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Professional Development in Integrating Technology Into Teaching and Learning: Knowns, Unknowns, and Ways to Pursue Better Questions and Answers

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The literature base on technology professional development for teachers reveals that there is a long way to go in understanding methods of effective practice with respect to the various impacts of these activities on teaching and learning. In the No Child Left Behind era, with programs like Preparing Tomorrow's Teachers to Use Technology, the Fund for the Improvement of Post Secondary Education, and E-rate (the schools and library portion of the Universal Service Fund) that have been targeted as No Demonstrated Results, we need to move to a more systematic study of how technology integration occurs within our schools, what increases its adoption by teachers, and the long-term impacts that these investments have on both teachers and students. In addition to the findings of a comprehensive literature review, this article also articulates a systematic evaluation plan that, if implemented, will likely yield the information needed to better understand these important educational issues.

Keywords: *technology, professional development, teachers, evaluation.*

I. Introduction and Overview

Improving the depth and breadth of teacher qualifications and student learning are major national goals (No Child Left Behind [NCLB] Act, 2002). Recent federal legislation and funding initiatives have focused on the provision of professional development for in-service teachers as a vehicle for changing teacher practice and improving student achievement. Professional development is critical to ensuring that teachers keep up with changes in statewide student performance standards, become familiar with new methods of teaching in the content areas, learn how to make the most effective instructional use of new technologies for teaching and learning, and adapt their teaching to shifting school environments and an increasingly diverse student population. However, despite national recognition of the importance of teacher professional development, report after report depicts the state of teacher professional development as inadequate (e.g., Ansell & Park, 2003; CEO Forum on Education and Technology, 1999; "Technology Counts," 1997). Many have purported that this deficiency can be attributed to an insufficient number of hours of professional development. In light of this, there has been a steady increase in the quantity of professional development opportunities, across all pedagogical domains, afforded to teachers over the past several years (e.g., Fishman, Best, Marx, & Tal, 2001b). However, although the number of professional development opportunities for teachers has increased, our understanding about what constitutes quality professional development, what teachers learn from it, or its impact on student outcomes has not substantially increased (Fishman, Best, Marx & Tal, 2001a; Wilson & Berne, 1999).

Advances in technology have instigated other trends and subtrends. That is, the potential value of technology as a tool for teaching and learning has not gone unnoticed by major actors in education. These include federal, state, and local education agencies; professional organizations; and institutions of higher education. For example, over the past decade, the federal government has invested heavily in numerous initiatives to assure that schools keep pace with technology developments. These initiatives include (a) improving the capacity of schools to use technology, (b) training the next generation of teachers to use technology in their classrooms, (c) retraining the current teaching workforce in the use of technology-based instructional tactics, and (d) minimizing inequitable access to technology. As a signal of the perceived importance of these activities and commitment to "technologizing" U.S. schools, performance goals (e.g., student-to-computer ratios of 5:1) have been established, and the federal government has monitored the progress annually.

Much of the activity under way on multiple levels of the educational system is driven by a very strong perceived need for action, but it is often not guided by any substantial knowledge base derived from research about what works and why with regard to technology, teaching, and learning. Evidence to this effect comes from the collective set of papers presented by experts at a February 2000 conference on educational technology research. It was concluded that "multiple and complementary research strategies are needed to measure the implementation and impacts of learning technologies. No single study, genre of studies, or methodology is adequate to the task" (Haertel & Means, 2003, pp. 257–258). Based on their analysis and synthesis of the research strategies proposed by multiple experts, Haertel and Means argued that substantial funding was needed for a coordinated, large-scale program of research on educational technology and learning in K–12 schools. Such a research program would, of necessity, require the use of multiple research and data collection approaches to address the many questions still in need of answers.

The importance of technology in educational settings has also prompted various organizations, including those responsible for accrediting teacher-education programs, to develop technology-related standards. This activity has ensued despite the lack of a compelling knowledge base for understanding technology's impact on learning. The National Educational Technology Standards (NETS) for Teachers and the NETS for Students (both from the International Society for Technology in Education), the National Council for Accreditation for Teacher Education 2000 Teacher Education Program Standards, and individual state licensure standards are cases in point. The clear prediction is that further, and possibly quite substantial, changes will occur in these areas over the remainder of this decade, especially as attempts are made to give the standards meaning by designing assessments that purportedly reflect these standards. In turn, teacher-training programs within institutions of higher education have begun altering their practices. In the midst of these changes in education and teacher preparation, U.S. schools are facing a shortage of teachers. This potential shortfall has prompted the emergence of nontraditional mechanisms to train individuals to assume teaching roles in schools. These alternative certification routes are increasingly turning to technology as a basis for instruction and management. But in the absence of empirically grounded knowledge about how to best integrate technology, instruction, and learning into a coherent whole, the current model of innovation seems to be best characterized as "letting a thousand flowers bloom."

A quintessential example of this strategy at the federal level is the U.S. Department of Education's Enhancing Education Through Technology (EETT) program. The U.S. Department of Education (2004) has engaged in a substantial initiative attempting to "facilitate the comprehensive and integrated use of educational technology into instruction and curricula to improve teaching and student achievement" (Goal 8). Substantial funds have been provided to the states to achieve Goal 8. For example, awards in fiscal year 2004 alone totaled $659,438,400. Objective 8.3 under Goal 8 is "to provide professional development opportunities for teachers, principals and school administrators to develop capacity to effectively integrate technology into teaching and learning." To operationalize the term "integrate technology into teaching and learning," the Technology in Schools Taskforce (2003) has offered this definition:

> Technology integration is the incorporation of technology resources and technology-based practices into the daily routines, work, and management of schools. Technology resources are computers and specialized software, network-based communication systems, and other equipment and infrastructure. Practices include collaborative work and communication, Internet-based research, remote access to instrumentation, network-based transmission and retrieval of data, and other methods. This definition is not in itself sufficient to describe successful integration: it is important that integration be routine, seamless, and both efficient and effective in supporting school goals and purposes.

This literature review is focused on what is known and unknown about professional development to support the integration of technology into teaching and learning. To answer such questions, we have assembled bodies of literature that are relevant to the design of research studies, the evaluation of the quality of the evidence obtained therein, and the possible utility of the conclusions. To structure that discussion, we focus on three major challenges in the literature. Section II discusses the first major challenge: defining and evaluating what constitutes quality professional development, irrespective of the specific professional development topic. Discussion of this literature reveals that there are many principles offered, but the existing empirical evidence to support them is generally weak. Section III discusses the second major challenge: that the integration of technology into teaching and learning is not a simple matter because there are many ways in which that integration can occur, some more productive and theoretically meaningful than others. Technology is not one thing but many things that can be woven into the instructional environment by a teacher to assist the teaching and learning process. Section III provides a contemporary perspective on the multiple roles for technology in supporting the design of more effective teaching and learning environments and its implications for evaluation. Section IV then discusses the third major challenge: the fact that the recent research literature on technology-related professional development is extremely limited in scope and markedly weak regarding the inferences one can draw about what makes a difference. Section IV discusses literature relative to a conceptual schema that can be used both retrospectively to categorize and evaluate the available published research and prospectively to lay the groundwork for future evaluation studies. Section V then lays out the kinds of questions that should be asked in evaluating how states, districts, and schools have invested their technology integration funds and the nature of the research designs and sources of evidence that might be used to better answer questions about what is effective and why. A multiphase design is proposed that focuses on different levels of questions and that progressively narrows and deepens the focus on critical teacher and student learning outcomes.

Before proceeding with the substance of this review as outlined above, there is an issue relating to teacher professional development and the integration of technology into teachers' instructional practices that bears discussion, in part because the literature we have reviewed cannot address it. In the past decade, much has been made of the digital divide, especially with regard to the inequitable distribution of educational technologies in urban and rural schools versus suburban schools (Hess & Leal, 2001; Wenglinski, 1998). Discussion of this topic includes efforts made by various agencies to overcome this problem by providing more equitable access to technology resources for those most likely to lag behind. Less has been noted, however, about the problem of technology further expanding the divide in K–12 educational opportunity not because of lack of access to technology in education but because of the human capital needs associated with effective use of that technology in the K–12 arena (Swain & Pearson, 2002).

It seems likely that children from most, if not all, social and economic strata will ultimately come to have reasonable levels of access to communications and information technologies in their schools. The most recent U.S. Department of Education data tend to support such a conclusion. Less clear, however, is the likelihood that they will have access to teachers who know how to use that technology well to support 21st-century learning and teaching. Thus, the digital divide could actually widen over time with the increased investment of technology in schools unless urban and rural K–12 educational settings attract and maintain a teaching force equipped to use technology effectively in support of student learning. The concerns we raise about the quality and efficacy of professional development programs are especially pertinent to programs developed for teachers serving such students. It is not possible, given the scope and quality of the literature we discuss in the remainder of this article, to make a judgment about how well the needs of urban and rural teachers are being met. However, based on what we do know about professional development programs in this area, it is highly likely that the quality of the training offered to them leaves much to be desired.

II. Defining and Evaluating Quality Professional Development

What Constitutes Quality Professional Development?

