruent style of teaching that is often evident across different classes and grade levels" (p. 66). In fact, given that the knowledge base of teaching consists of few, if any, indisputable "truths," Kagan postulated, "most of a teacher's professional knowledge can be regarded more accurately as a belief" (p. 73).

Yet some researchers have described inconsistencies between teachers' beliefs and their classroom practices (Calderhead, 1996; Ertmer, Gopalakrishnan, & Ross, 2001; Fang, 1996; Kane et al., 2002). For example, Fang described a number of studies in which researchers found little relationship between teachers' beliefs and their instructional reading practices, and suggested that contextual factors interfered with teachers' ability to consistently apply their beliefs in practice. Results from a study of technology-using teachers supported this as well. Ertmer et al. (2001) reported that teachers' visions for, or beliefs about, classroom technology use did not always match their classroom practices. Despite the fact that most of the teachers described themselves as having constructivist philosophies, they implemented technology in ways that might best be described as representing a mixed approach, at times engaging their students in authentic, project-based work, but at other times asking them to complete tutorials, practice skills, and learn isolated facts. Teachers' explanations for these inconsistencies often included references to contextual constraints, such as curricular requirements or social pressure exerted by parents, peers, or administrators. Scott, Chovanec, and Young (1994) observed a similar pattern in their study of the beliefs and classroom practices of 14 college professors. The authors described how their participants drew from more than one philosophical base and concluded that the "common theme in this research . . . is one of negotiation between what one assumes and believes to be true about teaching and the contextual factors (students, institution, and societal assumptions and beliefs) which serve as enablers or constrainers to playing out these assumptions and beliefs" (p. 23). These

results, then, point to the need for both researchers and practitioners to be aware of, and to account for, the potential influence of these types of contextual factors when examining teachers' beliefs or promoting teacher change.

While not discounting these types of inconsistencies, Pajares (1992) suggested that they simply illustrate the difficulties inherent in trying to measure beliefs accurately. Because beliefs exist, primarily, in tacit form (Kagan, 1992; Kane et al., 2002; Nespor, 1987), understanding teachers' beliefs requires making inferences based on what teachers say, intend, and do. If individuals are unable, or unwilling, to accurately represent their beliefs, this can lead to misjudging or misrepresenting that which truly motivates their behavior. According to Munby (1982), when beliefs about a particular subject area are inconsistent with a teacher's practice in that area, it may just be that "different and weightier" beliefs are the cause (p. 216). For example, although teachers may express the belief that technology is best used for high-level problem-solving activities, their day-to-day uses may include a large number of drill-and-practice applications, because they hold a more central belief that teachers are responsible for assuring that their students learn foundational, or prerequisite, skills. The problem, then, lies in sorting through these apparent contradictions to determine which beliefs, exactly, are influencing which actions.

Nature of Beliefs

The potential power of beliefs as an influence on behavior is inherently related to the nature of beliefs, as outlined by Nespor (1987). Among other characteristics, Nespor described beliefs as relying on episodic memory, with information being drawn from personal experiences or cultural sources of knowledge. Early episodes or events, then, have the potential to color perceptions of subsequent events, especially if early experiences are particularly unique or vivid. Furthermore, because of their highly personal nature, beliefs are unlikely to be affected by persuasion. This is readily illustrated when we consider how initial experiences with computers,

especially traumatic or negative experiences, can shape teachers' subsequent encounters for years to come, despite great efforts to persuade them differently. The past events have created a guiding image, or what Goodman (1988) termed "an intuitive screen," through which new information and experiences are now filtered.

According to Nespor (1987), beliefs also tend to be "unbounded," that is, readily extended to apply to phenomena that may be unrelated to the context in which they were formed, such as when teachers extend their beliefs about how to discipline their own children to include beliefs about how to discipline their students, despite the apparent differences between these contexts. Yet based on these characteristics, Nespor argued that beliefs have great value in dealing with complex, ill-defined situations such as those teachers tend to encounter, in which there are large amounts of information available and no single correct solution. In such contexts, the episodic and unbounded nature of beliefs makes it possible to apply them flexibly to new problems. Moreover, the nonconsensual nature of beliefs makes them relatively immune to contradiction.