The existing body of literature on professional development draws an important connection between student achievement and effective professional development (Darling-Hammond, 1999; National Commission on Teaching and America's Future, 1996; National Education Goals Panel, 2000; Wenglinski, 2000). A number of organizations and researchers have conducted elaborate reviews of the literature and evaluations in this area (e.g., Corcoran, Shields, & Zucker, 1998; Loucks-Horsley, Stiles, & Hewson, 1996; National Foundation for the Improvement of Education [NFIE], 1996; National Staff Development Council, 2001; Porter, Garet, Desimone, Yoon, & Birman, 2000). This knowledge base has consistently indicated that high-quality professional development activities are longer in duration (contact hours plus follow-up), provide access to new technologies for teaching and learning, actively engage teachers in meaningful and relevant activities for their individual contexts, promote peer collaboration and community building, and have a clearly articulated and a common vision for student achievement (Adelman et al., 2002; NFIE, 1996; Porter et al., 2000; Sparks, 2002).

Although these guidelines highlight important constructs to measure the success of professional development activities, they still lack grounding in empirical evidence that links different forms of professional development to either teacher- or student-learning outcomes. In 1999, Wilson and Berne commented, "What the field 'knows' about teacher learning is rather puzzling" (p. 173). They concluded that we simply do not have the research base necessary to support many of the recommendations proffered by the literature concerning issues of best practice. Even when research indicates that professional development quality is increasing, these experiences remain disconnected from the guidelines related to effective professional development (Berry et al., 2003).

To some extent, our lack of understanding can be tied to the approaches and methods used for evaluating teacher professional development when it is made public. The lion's share of the literature on professional development for teachers contains data obtained through surveys that ask teachers' opinions and attitudes concerning the experience. Successful professional development has typically been judged by measuring participants' satisfaction with the experience and their assessments regarding its usefulness in their work. Participant reactions, according to Kirkpatrick's (1959) Four Levels of Evaluation, are important to consider but are not sufficient to ensure learning. When these are the only type of evaluations rendered, we end up rarely knowing what impact the professional development activity had on pedagogical change or student learning. Smylie (1989) commented that "much of what is known about the effectiveness of sources of teacher's learning comes from a limited range of studies that report teachers' opinions about a specific source or group of related sources of learning" (p. 544). In support of this claim, Showers, Joyce, and Bennett (1987) found that professional development assessments only take into account how participating teachers react to the activity. Moreover, Guskey and Sparks (1991) stated that the effectiveness of programs is usually restricted to self-reported changes in knowledge, beliefs, and behaviors after going through some professional development activity. Consequently, we do not know what teachers learn from professional development or how it changes their pedagogies; we only know what they think about professional development activities. More elaborate and in-depth evaluations of professional development activities are crucial if we are to grow our knowledge base and to transform our practice in this area.

Furthermore, reports on the effectiveness of professional development have been limited to the perspective of teachers, without taking into consideration the impact on student learning. Kennedy's (1998) literature review found 10 of 93 studies that assessed the effects on students as a result of teacher professional development. Difficulties in understanding the effects of professional development on students are exacerbated by the fact that student learning is influenced by many different sources, not just by a direct link through a teacher from professional development. In addition, gains in achievement do not take place in isolation from other outcomes. Some professional development activities may focus on improving achievement and others on attainment (e.g., reducing dropout rates) or other outcomes (e.g., reducing drug use). There needs to be a clear articulation of the intended outcomes of professional development, and appropriate evaluation strategies must be implemented to assess them. This has not been the case with the majority of professional development evaluations reported in the literature.

Finally, the majority of professional development opportunities are attended on a volunteer basis (Bobrowsky, Marx, & Fishman, 2001). Volunteers differ from nonvolunteers in terms of their motivation to learn, their commitment to change, and their willingness to be risk takers (Loughran & Gunstone, 1997; Supovitz & Zief, 2000). The needs of volunteers and nonvolunteers may be intrinsically different from one another. These characteristics of the participants must be included in any design aimed at understanding successful professional development of all teachers, not merely those who seek out the opportunities on their own.

Having laid out some of the factors that must be considered in an evaluation scheme focused on the quality and efficacy of teacher professional development, we now turn to issues related to the content of that professional development. In the present case, the content is concerned with supporting teachers in developing the knowledge and skills to effectively integrate technology into the teaching and learning process. As we shall argue in the next section, there are multiple roles for technology in the teaching and learning process, and thus, any research and evaluation of professional development about technology in instruction must take into account the depth, the breadth, and the precise focus of the professional development activities.

III. Professional Development on What: The Integration of Technology Into Teaching and Learning

Technological literacy has fast become one of the basic skills of teaching. The sheer increase in the availability of electronic resources in schools and classrooms makes it important for teachers to be prepared to effectively integrate technology into their instructional practices. Unfortunately, the evidence suggests that technology is often poorly integrated with other classroom instructional activities. Word processing and basic-skills practice are the most frequent uses of computers in instruction, whereas the use of applications that engage analytical thinking and problem solving through simulations and other media is relatively infrequent (Becker, 1999; Hart, Allensworth, Lauen, & Gladden, 2002).

Contrasts between traditional and innovative uses of technology serve to underscore the fact that teachers can use technology to support a variety of instructional models that differ in their goals and approaches to learning and teaching (Cognition and Technology Group at Vanderbilt, 1996). Some of the debates over whether classrooms need computers and whether technology works hinge on the differences in philosophies of schooling, theories of learning, and visions of the role (or roles) of technology. For example, many initial uses of computer technology in schools mirrored the then-dominant teacher-directed models of instruction in which students memorized facts and practiced procedures (Suppes & Morningstar, 1968). As conceptions of learning expanded beyond the acquisition of factual and procedural knowledge, individuals began exploring ways for technology to support models of instruction that emphasized student development of conceptual understanding through processes that often required active engagement with complex academic content.

Available evidence suggests not that technology creates educational improvement but rather that educational improvement comes about through coherent instruction and assessment that supports high-quality student learning (Goldman, Lawless, Pellegrino, & Plants, 2005–2006; Newman, Smith, Allensworth, & Bryk, 2001). Technology can make it quicker or easier to teach the same things in routine ways, or it can make it possible to adopt new and arguably better approaches to instruction and/or change the content or context of learning. Decisions about when to use technology, what technology to use, and for what purposes cannot be made in isolation of theories and research on learning, instruction, and assessment.

National Research Council reports such as *How People Learn* (Bransford, Brown, Cocking, Donovan, & Pellegrino, 2000), *Knowing What Students Know* (Pellegrino, Chudowsky, & Glaser, 2001), and *How Students Learn History, Mathematics and Science in the Classroom* (S. Donovan & Bransford, 2005) provide important summaries of contemporary research and theory on the nature of learning, instruction, and assessment. They describe characteristics of powerful learning environments and simultaneously highlight the diverse ways in which information technologies can be used to help support the creation and enactment of environments that are instrumental for achieving the types of learning outcomes espoused in contemporary educational standards. An extensive discussion and review of the many technology-based resources available to support the design of effective instruction can be found in Goldman et al. (2005–2006).

The relevance of the literatures on learning, instruction, assessment, and technology to the purpose of this review should be clear. It is critical to ask about the content of professional development related to technology and instruction. It is essential to separate and contrast professional development focused on the integration of technology into instruction with professional development focused on learning about technology (e.g., what types of software and tools may be available) or professional development focused on learning how to use a particular piece of software, such as a browser, or a productivity tool, like a spreadsheet or a video capture or editing program.

Any attempt to evaluate professional development efforts for technology and instruction must of necessity carefully examine what was the content focus of the professional development and what were the measures used to ascertain whether that professional development had an impact on teacher knowledge and behavior and/or specific student-learning outcomes. Treating technology as an omnibus—an undifferentiated variable in education and in the professional development of teachers—perpetuates an overly simplistic view of what it means to integrate technology into the instructional environment.

IV. Conceptual Schema for Evaluation of Professional Development on Technology: Definition and Application to the Research and Evaluation Literature

Elements of the Schema

The prior sections provide some perspective on critical components that should contribute to any research and evaluation of professional development for teachers (or other educators) in the integration of technology into instruction. It points to the fact that research and evaluation must take into account the nature of the professional development program design with respect to features known to make a difference, such as how it was delivered, the nature of the activities that were pursued, the duration of the activity, and the nature of the content about technology and instruction. In essence, there are multiple possibilities about the form and content of the professional development, and these need to be sorted out in a principled way for absolute and/or comparative appraisals of the effects of programs. Professional development designs can be judged on their own merits and also in the context of the larger literatures of what we know about what typically constitutes quality professional development designs in general and what we also know about important versus less important forms for integrating technology into instruction.

In Figure 1, the issues raised above constitute one of three critical dimensions in an overall schema that can be used retrospectively to classify programs and research studies and prospectively to define possible research and evaluation study designs. Clearly, what we term *type of professional development*, which includes issues of delivery, duration, and content, is a critical component of any evaluation. A second, orthogonal dimension in any evaluation design concerns the unit (or units) of analysis that serves as the focus of any research/evaluation of the outcomes and efficacy of that program. The units vary from a focus on overall program outcomes to a focus on teacher change to a focus on student achievement. Each unit of analysis is typically associated with a range of possible outcome measures that also need to be specified. Some of the measures may be quantitative, whereas others may be qualitative, and the overall quality and meaningfulness of the measure, quantitative or qualitative, is of critical concern.

The third dimension concerns the nature of the research/evaluation study design and method, above and beyond the issues of unit of analysis and measures. In the literature on professional development, studies often range from descriptions of an

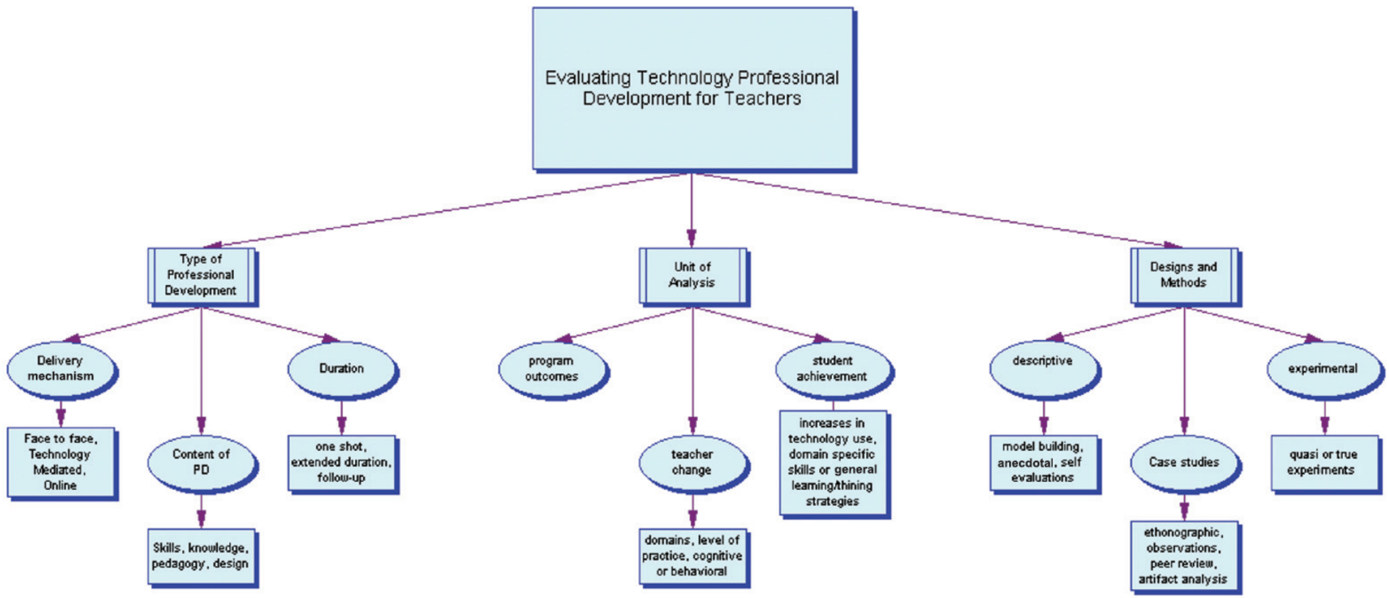

FIGURE 1. *Evaluation schema. PD = professional development.*

intervention to detailed case studies, single or comparative, to experimental designs representing true randomized experiments or quasi-experimental designs. The latter, however, tend to be rare. Clearly, the nature of the inferences one can draw from any study and the generalizability will depend on the nature and quality of the designs and methods.

The schema illustrated in Figure 1 was used to sort, classify, and evaluate the research studies that have been published on technology-related professional development. Doing so allows for a systematic appraisal of what is known about the professional development of teachers in technology integration and the overall quality of the research and evaluation literature in this field. Before discussing the outcomes from that application, we first present the process by which the relevant literature was identified and some of its general characteristics.

General Characterization of the Recent Research Literature

Using the four main database search engines for research literature in education (i.e., EBSCO, Firstsearch, ERIC, and Ed Abstracts), a query was conducted for articles published within the past 5 years examining technology professional development. This time frame for article selection was made due to the rapid changes in the technologies themselves. Prior to 1999, school infrastructures were significantly less rich, Internet speed was significantly lower, and federal funding initiatives for technology reform efforts were in their infancy. The resources and environments in which teachers and students were expected to use technology prior to 1999 are no longer analogous to current standards, and the literature from this period would likely add little to the understanding of professional development on the integration of technology into instruction. Articles that pertained to K–12 teacher professional development, focusing on technology integration (i.e., not through technology), and that contained empirical data evaluating the professional development activities or programs were retained. An empirically based study was defined as any study that had a systematic data collection plan (qualitative or quantitative) that was created to answer specific research/evaluation questions that were established a priori. This search isolated 28 manuscripts relevant to the topic keywords. Each of these papers was then cross-referenced using the Web of Science–Social Science Citation Index, yielding an additional 10 articles. Finally, a Web search of large research organizations known to conduct evaluation research projects produced another 4 articles. This pool of 42 articles was then reviewed more closely for content. The final pool of research papers meeting all of these criteria was 21 articles or conference papers, which are outlined in Table 1. Aside from these 21 articles, the majority of the literature published or archived relating to technology professional development for teachers was found to be descriptive pieces detailing individual programs and lessons learned from implementations or studies that use technology not as content but as a medium for delivering professional development in other teaching and learning domains.

The paucity of empirical research examining the area of technology professional development for teachers is astonishing. Although there has been substantial funding for training teachers to use technology (e.g., NCLB, Preparing Tomorrow's Teachers to Use Technology [PT3], and the Fund for the Improvement of Post

(text continues on p. 593)

TABLE 1
Instructional technology professional development evaluation articles

Article reference	Type of professional development	Type of evaluation (type of data)	What was evaluated (unit of analysis)	Number of participants
Holland, P. E. (2001). Professional development in technology: Catalyst for school reform. *Journal of Technology in Teacher Education*, *9*(2), 245–267.	Not specified	Case study, survey–no real method section	Teacher's knowledge level, alignment to best practices, and the role of professional development in school reform	61 teachers
†Cole, K., Simkins, M., & Penuel, W. R. (2002). Learning to teach with technology: Strategies for inservice professional development. *Journal of Technology and Teacher Education*, *10*(3), 431–455.	Mentors, minigrants, design–based partnerships, and multimedia fairs	Qualitative and quantitative: annual survey of teachers, observation data, interviews, and student performance assessment	Targeted as an evaluation of the overall project and its implementation and replicability but also looked at teacher perception and quality of student work	150 teachers from 50 schools in 11 districts
†Rosaen, C. L., Hobson, S., & Kahn, G. (2003). Making connections: Collaborative approaches to preparing today's and tomorrow's teachers to use technology. *Journal of Technology and Teacher Education*, *11*(2), 281–306.	Collaborative approach to develop teacher candidates, with collaborating teachers and teacher educators	Multiple-choice survey, artifact analysis	Teachers' basic skills, technology use (frequency), and attitudes about technology prior to professional development	24 teacher candidates and 15 collaborating teachers

(continued)

TABLE 1 (continued)

Article reference	Type of professional development	Type of evaluation (type of data)	What was evaluated (unit of analysis)	Number of participants
†Mitchem, K., Wells, D. L., & Wells, J. G. (2003). Effective integration of instructional technologies (IT): Evaluating professional development and instructional change. *Journal of Technology and Teacher Education*, *11*(3), 397–414.	Series of yearlong professional development activities including a summer institute	Pre-professional development lesson plan, basic skills survey, lesson unit-scoring rubric across critical variables of sound technology-infused lesson planning	Teachers self-assess computer skills and technology integration in lessons as a measure of pedagogical change	27 teachers
Hughes, J. E., & Ooms, A. (2004). Content-focused technology inquiry groups: Preparing urban teachers to integrate technology to transform student learning. *Journal of Research on Technology in Education*, *36*(4), 397–411.	Content-focused technology inquiry groups	Longitudinal case study including initial interview and annual interviews, meeting agendas, field notes of consultations, and observations	Utility of inquiry groups for reform (implementation)—no information on observations was provided as a measure of pedagogical change	5 teachers
Keller, J. B., Ehman, L. H., & Bonk, C. (2004, April). *Professional development that increases technology integration by K-12 teachers: Influence of the TICKIT program*. Paper presented at the annual meeting of the American Educational Research Association, San Diego, CA.	Technology integration projects, graduate course work, and workshops	Level of Technology Implementation Scale, demographic data, perceptions of Teacher Institute for Curriculum Knowledge About the Integration of Technology (TICKIT), and self-report teaching change	Teacher levels of technology implementations as self-reported data and perceptions of their experience	133 teachers in treatment and control combined