Beliefs about teaching and learning (and all beliefs for that matter) tend to be embedded within a larger, "loosely bounded" belief system, which Rokeach (1968) defined as "having represented within it, in some organized psychological but not necessarily logical form, each and every one of a person's countless beliefs about physical and social reality" (p. 2). According to Nespor (1987), belief systems, unlike knowledge systems, do not require group consensus, and thus may be quite idiosyncratic. This may explain why two teachers who *know* the same things about technology might *believe* different things about its use (e.g., one seeing it as a blessing; the other as a curse). In fact, as has been noted earlier, even individual beliefs within the system do not, necessarily, have to be consistent with each other. This property makes belief systems more inflexible and less dynamic than knowledge systems (Pajares, 1992), making the prospect of trying to promote change in teachers' beliefs utterly daunting.

How Beliefs Are Formed

In general, beliefs are created through a process of enculturation and social construction; they can be formed by chance, an intense experience, or a succession of events (Pajares, 1992). As noted above, early experiences tend to color later experiences, even to the extent that subsequent, contradictory information will be manipulated to fit with earlier interpretations. Griffin and Ohlsson (2001) claimed that this is because beliefs serve both cognitive and affective-social functions. Thus, people might accept a certain idea independent of its coherence with relevant knowledge, or perhaps even change a belief, despite reducing conceptual coherence, because it enables the achievement of affective or social goals. Given this, personal theories and beliefs are rarely sufficiently revised and, thus over time, become deeply personal, highly engrained, and extremely resistant to change.

Although little has been written about how teachers' beliefs about technology are formed, there is little reason to think they follow a path different from that described for other beliefs. Because few current teachers have experienced, or even observed, the use of technology in their own K-12 schooling, they are unlikely to have many preconceived ideas about how technology should be used to achieve student learning. Yet based on the nature of beliefs described above, both inexperienced and seasoned teachers are likely to respond to these new instructional situations by relying on previous beliefs and experiences (Kagan, 1992). Even new information (about technology, alternative teaching methods, etc.), if attended to at all, will be filtered through these existing belief systems. Thus, teachers are likely to think about technology in the same way they think about other teaching methods, tools, or reform initiatives, depending on if or how they classify technology into one of these categories. Whereas some teachers may think of technology as just another tool they can use to facilitate student learning, others may think of it as one more thing to do (i.e., an innovation). These early perceptions and classifications, then, result in vastly different beliefs regarding if, when, and how to use the tool.

Previous evidence suggests that, if technol-

ogy is treated as an instructional innovation, beliefs will play a significant role in whether or how it is adopted and implemented (Cuban, 1986; Czerniak & Lumpe, 1996; Peterson, Fennema, Carpenter, & Loef, 1989). Based on the reported relationship between teachers' beliefs and their implementation of reform initiatives, Niederhauser and Stoddart (2001) suggested that teachers use technology in ways that are consistent with their personal beliefs about curriculum and instructional practice. That is, if technology is presented as a tool for enacting student-centered curricula, teachers with teacher-centered beliefs are less likely to use the tool as advocated. Rather, they are more likely to use it, if at all, to support the kinds of traditional activities with which they are comfortable. According to Zhao et al. (2002), the further a new practice is from existing practice, the less likely it will be implemented successfully. Given this, instructional technologists might consider introducing technology as a tool to accomplish that which is already valued (e.g., communicating with parents, locating relevant instructional resources). Then, once the tool is valued, the emphasis can switch to its potential for accomplishing additional or new tasks, including those that are supported by broader, or different, beliefs (Ertmer, 2001). For example, once teachers become comfortable using e-mail to communicate with parents, they may be more willing to consider allowing students to use e-mail to communicate with peers across the state or even across the world, an activity that has the potential to influence teacher beliefs about using technology to achieve higher level goals (e.g., authentic writing activities; cross-cultural collaborations).