†Beckett, E. C., Wetzel, K., Chisholm, I. M., Zambo, R., Buss, R., Padgett, H., et al. (2003). Supporting technology integration in K–8 multicultural classrooms through professional development. *TechTrends*, *47*(5), 14–17.	Training and design of a unit of practice (UOP)	42-item Likert-type scale of beliefs and self-reported skill levels at pre-post	Teachers' knowledge and skill, self-reported	43 preservice teachers and 19 in-service teachers
†Mills, S., & Tincher, R. C. (2003). Be the technology: A developmental model for evaluating technology integration. *Journal of Research on Technology in Education*, *35*(3), 382–401.	Institute, workshops, seminars, and college credit courses	Technology Integration Standards Configuration Matrix: self-report rubric	Progress of teachers in meeting technology standards and progressing through stages of technology integration	46 sets of pre-post sets of teachers—attrition
Parr, J. (1999). Extending educational computing: A case of extensive teacher development and support. *Journal of Research on Computing in Education*, *31*(3), 280–291.	5-year student laptop initiative and in-house development—specific training mechanisms not specified	Questionnaire and interview along with some document analyses and a few observations	Teacher's self-report knowledge, self-report use at home and in classroom, and concerns with different uses of computer for classroom purposes	48 teachers

(continued)

TABLE 1 (continued)

Article reference	Type of professional development	Type of evaluation (type of data)	What was evaluated (unit of analysis)	Number of participants
+Holbein, M. F., & Jackson, K. (1999). Study groups and electronic portfolios: A professional development school inservice project. *Journal of Technology and Teacher Education*, *7*(3), 205–217.	Study groups for computer skill training and portfolio development with a university liaison—direct instruction, independent work, and coaching	Teachers reflected after each session—no real discussion of how this was collected	Teacher's reflection of comfort and need for support	12 teachers
#Orrill, C. H. (2001). Building technology-based, learner-centered classrooms: The evolution of a professional development framework. *Educational Technology, Research and Development*, *49*(1), 15–34.	Reflection, proximal goals, collegial support groups, one-to-one feedback (coaching), and support materials	Participant observation and interviews	Utility of 5 components of the framework	2 teachers
Kariuki, M., Franklin, T., & Duran, M. (2001). A technology partnership: Lessons learned by mentors. *Journal of Technology and Teacher Education*, *9*(3), 407–417.	Instructional technology graduate students become mentors to elementary teachers	Participant journals, focus groups with graduate students and teachers, field notes from discussions, classroom observations, and meetings	Effectiveness of project for pedagogical change and recommendations for change	8 pairs

†Mulqueen, W. E. (2001). Technology in the classroom: Lessons learned through professional development. *Education*, *122*(2), 248–256.	Technical training, workshops, on-site visits, and online communication focused on the design of curricular materials	Could not be determined	Teachers' comfort and confidence levels	Could not be determined
Gonzales, C., Oickett, L., Hupert, N., & Martin, W. (2002). The regional educational technology assistance program: Its effects on teaching practices. *Journal of Research on Technology in Education*, *35*(1), 1–18.	Peer-directed constructivist-based workshops, train the trainers, pedagogy focused	Demographic data, self-report use and attitudes, open-ended questions about the useful aspects of the professional development, instructor interviews and observations of professional development training instruction, and self-assessments	Teachers' reported use of technology in the classroom, increased constructivist practices, increased collaboration, leadership—although collected, no information about change in actual student assignments was included	190 teachers
†Seels, B., Campbell, S., & Talsma, V. (2003). Supporting excellence in technology through communities of learners. *Educational Technology Research and Development*, *51*(1), 91–104.	Individualized training, summer camp, monthly professional development meetings, project sharing, technological skills workshops, and on-site staff support	Self-reporting instruments, event evaluations, journal entries, project checklists, videotaped presentations, and interviews	Teachers' skills, attitudes, and preferences	Hard to tell what the data are tied to, talked about project participation, but data seem to vary and came from different cohorts

(continued)

TABLE 1 (continued)

Article Reference	Type of professional development	Type of evaluation (type of data)	What was evaluated (unit of analysis)	Number of participants
#Yamagata-Lynch, L. (2003). How a technology professional development program fits into a teacher's work life. *Teaching and Teacher Education*, *19*(6), 591–607.	TICKIT—workshops, technology integration projects, and school support	Case studies at the district level, including document analysis, classroom observations, and interviews	How participants fit professional development in their work lives, teachers' perceptions of TICKIT, and self-report of how they use technology in teaching (not supported with information from observations)	7 teachers
#Martin, W., Culp, K., Gersick, A., & Nudell, H. (2003, April). *Intel Teach to the Future: Lessons learned from the evaluation of a large-scale technology-integration professional development program*. Paper presented at the annual meeting of the American Educational Research Association, Chicago, IL.	Train-the-trainer model, inquiry-oriented and project-based teaching curriculum development	End-of-training satisfaction surveys; self-report of technology use, materials use, and collegiality; observations of training, teachers' classrooms, and support interviews; and three case studies that included all of the above and interviews with students and student work analysis	Perceptions of training and efficacy of implementation model and its scalability	Total not specified

Ludlow, B. Foshay. J., Brannan, S., Duff, M., & Dennison, K. (2002). Updating knowledge and skills of practitioners in rural areas: A Web-based model. Rural *Special Education Quarterly*, *21*(2), 33–44.	Web-based content modules, reflection, and case studies	Audit trails, online surveys (participant perception and evaluations), discussion board content analysis, and focus groups	Teacher knowledge, skills, and satisfaction	Could not be determined
Gross, D., Truesdale, C., & Bielec, S. (2001). Backs to the wall: Supporting teacher professional development with technology. *Educational Research and Evaluation*, *7*(2), 161–183.	A technology-supported environment for teachers to plan, select, and implement technology-based professional development in their local contexts; begins with 1-day content training and has face-to-face and online support	Case studies including observations during school team meetings and some classroom enactments, 1-to-1 interviews with select participants, copies of lesson plans, and participant e-mail	Formative evaluations regarding the system	2 schools with 8 and 10 teachers each

(continued)

+Henríquez, A., & Riconscente, M. M. (1999, November). *Rhode Island Teachers and Technology Initiative: Program evaluation final report*. New York: Education Development Center's Center for Children and Technology.	Traditional paid training in 2-week summer institute and laptops	Pre-post survey	Teachers' perceptions of benefits and barriers to using technology, participant background and prior training experiences, what kind of technological classroom activities they are engaged in and their impact, and motivation to participate in training: all self-report	570 teachers
Nisan-Nelson, P. D. (2001). Technology integration: A case of professional development. *Journal of Technology and Teacher Education*, *9*(1), 83–103.	Summer workshop on technology-integrated health-related projects with students	Case study	Teachers' perceptions, with implications for design of professional development, learning-style inventory, problem-solving inventory, technology integration instrument (self-report) interview questionnaire, e-mail, and lesson plans	3 teachers

†Authors acknowledge federal funding for project (7 studies).
+Authors acknowledge state funding for project (2 studies).
#Authors acknowledge private foundation funding for project (3 studies).

Secondary Education), the majority of this funding has been directed toward the development and implementation of these outreach activities. Out of the 21 articles, only seven of the authors acknowledged federal support for their projects (Beckett et al., 2003; Cole, Simkins, & Penuel, 2002; Mills & Tincher, 2003; Mitchem, Wells, & Wells, 2003; Mulqueen, 2001; Rosaen, Hobson, & Kahn, 2003; Seels, Campbell, & Talsma, 2003). Five of these articles were linked to PT3 funding, where the emphasis on funding is directed at the reform of teacher preparation programs. In these projects, teacher professional development programs were only conducted in support of preservice teachers' field experiences. The professional development activities were not a central focus of the grant activities, and it is highly likely that little funding was allocated to producing research on best practices in this area. Private foundations funded an additional 3 studies, and 2 were funded by state-initiated professional development programs (Henríquez & Riconscente, 1999; Holbein & Jackson, 1999; Martin, Culp, Gersick, & Nudell, 2003; Orrill, 2001; Yamagata-Lynch, 2003). In each of these cases, the authors were either contracted to produce an external evaluation of the programs or to study the issues of implementation and local program impact for future scale-up models. In each of these cases, the research was constrained to the framework developed by the designers of the professional development opportunity and, as such, limited the ability to construct a high-level evaluation design targeted at providing generalizable information to the larger research community.

Furthermore, it is important to note that several of the studies used in this review varied in terms of the overall quality of the reported research. Many of the articles are missing key pieces of information that were needed to make a thorough evaluation of their merit. In addition, the format of many of the articles made it difficult to follow their exact treatments and methods, placing the replicability of the programs in question. Overall, issues such as these leave the literature base on technology professional development at best impoverished and at worst uninformative.

Although there are fewer empirical studies evaluating technology professional development than might be expected, and the overall quality of many of the articles is debatable, the essential elements of the existing studies can be mapped against elements of the organizing schema discussed earlier and shown in Figure 1. The schema provides a means for examining the body of knowledge that does exist and what it potentially reveals about best practice.