How Beliefs Are Changed

Beliefs vary in strength and kind; the ease with which teachers can change their beliefs is related to the strength of the particular beliefs under scrutiny (Block & Hazelip, 1995). In general, stronger beliefs are those that are more central to an individual's identity (Rokeach, 1968), quite possibly because they were established during earlier experiences and, thus, were used in the

processing of subsequent experiences (Pajares, 1992). According to Rokeach, the centrality of a belief relates to its *connectedness*: "The more a given belief is functionally connected or in communication with other beliefs, the more implications and consequences it has for other beliefs and, therefore, the more central the belief" (p. 5).

Using the analogy of an atom, Rokeach (1968) described a belief system as being anchored by a nucleus, or a set of core beliefs, and outlined five types of beliefs that vary along this central-peripheral dimension:

1. At the center are Type A beliefs, that is, core beliefs that are formed through personal experiences, reinforced through social consensus, and highly resistant to change. Type A beliefs include beliefs about one's identity or self, as well as beliefs that are shared with others.
2. Moving out from the core are Type B beliefs which, like Type A, are formed through direct experience but, because they are held privately, tend to be unaffected by persuasion.
3. Next are Type C beliefs, which relate to which authorities to trust, and although they are resistant to change, it is expected that opinions about them will differ.
4. Closer to the periphery are Type D beliefs, which are derived from the authorities in which we believe and which can be changed, providing the suggestion for change comes from the relevant authority.
5. Finally, Type E beliefs are located at the outermost edge and include inconsequential beliefs that are essentially matters of taste.

Rokeach did not specifically address teachers' beliefs about teaching, but it would not be surprising if at least some beliefs about the nature of teaching are formed over many years of experience as a student and are resistant to change because they have been supported by strong authority and broad consensus (Albion & Ertmer, 2002). If this is true, then core beliefs about teaching will influence how new information about teaching is processed (Kagan, 1992), including ideas related to teaching with technology. Additional research is needed to verify the validity of this concept: Where do teachers'

beliefs exist in Rokeach's scheme and how are they used to process information related to teaching with technology?

Griffin and Ohlsson (2001) described belief revision as being highly subject to motivational influence and epistemological values. Participants in their study indicated that, even if presented with sound conflicting evidence, they would not be willing to change their affect-based beliefs (e.g., belief in an afterlife; disbelief in evolution), but were relatively willing to change their knowledge-based beliefs (e.g., belief in evolution; disbelief in an afterlife). The authors explained these results by noting, "Affect-based beliefs by virtue of their *lack* of coherence with the conceptual framework might be immune to threats posed by conflicting information. Any new information is likely to be distorted, and if it is accurately comprehended, it will have little influence . . ." (p. 6; *italics added*). Based on Rokeach's scheme (1968), it may be that affect-based beliefs, because they are more intimately connected to our personal identities, reside in a more central position in our belief systems, while knowledge-based beliefs, because they are less personal, exist somewhere on the periphery. Additional work is needed to clarify these ideas.

Although beliefs are not readily changed, this does not mean that they *never* change (Nespor, 1987; Pajares, 1992). According to Nespor, beliefs change, not through argument or reason, but rather through a conversion process or Gestalt shift. Posner, Strike, Hewson, and Gertzog (1982) noted that, in order for beliefs to change, individuals must be dissatisfied with their existing beliefs. This is most likely to happen when either existing beliefs are challenged or new beliefs cannot be assimilated into existing ideas. Based on the conceptual change literature, Kagan (1992) noted that if a teacher education or professional development program is to be successful at promoting belief change among teachers, "it must require them to make their preexisting personal beliefs explicit; it must challenge the adequacy of those beliefs; and it must give novices extended opportunities to examine, elaborate, and integrate new information into their existing belief systems" (p. 77).

This same sentiment has been expressed in

recent professional development literature (e.g., Garet et al., 2001; Howard, McGee, Schwartz, & Purcell, 2000; Putnam & Borko, 2000), including that related to technology development (Niederhauser & Stoddart, 2001; Pedersen & Liu, 2003; Windschitl, 2002; Windschitl & Sahl, 2002). For example, Windschitl and Sahl suggested that there "can be no institutional 'vision of technology use' that exists separately from beliefs about learners, beliefs about what characterizes meaningful learning, and beliefs about the role of the teachers within the vision" (p. 202). Based on their study of the implementation of a laptop initiative in one middle school, they recommended that members of the school community hold public conversations to reveal their beliefs about learners and learning and to make explicit the ways in which technology can facilitate progress toward shared goals, based on those beliefs.

Implications for Professional Development

How, then, is belief change most likely to happen? What experiences will teachers need in order to question, and to be dissatisfied with, existing beliefs? Three strategies seem to hold particular promise for promoting change in teacher beliefs about teaching and learning, in general, and beliefs about technology, specifically: (a) personal experiences, (b) vicarious experiences, and (c) social-cultural influences. These strategies are predicated on the idea that beliefs are grounded in experience and authority, as described above (Nespor, 1987; Rokeach, 1968).

Personal experiences. If beliefs are formed through personal experience, then changes in beliefs might also be facilitated through experience. Although it was suggested earlier that beliefs shape practice (e.g., Cuban, 1986; Kagan, 1992; Niederhauser & Stoddart, 2001), this does not mean, necessarily, that the best way to change teacher practice is by changing their beliefs. In fact, Guskey (1986) argued that change in beliefs *follows*, rather than *precedes* practice, and that by helping teachers adopt new practices that are successful, the associated beliefs will also change. This idea is supported

by the self-efficacy literature (e.g., Bandura, 1997; Schunk, 2000), which highlights the importance of building a teacher's confidence through successful experiences with small instructional changes before attempting larger changes.

Particularly when technology is involved, starting with relatively simple uses may be a more productive path to achieving teacher change than expecting teachers to use technology, from the outset, to achieve high-end instructional goals. According to Zhao and Cziko (2001), many teachers use technology, not because it helps them achieve a new goal, but because it allows them to achieve their current goals more effectively than do their traditional methods. Zhao and Cziko explained that because technology is at a lower level of the belief-goal hierarchy than pedagogical beliefs and teaching approaches (or, in Rokeach's 1968 schema, less central to a teacher's belief system), and because lower-level goals are easier to vary, it is no surprise that many teachers adopt technology without changing their pedagogy. In fact, if teachers feel pressured to change their pedagogy in order to accommodate new technologies, they are more likely to resist adopting technology altogether (Zhao & Cziko).

Although introducing teachers to relatively simple uses of technology may be the most feasible way to initiate the adoption process (Ertmer, 2001; Snoeyink & Ertmer, 2001–2002), additional strategies, such as those advocated here (e.g., engaging teachers in explicit belief exploration, providing opportunities to examine new practices supported by different beliefs), are likely to be needed to move teachers beyond their initial, low-level uses. Without these extra strategies, there is little reason to expect that teachers will adopt higher level uses, as evidenced by the results of a number of recent studies (Barron et al., 2003; Cuban et al., 2001; Newman, 2002).