Application of Schema Category 1: Type of Professional Development

There are numerous approaches to professional development that have been summarized in the literature. Each approach has its own strengths and weaknesses. Moreover, each approach focuses on different types of content, affords different outcomes, practices different methods for achieving teacher change, and varies in terms of the duration of the training. In prior reviews of professional development, the most common form of professional development is offered via one-shot workshops, with teachers spending as little as 1 hour to 1 day in professional development per year in any given content area (Parsad, Lewis, & Farris, 2001). This traditional approach to technology-based professional development has focused on showing teachers how to operate equipment and software rather than how to integrate technologies into instruction (Knapp, 1996; McCannon & Crews, 2000).

Research has indicated that this type of fragmented approach to professional development does not meet the ongoing pedagogical needs of teachers and is often too far removed or disconnected from day-to-day classroom practice (Gross, Truesdale, & Bielec, 2001; Moursund, 1989). Although several of the studies collected for this review indicated that they used these workshops as part of their overall comprehensive model (Gross et al., 2001; Keller, Ehman, & Bonk, 2004; Mills & Tincher, 2003; Mitchem et al., 2003; Mulqueen, 2001; Seels et al., 2003), only two studies reported a short inoculation training as the primary vehicle for professional development (Henríquez & Riconscente, 1999; Nisan-Nelson, 2001). The movement of the field away from quick in-and-out workshops for technology integration would support the notion that the best professional development activities are spread out over time with opportunities for follow-up learning and feedback.

Many of the teacher professional development programs reviewed also included design-based components as part of their curriculums (Beckett et al., 2003; Cole et al., 2002; Keller et al., 2004; Martin et al., 2003; Mitchem et al., 2003; Mulqueen, 2001; Yamagata-Lynch, 2003). The design-based approach affords teachers the opportunity to learn how to use specific technologies situated in the context of their curricular needs. As a result, teachers take more ownership of the resources, have higher confidence in integrating the unit as a teaching tool, and are more likely to believe that the curriculum resources will have a positive impact on student achievement (Kubitskey, Fishman, & Marx, 2003). An essential element of this approach was the inclusion of opportunities for teachers to reflect on their learning and pedagogy as well as sessions aimed at sharing their newly developed curricular units. These aspects of the design-based model add to the active engagement of the teachers and help to build communities of colleagues within and across school settings that will sustain the efforts long after the conclusion of the training.

A third common component of much of the research published in the past few years indicates a new trend toward using a mentoring or coaching model to support teacher change (Cole et al., 2002; Holbein & Jackson, 1999; Kariuki, Franklin, & Duran, 2001; Mulqueen, 2001; Orrill, 2001). Key features of the mentoring approach are that assistance is provided in the context of a personal relationship and is focused on the individual needs of the protégé (MacAurthur & Pilato, 1995). The type of mentor or coach provided varied from project to project and included technology-savvy colleagues, graduate students in instructional technology, and online or virtual mentors. Evaluation of the mentor component of these programs illustrated that the teachers became more comfortable with the technology and developed a greater proficiency in their computer use as a result of their participation. Furthermore, results revealed that both mentors and mentees benefit from this type of activity, with transformation in understanding technology as a tool for teaching and learning as well as how to best provide collegial support over time.

Finally, a few of the studies employed a train-the-trainers model of professional development (Gonzales, Oickett, Hupert, & Martin, 2002; Martin et al., 2003). The practice of initially working with one group of teachers who will then assume the responsibility of training a new group of colleagues has shown promise as a means to support the scale-up of many smaller interventions. Furthermore, research has indicated that teacher instructors understand classroom culture and the demands of teaching. As a result, their guidance is often more relevant and credible to other teachers (Howard, McGee, Schwartz, & Purcell, 2000). Research has indicated that train-the-trainer models were successful in reaching large audiences of teachers, providing a much larger impact. However, evaluators of the Intel Teach to the Future program (Gonzales et al., 2002) also cautioned the field that this model often failed to account for the local needs of teachers in technology training and might not provide the most relevant training for certain contexts.

No studies identified for this review compared models of professional development. Each study only examined characteristics relevant to its own design. As a field, if we are to understand which types of activities and programs establish best practice, then future studies must begin to systematically manipulate the various design elements and isolate not only what works but also what does not work, for whom, and the contexts in which each element is most appropriate.

Application of Schema Category 2: Unit of Analysis

In any project-based evaluation, there are a large number of variables that can be examined and a plethora of stakeholders and data sources that can provide information pertaining to change over time. When considering what elements are critical to the study in the context of technology professional development for teachers, there are three main categories that are important to consider: programmatic issues, teacher change, and student achievement.

Program Outcomes

Programmatic evaluations center on formative issues of implementation, cost, and feasibility. Results from this genre of evaluation are typically used for revision of the professional development or scaling of the project for delivery to a larger audience. Six of the studies included in this literature review focused on programmatic issues (Cole et al., 2002; Gonzales et al., 2002; Gross et al., 2001; Hughes & Ooms, 2004; Keller et al., 2004; Orrill, 2001; Martin et al., 2003). In several instances, an external evaluation group that was not directly involved in the design or delivery of the professional development activities conducted these evaluations. All six of these studies employed a mixed methodological approach. That is, they used both qualitative and quantitative approaches to collecting data, most commonly using interviews and survey collection procedures. In addition, compared to the remaining pool of studies in this review, these studies tended to have much larger sample sizes and had multiple data collection periods over the entire duration of the project.

Large-scale implementation studies such as these have the potential to shape our understanding of best practice. For example, prior research in the area of professional development has emphasized the need for activities to be tailored to individual teachers' needs and the contexts of the teachers that they serve (Culp, Hawkins, & Honey, 1999; Hawkins, Panush, & Spielvogel, 1997) as well as a connection to a school's overall vision for change and administration (Adelman et al., 2002; NFIE, 1996; Porter et al., 2000; Sparks, 2002). However, in their review of the Intel Teach to the Future program, Martin et al. (2003) found not only that participants found the material relevant to their own classroom practices but that the large scale of the project was also useful in leveraging changes in infrastructure and resources within their local settings—an unanticipated impact. Studies like this are necessary to challenge common practice in professional development, to make evidence-driven decisions, and to improve our knowledge base of what constitutes best practice in technology integration programs.

By contrast, none of the studies included in this review conducted a cost-benefit analysis or a feasibility study for scaling a particular intervention from the local to the national level. To understand if a particular intervention is viable on a larger scale, there must be a more careful analysis of the necessary resources for its implementation and the benefits for conducting a particular intervention across multiple contexts.

Teacher Outcomes

Issues of teacher change and enhancement are central to most professional development activities. Research has indicated that change is a multidimensional variable, including both cognitive and affective components (Schrader & Lawless, 2004). Researchers must consider increases in teachers' knowledge levels and elevating their attitudes and confidence. Moreover, these constructs are tied not just to knowing how to use a particular piece of technology or software or to the belief that students in the 21st century must engage with technology on a regular basis; they are also centrally tied to a teacher's understanding of pedagogy (i.e., pedagogical content knowledge) and to how these various technologies can facilitate learning and achievement among students and to how to assess the various outcomes of learning in these contexts.

In all, 9 of the 21 studies included in this review used an explicit method for evaluating change in teacher technology skill levels and reported increases in skill with technology as a result of teachers' participation in the professional development (Beckett et al., 2003; Gonzales et al., 2002; Holland, 2001; Keller et al., 2004; Ludlow, Foshay, Brannan, Duff, & Dennison, 2002; Mitchem et al., 2003; Parr, 1999; Rosaen et al., 2003; Seels et al., 2003). Each of these studies used a self-report rating-scale method for assessing skill improvements. Although this is an easy way to obtain an outcome measure, research has indicated that what is actually being measured is not knowledge but a person's confidence within a particular topic area or domain (Lawless, Kulikowich, & Smith, 2002; Schrader & Lawless, 2004). Although more objective measures of knowledge are much more difficult to construct, if we are to understand the true impact of professional development on increments in technology procedural knowledge and skill, as well as pedagogical content knowledge, we will need more accurate gages of actual knowledge growth.

As is the case with teacher attitudes toward professional development in general, measuring perceptions of the activities, technology integration, and teacher confidence with technology are still a common practice in the current literature on technology professional development. Data on these outcomes were witnessed in almost all of the evaluations, with the trend being that, overall, teachers liked the experiences and felt more comfortable using technology and more confident in their abilities to integrate technology into their classrooms. Although this information is interesting and indicates that the professional development activities did not increase stress or decrease a teacher's sense of self-efficacy, these data alone are not all that enlightening with respect to helping to delineate best practices. Because all studies provided positive results across these constructs, it leads one to conclude that perhaps this information is lacking in evaluative power and that researchers should consider combining such information in a statistical model with other variables that tap into deeper levels of teacher change.

Arguably, the most important impact a professional development activity can have on a teacher is that of pedagogical practice change ostensibly reflecting a deeper change in pedagogical content knowledge. What do teachers do differently in their classrooms as a product of professional development? How has their instruction changed? How do these changes inform future practice? A number of studies attempted to address questions such as these by observing teacher classroom practice (Cole et al., 2002; Hughes & Ooms, 2004; Kariuki et al., 2001; Martin et al., 2003; Orrill, 2001; Parr, 1999; Yamagata-Lynch, 2003). Unfortunately, although these studies reported collecting such data, few used the data as an evaluative source, nor did they detail the findings of the observations. Where the classroom teaching observation data were detailed, they were used as information that informed the researchers on the design of the professional development and did not focus on any pedagogical changes that had transpired (Orrill, 2001; Parr, 1999; Yamagata-Lynch, 2003).