According to Nespor (1987), instructional change is not a matter of completely abandoning beliefs, but of gradually replacing them with more relevant beliefs, which Dwyer, Ringstaff, and Sandholtz (1990) suggested are shaped by personal experiences in an "altered" context. To achieve this type of change, Windschitl (2002) recommended approaches to professional development that comprise (a) questioning

one's own practice and the practices of others, (b) making assumptions explicit, and (c) using classrooms as sites for inquiry. This approach combines suggestions made in the conceptual change literature (i.e., making beliefs and assumptions explicit) with suggestions made in the professional development literature (i.e., providing altered experiences in a relevant context). According to Windschitl, this kind of learning can be transformative, fostering fundamental changes in deeply held beliefs, knowledge, and habits of practice. Additional research is needed to determine the efficacy of this approach.

Vicarious experiences. The power of vicarious experiences for building teacher confidence and competence is supported by both the self-efficacy literature and the literature on technology professional development (Bandura, 1997; Downes, 1993; Handler, 1993). For example, Downes noted in her study that the influence of a supervising teacher's uses of computers was so strong that first-year students, whose supervising teachers used computers with children, were more likely to use computers with children than were third-year students whose supervising teachers did not. Others (Calderhead, 1996; Kagan, 1992) also have described the relatively strong influence of the supervising teacher, noting that this influence easily outweighs that of college courses or university instructors.

Vicarious experiences are considered to be a powerful learning tool because observing similar others serves both informational and motivational functions (Schunk, 2000). That is, models can not only provide information about how to enact specific classroom strategies, they can also increase observers' confidence for generating the same behaviors. Furthermore, having access to multiple models increases both the amount of information available about how to accomplish the performance and the probability that observers will perceive themselves as similar to at least one of the models, thus increasing their confidence for also performing successfully.

If, as Guskey (1986) suggested, beliefs follow successful practice, and confidence and competence are foundational to achieving that success,

then at the very least, confidence and competence must be built before changes to beliefs can be expected. According to Elmore, Peterson, and McCarthy (1996), "... teachers' practices are unlikely to change without some exposure to what teaching actually looks like when it's being done differently" (p. 241). As suggested by Zhao and Czikowski (2001), observing successful others might increase teachers' perceived need for change as well as assure them that the required changes are not impossible. In addition, if teachers are going to actually change their practice, they will need access to others who can both challenge and support them as they implement these new ideas in their classrooms.

Yet providing opportunities for teachers to experience alternative approaches to teaching is not readily accomplished because of difficulties involved in locating suitable models and in releasing teachers from their classrooms (Albion & Ertmer, 2002). This suggests the need for alternative approaches that introduce teachers to different methods, and provide opportunities for them to test their ideas without having to worry about making mistakes or jeopardizing the progress of their students. Based on the proven effectiveness of vicarious experiences, but recognizing the logistical difficulties involved in arranging them, educators have suggested presenting teacher models via electronic means: video, CD-ROM, or Web-based technologies (Albion, 2003; Ertmer et al., 2003).

Preliminary results suggest that these types of electronic models can be effective in increasing preservice teachers' ideas about and self-efficacy beliefs for implementing technology in their classrooms. For example, Albion (2003) found that preservice teachers, who interacted with a set of multimedia problem-based scenarios in which practicing teachers discussed possible solutions to technology issues, showed significantly greater increases in their self-efficacy for teaching with computers compared to a control group. Other data supported the contention that users had changed their conceptions of how to integrate technology into their teaching. Ertmer and her colleagues (2003) found similar results with 69 preservice teachers who explored VisionQuest®, a CD-ROM that featured six classroom teachers who used technology effec-

tively in their classrooms. Significant increases were noted in participants' ideas about and self-efficacy for technology integration. Although pedagogical beliefs were not specifically addressed in these studies, there is some indication that it may be possible to address teacher beliefs using similar strategies. Additional research, on the effectiveness of these and other methods for changing and/or refining pedagogical beliefs, is needed.

Social-cultural influences. According to Becker and Riel (1999), teachers' practices and beliefs are continually shaped by their ongoing experiences as teachers, by the values and opinions expressed by those around them, and by the expectations of influential others, all of which are transmitted through formal and informal norms, rules, and procedures. Putnam and Borko (2000) noted that teachers' practice is more likely to change as they participate in professional communities that discuss new materials, methods, and strategies, and that support the risk taking and struggle involved in transforming practice.

The establishment of a professional learning community as a means to renew both teachers and schools is a common recommendation in the professional development literature (Grant, 1996; Guskey, 1995; Little, 1993). In 2001, the National Staff Development Council (NSDC) revised its professional development standards to reflect these new ideas. Listed first among the 12 revised standards was the acknowledgement that effective staff development "organizes adults into learning communities whose goals are aligned with those of the school and district" (online).

The importance of a social network of computer-using teachers for sustaining the work of exemplary computer-using teachers has also been reported (Becker, 1994). In one study, the only significant predictor of teachers' computer use was "subjective norms," that is, expectations for computer use by influential others in teachers' lives—principals, colleagues, students, and the profession (Marcinkiewicz & Regstad, 1996). More recently, Lumpe and Chambers (2001) found that teachers' reported uses of technology-related teaching practices was influ-

enced by their self-efficacy for teaching with computers, their context beliefs about factors that enabled them to be effective teachers, and the likelihood of those factors occurring in their schools.

These studies point to the influence of the school environment on how teachers' beliefs about technology use might be developed and implemented. A recent study (Windschitl & Sahl, 2002) of three teachers learning to use technology in the context of a laptop program found that the ways in which they learned to integrate technology were "powerfully mediated by their interrelated belief systems about learners in schools, about what constituted 'good teaching' in the context of the institutional culture, and about the role of technology in students' lives" (p. 165). Results from the work of Zhao et al. (2002) suggest a similar interpretation: An innovation is less likely to be adopted if it deviates too greatly from the prevailing values, pedagogical beliefs, and practices of the teachers and administrators in the school. Furthermore, Zhao and Frank (2003) reported that although professional development was available that provided information to their participants about new methods and tools, these activities had little effect on teachers' classroom practices. Rather, change in teacher beliefs regarding the value of computers was more likely to occur when teachers were socialized by their peers to think differently about technology use. This suggests the need to provide ample time for colleagues to interact with and help each other as they explore new technologies, as well as new pedagogies.

In summary, given what is known about the manner in which beliefs are formed, as well as the relative resistance of beliefs to change, the three strategies described above appear to hold promise for affecting changes in teachers' beliefs specifically related to integrating technology in the classroom. Furthermore, if these strategies were to be combined with strategies recommended in the conceptual change literature (e.g., requiring teachers to explicate their beliefs, providing opportunities to question the adequacy of one's own beliefs), the potential for change appears greater.

Specifically, if school personnel were interested in designing professional development

experiences to effectively initiate and support teachers' uses of technology, including those supported by new pedagogical beliefs, the following components might be considered for inclusion:

- Ongoing public conversations explicating stakeholders' (teachers, administrators, parents) pedagogical beliefs, including explicit discussions about the ways in which technology can support those beliefs.
- Small communities of practice, in which teachers jointly explore new teaching methods, tools, and beliefs, and support each other as they begin transforming classroom practice.
- Opportunities to observe classroom practices, including technology uses, that are supported by different pedagogical beliefs.
- Technology tools, introduced gradually, beginning with those that support teachers' current practices and expanding to those that support higher level goals.
- Ongoing technical and pedagogical support as teachers develop confidence and competence with the technological tools, as well as the new instructional strategies required to implement a different set of pedagogical beliefs.

Implications for Research

Although research on teacher beliefs is not new (Pajares, 1992), relatively few researchers have examined the relationship between teachers' pedagogical beliefs and their classroom uses of technology. Yet without a clear understanding of this relationship, practitioners and researchers may continue to advocate for specific uses of technology that they are unable to facilitate or support, because of these underlying fundamental beliefs. Suggestions for research have been made throughout this article; a few additional questions and issues are highlighted here. For example, based on the current understanding of teachers' beliefs and their relationship to teachers' practice, additional research is needed to determine:

- How and when are teachers' pedagogical beliefs formed?