The collection and analysis of teacher lesson plans was pursued in a few of the investigations (Gross et al., 2001; Mitchem et al., 2003; Nisan-Nelson, 2001; Yamagata-Lynch, 2003). Mitchem et al. collected teacher lesson plans prior to participation in a summer institute professional development experience. In addition, they conducted a random lesson plan sweep from participants in the academic year following the institute. Using a research-based 37-item rating scale, raters scored the pre- and posttraining lesson plans looking for indicators of instructional changes such as objectives, procedures, strategies, integration, and assessment. Postinstitute lesson plans scored significantly higher on each indicator, except on objectives and assessment. The authors concluded that, overall, the teachers had begun to change their pedagogical approaches through the integration of technology but that they needed to reform their professional development to include issues such as how to assess student learning with and through technology.

As a proxy to more direct measures of teacher pedagogical change, teacher interview or focus group questions were a common technique (Cole et al., 2002; Gross et al., 2001; Holland, 2001; Hughes & Ooms, 2004; Kariuki et al., 2001; Martin et al., 2003; Orrill, 2001; Parr, 1999; Yamagata-Lynch, 2003) as was self-report technology use in the classroom (Cole et al., 2002; Gonzales et al., 2002; Henríquez & Riconscente, 1999; Keller et al., 2004; Mills & Tincher, 2003; Parr, 1999). Across all of these studies, most teachers reported an increase in technology use in the classroom and a broader number of technology-mediated tools for teaching. It is important to note, however, that if these data are not triangulated with more direct measures of pedagogical change, it is difficult to determine how much of the increase in participant ratings is actually attributable to the professional development versus other factors that may boost the self-reports, such as administrative, peer, or parental pressure to integrate technology.

Student Outcomes

The overarching rationale for the increase in state and federal funding that has been leveraged for technology professional development for teachers is to provide better instruction for the 21st-century learner and increase student achievement through technology-enhanced learning opportunities. In light of this rationale, a critical evaluative audience regarding the success of a particular professional development program is the students. However, only 2 of the 21 studies collected as part of this review collected any data from the students of teachers participating in professional development. Although student interviews were conducted as a part of the Intel Teach to the Future evaluation (Martin et al., 2003), the data were not presented in the paper reviewed. In contrast, Cole et al. (2002) looked at artifacts from classroom projects to judge the impact on student outcomes. In an analysis of the multimedia projects produced by students of teachers who completed a professional development program, they found that students of teachers receiving professional development outscored other students on performance measures of content, design, and overall quality.

The dearth of data collected on student outcomes from teacher professional development programs provides little insight into how technology is affecting our classrooms. We have no information on how students are integrating technology across disciplines and grade levels or even if their skill with the technology, in and of itself, has improved as a result of the professional development opportunities. Assessment at the student level must be a key component of future professional development study designs if we are to inform practitioners of best practice in this field.

Application of Schema Category 3: Designs and Methods

Mandinach and Cline (1997) point out that different data collection techniques are common among program evaluation studies in the area of educational technology and that it is not a straightforward process to integrate these data sources into an overall metaevaluation study. They suggested the need to focus on longitudinal designs, using multiple methods, including several levels of analysis, and systems analysis in lieu of more traditional methods. Perhaps the issue was stated best by Coley (1997):

> Traditional research designs are inadequate, inappropriate, and often ask the naive question, "Does it work?" The impact of technology is too multifaceted for such a simple question, which cannot be answered without considering the impact on students' learning and motivation; classroom dynamics, including interactions among students, teachers, and technology; and schools as formal organizations.

The design and methodological approaches incorporated into the evaluation of technology professional development found in this literature base reflected many of these tenets. However, although it is true that technology integration is a moving target and research designs need to be flexible to capture the dynamic nature of preparing and supporting teachers to integrate technology into their classrooms, there is still a great need to develop a structured and theoretically grounded approach to evaluating the impact of technology-based professional development. By and large, the use of systematic designs, driven by specific research questions, was a missing element in this literature base. In many cases, it was difficult to delineate from the written reports the exact methods and procedures that were followed. With a few exceptions, most of the studies presented in this literature review examined portions of the design implementation or outcomes of the professional development activities in isolation from one another and other important constructs. In addition, many researchers used data as a vehicle for developing the direction of the research inquiry rather than allowing the theoretical rationale from the literature to direct the evaluation. Across studies, multiple sources of information were sought and varied with respect to how they informed the conclusions of the analysis, and in many cases, data were collected and did not seem to contribute to the overall analysis.

As depicted in Figure 1, the studies reviewed here can be grouped into three main categories: descriptive accounts, case studies, and (quasi) experimental reports. Many of the descriptive accounts in this area take the form of anecdotal explanations of process and implementation. Although this genre of studies informs the field of current practice in the area of technology professional development, it provides little direction in identifying what works, for whom, and under what conditions. In light of this, this review does not include any research that does not contain empirical data evaluating the programs of study.

The dominant mode guiding the data collection among the present group of studies was a case analysis technique. This emergent-design approach can afford rich data concerning issues of implementation, teacher change, and the process of curriculum reform. In this approach, researchers employed a variety of techniques to assemble evidence regarding program success and efficiency in achieving goals, ranging from teacher interviews, observations, questionnaires, and document analysis. Holland (2001), performing a case study of one school that engaged in professional development, found that across teacher comfort levels with technology it was the human infrastructure and support resources provided that were the primary ingredient to helping teachers to reinvent their role as technology continues to redefine methods of best practice. Cole et al. (2002), using similar techniques, also found that professional development opportunities alone were not sufficient in promoting reform. They stated that it was the synergistic effect of providing training along with longer term support for teachers that yielded the most successful results. Other case studies isolated similar conclusions in terms of institutional support (e.g., Nisan-Nelson, 2001; Yamagata-Lynch, 2003). Although these findings yielded important information concerning the challenges of sustaining reform, each one failed to approach the evaluation in a longitudinal manner. This research only reports data collected post hoc, after training had been developed and implemented. As a result, the field is left with only a portion of the total picture. Without periodic collection of data over the entire span of the professional development program, it is difficult to make conclusions about which variables changed due to the training and which changed because of other intervening constructs not under investigation.

A few studies did take a more longitudinal approach to examine effects over time through case studies (Gonzales et al., 2002; Gross et al., 2001; Hughes & Ooms, 2004; Martin et al., 2003). One of the more rigorous case study designs, reported by Gonzales et al., evaluated the impact of the Regional Educational Technology Assistance (RETA) program. They state that the aim of their study was to describe "more concretely how children's learning environments and experiences change as a results of their teacher's involvement with the RETA project" (p. 1). Investigators collected pre- and postworkshop surveys, workshop evaluations, and teacher interviews and observations and employed self-assessment surveys. Through data triangulation, they found that teachers participating in the RETA program increased their use of computers both at home and in the classroom, improved their level of sophistication with computers, and worked more collaboratively with colleagues. However, although several data sources were collected, these conclusions were overly reliant on the teacher self-report surveys of computer use and integration, and no comparisons were made to teachers who did not participate in the training. Furthermore, although their stated efforts were focused on the impact on children, no data from students in the classroom were collected, and the classroom observations seemed to have little impact on how the results of the RETA program were reported.

In a similar study, Martin et al. (2003) reported on the impact of the Intel Teach to the Future national initiative. This evaluation, however, extended data collection to include student interviews and student work analysis. Unfortunately, most of the data discussed in the manuscript again came from self-report surveys and interviews, so it is difficult to ascertain what impact the professional development had on the students or what support the student data provided concerning classroom achievement.

Although case studies are an important avenue to pursue, they generate evidence regarding only which aspects of an existing or ongoing program of professional development facilitate change. Comparative studies must be conducted in conjunction with case studies if we are to determine how much these aspects promote positive growth. Furthermore, studies that are set up in an experimental fashion afford the ability to hold constant or to control certain variables in the teaching and learning context to better isolate mechanisms that are contributing to change.

Pre-post designs, although not the most rigorous of the experimental genre, allow participants in professional development to serve as their own controls. By measuring where teachers, students, and curricula are prior to participation in professional development, we can examine gains over time without the confound of prior experience or dispositions. Examining the constructs of knowledge and attitude gains in participating teachers, a number of studies employed a pre-post assessment design (Beckett et al., 2003; Henríquez & Riconscente, 1999; Mills & Tincher, 2003). In all cases, participating teachers indicated higher levels of skill with technology and integration, increased confidence in their abilities, and a greater appreciation for the uses of technology as a teaching tool.

Attempting to isolate the construct of instructional change, Mitchem et al. (2003) conducted a pre-post design study examining changes in randomly selected lesson plans prior to and after participation in professional development. Using a researcher-designed scoring rubric, they found that teachers participating in their professional development program significantly increased the number of technology-enhanced instructional strategies and procedures in their lessons; active student engagement was increased as well.

Pre-post research designs only scratch the surface with respect to controlling for extraneous variables. To systematically rule out competing hypotheses, designs must study not only participants of professional development but nonparticipants as well. Only 1 study of the 21 qualifying for this literature review employed a quasi-experimental approach. Keller et al. (2004) conducted a quasi-experiment examining the Teacher Institute for Curriculum Knowledge About the Integration of Technology (TICKIT) model of professional development. In total, 133 teachers were evaluated. One group of teachers had already completed the TICKIT program, and the second were teachers that had applied to participate in the TICKIT program in the future but had not yet experienced the program. Respondents from both groups completed a two-part survey. The first part of the survey focused on demographics and current teaching practice. The second half of the survey was composed of the Level of Technology Implementation Scale, an instrument that measures a teacher's level of technology integration in a rating-scale format. Results indicated significant differences favoring TICKIT completers over noncompleters across all variables measured.

Selected Conclusions About the Research Literature

A few concluding remarks regarding overall patterns of technology professional development evaluation design and method are clearly warranted. First, although the literature indicates that research in this area should be flexible and perhaps nontraditional in some instances, nowhere is it indicated that rigor should be sacrificed. If we are to gain any insight into best practice, we must be more careful and systematic with our research plans. There is a clear need for theoretically driven research questions that inform issues of sampling, instrumentation, and analysis. For example, no study included in this review examined any individual who had not already participated in the professional development program offered or who had not indicated interest in doing so in the future. If we are to understand who is best served by different approaches to professional development then we need to examine why certain teachers volunteer to participate and others do not. Furthermore, we need to pursue a much larger continuum of research and evaluation designs. The majority of studies included in this review implemented case study designs. Case studies are a useful first step to illuminate which variables are important to examine in more depth, but we need to push ourselves to take the next step and design more controlled studies that are more experimental in nature. Finally, new and more innovative approaches to collecting evidence and measuring change are desperately needed. The common practice of using self-report measures is not going to yield the type of data required to make evidence-based decisions regarding the adoption of professional development programs.

V. Prospective Application of the Evaluation Schema: Questions That Need to Be Addressed and Possible Approaches

Design Constraints

In considering the design of studies that might be pursued to evaluate professional development activities, attention must be given to possible constraints on the manipulation of conditions that teachers experience and/or on the processes of data collection. For example, the Section IV review of research on professional development for technology integration in instruction discussed the limitations of certain types of designs. It also called for more studies that involve experimental or quasi-experimental designs. Such designs provide for principled and systematic variation of one or more of the critical professional development component variables within our overall conceptual schema.

It is essential that the research agenda also focuses on key questions that need to be answered about the characteristics and quality of the professional development experiences and, so far as it can be determined, the relationships among the various program characteristics and important outcomes at the level of teacher knowledge and behavior and student achievement. Careful documentation and mapping of these relationships can provide strong guidance for the development of subsequent intervention designs that might be pursued using stronger inference schemes associated with experimental and quasi-experimental research designs.

Components of a Possible Three-Phase Evaluation Design

An evaluation design that should be considered to guide the research process is illustrated in Figure 2. It involves successive data collection efforts that selectively focus on key components highlighted in the conceptual and empirical literatures on professional development and technology for teaching and learning (Sections II and III of this article). The three-phase design also allows for an examination of how variation among key characteristics at one level effects variation in important outcomes at the next level. Thus, it follows an assumed causal chain in which variation in the nature and quality of the professional development experience is linked to variation in important outcomes for teachers regarding technology and pedagogy that in turn can be linked to variation in important academic outcomes for students. This evaluation plan is similar in intent to Kirkpatrick's (1959) Levels of Evaluation in that it addresses important components of an overall program and assumes a hierarchical relationship among these components. However, it differs from Kirkpatrick's model ostensibly in its target. Rather than evaluating a particular professional development program in isolation, the model presented in Figure 2 attempts to situate the program and its evaluation within the field of technology professional development such that each evaluation contributes to the larger database of known effective practices.

Given the sequential and contingent nature of the proposed three-phase design that is elaborated in the following discussion, serious consideration needs to be given to the process of defining the universe of professional development programs from which to sample and that would be subjected to detailed study within and across Phases I, II, and III. For reasons to be elaborated below, we believe that a staged approach to conducting the Phase I components of an evaluation needs to be given serious consideration, such that the universe of programs to be studied is defined more broadly than state- and district-level programs, with an initial focus on the identification and careful study of leading-edge professional development programs focused on technology integration prior to similar study of state- and district-supported programs. We believe that such an approach is likely to be more informative and cost effective if a major goal is to find out about the characteristics of quality and effective professional development practices in the area of technology integration and use that knowledge to determine whether such practices are part of the larger state and district landscape and with what frequency.

Put simply, there may be little sense in pursuing detailed study and documentation of professional development programs that lack the content specificity and quality features identified in our prior review of the literature. Rather, one would like to begin the analysis of the programs with a clearer sense of what constitutes quality professional development for technology integration across the K–12 grade span, taking into account issues of disciplinary content and instructional level. The identification of such candidate programs followed by careful study of their characteristics provides a context in which to both document and comparatively evaluate the professional development opportunities supported by a range of federal,

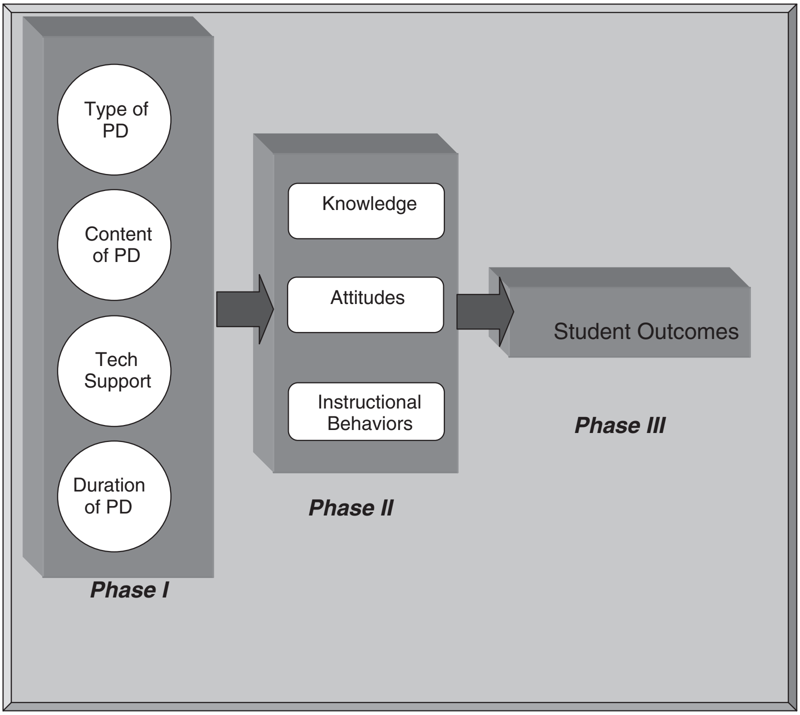

FIGURE 2. *Overall evaluation design. PD = professional development.*

state, and local funds. The next section elaborates on the rationale for such an evaluation strategy as part of the Phase I design and describes elements of the execution of such an evaluation plan.

Phase I: Focus on Types and Quality of Professional Development Opportunities

Key Questions

What are the key characteristics of technology professional development opportunities being offered at large to teachers? To what extent are these professional development opportunities reflective of the features of quality professional development programs in general? How do these factors vary as a function of content areas and grade levels of students? To what extent do the professional development opportunities focus on important pedagogical uses of technology?

To understand what constitutes quality technology professional development for teachers and the impact of such activities on teacher practice and student achievement, there must first be a grounded study of the universe of approaches that have been and are being offered as well as documentation of key constructs contributing to programmatic success. As stated earlier in the review of literature, there are a host of approaches to professional development. Each approach has its own strengths and weaknesses. Moreover, each approach focuses on different types of content, affords different outcomes, practices different methods for achieving teacher change, and varies in terms of the duration of the training. Although the literature provides individual accounts of professional development programs, there needs to be a more macrolevel study that examines and catalogues variation across programs on common constructs that delineate the professional development continuum.

In addition to identifying the common approaches, there needs to be assessments of how these various approaches address the indicators of quality professional development. According to the NFIE (1996), the quality of a professional development activity can be defined by a spectrum of variables including

Number of contact hours
Frequency and type of follow-up support
Level of access to new technologies for teaching and learning
Active engagement of teachers
Relevance of the activities to teachers' individual needs
Use of peer collaboration and community building
Clear articulation of a common vision for student achievement

The necessity here is not to develop an average for each professional development category on the key indicators. Rather, to later investigate which indicators have the largest impact, there must be documentation of how programs vary in terms of each indicator within each professional development approach category.