- How central are these beliefs to a teacher's identity? How are they used to process new information about teaching methods and tools, including technology tools?
- What are the similarities and differences between teachers' pedagogical beliefs and their beliefs about technology (i.e., the extent to which these beliefs are held as either core or peripheral beliefs)?
- What are appropriate instruments for measuring these different types of beliefs?
- What is the influence of contextual factors on teachers' ability to apply their beliefs in practice?

The answers to these questions have implications for professional development efforts and, as such, lead to another set of questions regarding the most effective means for changing teachers' beliefs:

- How viable are the suggestions listed above?
- Is one strategy (personal vs. vicarious experiences; individual vs. group exploration) relatively more or less effective for changing beliefs?
- To what extent can we expect these strategies to be effective when used individually rather than in combination?
- If a combination is needed, what is the most effective combination?
- Does change in beliefs occur from the core out, or from the periphery in; that is, should our early professional development efforts focus more on changing core or peripheral beliefs, with the expectation that connected beliefs will change later?

Although few researchers have yet to examine these issues, this is an area that holds great promise for the future. As noted by Pajares (1992), "Attention to the beliefs of teachers . . . can inform educational practice in ways that prevailing research agendas have not and cannot" (p. 329). Furthermore, "when [beliefs] are clearly conceptualized, when their key assumptions are examined, when precise meanings are consistently understood and when specific belief constructs are properly assessed, they can be the single most important construct in educational research" (p. 329).

CONCLUSION

While the foundations for successful technology integration finally appear to be in place (U.S. DOE, 2003; MDR, 2002), high-level technology use is still surprisingly low (Barron et al., 2003; Newman, 2002; Zhao et al., 2002), suggesting that additional barriers, specifically related to teachers' pedagogical beliefs, may be at work. Although it is not clear whether beliefs precede or follow practice (Guskey, 1986), what is clear is that we cannot expect to change one without considering the other. As Clark and Peterson (1986) warned, "Teachers' belief systems can be ignored only at the innovator's peril" (p. 291). Thus, if we truly hope to increase teachers' uses of technology, especially uses that increase student learning, we must consider how teachers' current classroom practices are rooted in, and mediated by, existing pedagogical beliefs.

When considering ways to change teachers' practice, particularly their uses of technology, the literature reviewed here suggests that is impossible to overestimate the influence of teachers' beliefs. Given that teachers' decisions are more likely to be guided by familiar images of what is proper and possible in classroom settings than by instructional theories (Windschitl, 2002), the challenge becomes one of finding the most effective ways to alter these images. Although personal and vicarious experiences, as well as social and cultural norms, appear to have some potential for altering teachers' beliefs, research is needed to verify their relative impact.

Still, it is important to remember that it is not necessary to change teachers' beliefs before introducing them to various technology applications. A more effective approach might be to introduce teachers to the types of technology uses that can support their most immediate needs (Ertmer, 2001). At the very least, this should increase teachers' confidence for using technology so that, over time, higher level uses become more plausible. Still, this has not yet been borne out by the literature. It will be important to revisit, in the future, those teachers who are currently reporting a variety of low-level uses (Barron et al., 2003) to see if this change occurs and, if it does, to determine the factors that initiated and supported the change.

"As schools continue to acquire more and better hardware and software, the benefit to students increasingly will depend on the skill with which some three million teachers are able to use these new tools" (President's Panel on Educational Technology, 1997, p. 47). Furthermore, given that these skills are unlikely to be used unless they fit with teachers' existing pedagogical beliefs, it is imperative that educators increase their understanding of and ability to address teacher beliefs, as part of their efforts to increase teachers' technology skills and uses. In the best of all worlds, then, this will not only enable teachers to use computers to their full potential but will enable students to reach their full potential as well.

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