Beyond issues of the quality of professional development in general, there must also be a systematic collection of data related to the landscape of technology professional development more specifically. Of major concern is how the programs of professional development differ in terms of their approaches, impact, and effectiveness across content areas and grade levels. For example, although it is logical that the manner and type of technologies integrated in social studies would differ dramatically from those used in science, it is not clear whether these differences are made explicit to teachers during professional development. In reverse, we also do not know the extent to which teachers transfer specific training across content areas. These same arguments can be applied to professional development for teachers whose students vary in terms of developmental levels (i.e., elementary, middle, secondary). To the extent that technology leverages different outcomes across domains and levels of learners, the professional development must also vary.

Finally, the literature review also highlighted a number of adjunct issues related to the integration of technology into instruction that need to be addressed. These include

Focus of professional development (technology grounded or content embedded)
Delivery mechanism (face-to-face or online)
Skill development or pedagogy enriching
Linkages to theories of how people learn and how to assess this learning

Each of these constructs will likely impact how, when, and how often technology is integrated in classroom practice, and they are specific indicators of technology professional development versus more generic professional development opportunities.

Possible Outcomes

The key outcomes of a Phase I evaluation should include

- An understanding of the universe of professional development approaches pursued in programs across the nation and representative of multiple grade levels and content-specific pedagogies
- The identity of programs that align to key indicators for quality professional development and technology training practice as a baseline comparative group
- Descriptive observations of the implementation and impact of technology training practice to buttress self-report data from surveys
- Survey and observation protocols that can be administered for evaluative purposes in subsequent technology professional development initiatives
- A pool of candidate programs to examine in greater depth, both quantitatively and qualitatively, for Phases II and III

Phase II: Focus on Teacher Outcomes

Key Questions

What are the outcomes of different approaches to professional development on teachers' knowledge of (a) technology and technology-infused pedagogical approaches; (b) teacher attitudes and perceptions of professional development opportunities, including their self-efficacy concerning technology use for instruction; and (c) teachers' technology-related pedagogical behaviors in the classroom? To what extent are the various outcomes a function of teacher and context variables?

The notion that various aspects of learning correspond to more than one outcome measure is not a new idea. Bloom began developing a taxonomy of instructional objectives in three domains as early as 1956 (i.e., cognitive, affective, and psychomotor; see Bloom, 1976; Bloom, Englehart, Furst, Hill, & Krathwohl, 1956; Bloom, Hastings, & Madaus, 1971). Research not only confirms the importance of these constructs as outcomes of learning but describes a relationship among the cognitive, affective, and behavioral dimensions as well (Woolfolk, 1998). For example, Alexander (2003) has found strong ties between the cognitive and affective attributes of learners and their impact on the acquisition and comprehension of information. Ajzen and Fishbein (1977) reported that, although it is not the sole indicator, attitude is a factor in determining behavior, and Kim and Hunter (1993) added that the higher the attitudinal relevance, the stronger the relation between attitude and behavior.

With these arguments in mind, a growing body of research from different areas has ventured to adapt Bloom's taxonomy of instructional objectives into a multiconstruct approach to assessment that evaluates not only knowledge but attitude and behavioral change as well (Bruvold, 1990; Byrd-Bredbenner, O'Connell, & Shannon, 1982; Coyle et al., 1999; D. T. Donovan & Singh, 1999; Heppner, Humphrey, Hillenbrand-Gunn, & DeBord, 1995; Kapoor, 1989; Kirby, 1985; Lawless, Brown, & Cartter, 1997; Looker & Shannon, 1984; Miller, Booraem, Flowers, & Iversen, 1990). This approach has more simply become known as the KAB (i.e., knowledge, attitudes, and behaviors) method.

In addition to being a multidimensional approach to evaluation, each of the constructs within the KAB model is also composed of multiple components. Knowledge, for example, must tap several domains, including technology skills, technology-enhanced pedagogy, and theories of student learning and assessment with technology. Attitudes should measure not only satisfaction with the professional development but also the level of importance teachers place on infusing technology into instruction, self-efficacy in using technology in the classroom setting, and perceptions of the influence of new pedagogical approaches on student learning, to name a few. Finally, behaviors should be documented in terms of frequency of use, the type of technology that is integrated, and the intended instructional outcomes from these instructional approaches.

Although the type of professional development provided and its quality are likely to produce different KAB outcomes, there are also a number of teacher and context variables that may contribute to variation in these outcomes. The systematic investigation of these variables will begin to illuminate which approaches work well under a variety of conditions, leading to findings that are more generalizable than those reported by the current literature base. Many of these were highlighted in the review of the literature and include

- Teacher grade level
- Subject-matter area
- Years of teaching experience
- Support structures and climate for technology use within their respective schools and districts

Possible Outcomes

The key outcomes of a Phase II evaluation should include

- Development of psychometrically sound KAB instruments for wide-scale implementation across professional development programs
- Isolation of teacher and context constructs that meaningfully predict variance in teacher outcomes
- Identification of high-performing professional development programs in terms of teacher change
- Isolation of program attributes that consistently indicate quality professional development

Phase III: Focus on Teacher Change Over Time and Student Achievement Effects

Key Questions

What are the long-term outcomes of participation in technology-based professional development initiatives? Is teacher practice in the pedagogical use of technology for teaching and assessment sustained? What mechanisms were instituted to ensure long-term changes?

Although isolating critical attributes of quality professional development programs and measuring the resulting teacher change from these activities are key outcomes, perhaps the more important question rests on the outcomes these initiatives have on student performance. Unfortunately, regardless of the power of a professional development approach in promoting immediate teacher change, increases in student achievement take time. There is little precedence in the current literature base for long-term investigation of the outcomes of professional development. Furthermore, no studies identified in the review of recent literature examined even the short-term effects that technology professional development has on student learning or its relationship to achievement.

There are a number of factors that can interfere with studying student change. We know very little, for example, about the sustained level of teacher change as a result of participation in technology professional development. Although several studies have indicated that technology infusion increases immediately following training, we have no indication that pedagogical change persists. Nor do we know what support structures are helpful in maintaining long-term pedagogical change when it does take hold. Without ensuring that teachers continue to implement the new pedagogical practices they acquire through professional development, we have no way of correlating professional development approaches to changes in student performance.

Long-term change through technology-infused pedagogy is also complicated by the ever-evolving nature of the technology itself. Just as soon as a teacher becomes comfortable with one technology, a host of new and promising technologies emerge. The deictic nature of the soft and hard technologies for instruction and assessment demands that teachers continue to pursue professional development opportunities. From an instructional standpoint, this is a positive. However, from an evaluation standpoint, it is a complicating factor, adding confounds to the typical one-shot or cross-sectional designs employed in this area.

Possible Outcomes

The key outcomes of the Phase III evaluation should include

Detailed evidence of how teachers incorporate technology in their pedagogies over time and some of the prior training and/or concurrent support factors that influence observed changes

Evidence of any cumulative effect of teachers' use of technology on the academic achievement of their students

Evidence of differential effects of teachers' use of technology on the academic achievement of their students based on longitudinal and cross-sectional differences in how teachers incorporate technology into their pedagogical practices

Comments on Instrumentation, Measurement, and Analysis Issues

Much of the work outlined above for the three-phase evaluation plan depends on data collection instruments and protocols, most of which do not currently exist. In fact, the instrument creation, piloting, field-testing, and validation activities are a major component of the larger evaluation research endeavor. Selected subsamples of larger samples targeted for full-scale data collection within a given phase of the research plan will need to be used for the processes of testing and refining instruments and scoring procedures and determining their measurement properties. Issues of measurement sensitivity and reliability will need to be resolved to properly estimate the sizes of appropriate subsamples for Phases II and III to ensure sufficient statistical power for any proposed contrastive analyses. It is well beyond the scope of this article to provide details regarding all of the instrumentation that needs to be developed and validated for each of the three phases of the proposed evaluation research plan.

Although it may appear rather obvious, the types of data that would be collected under the proposed multiphase design, although rich in information, pose a variety of analysis and reporting challenges. Not the least of these challenges is the multivariate nature of the data and the need to employ methods that can effectively explore complex and contingent relationships among the data within a given design phase and across phases. Rather than waiting until the data are in hand to consider the modes of analysis, the design of the actual data collection should be done with full consideration of the types of analysis and reporting that are ultimately desired. This will ensure that instrument designs, sample characteristics, sample sizes, data collection, and scoring procedures are commensurate with the desired forms of analysis and reporting.

VI. Concluding Remarks

The proposed evaluation research plan has the potential to provide rich sources of information about critical issues regarding the types of professional development for technology integration in instruction and evidence regarding the impact on teachers and students. However, it is also clear that the yield from such a staged design, and its very execution, depend on what is actually observed in Phase I. It may well be the case that there is a wide array of quality professional development practices that focus on important aspects of technology use for instruction. If so, then further exploration of the impact of those practices on teacher behaviors and student achievement will be warranted and valuable. However, the possibility exists that the Phase I studies will return limited evidence of professional development opportunities and programs worthy of further, in-depth exploration. Thus, the outcomes of Phase I studies may yield insufficient cases to sustain the types of contingent, in-depth analyses that have been proposed for Phases II and III. Although this would be disappointing, it would nevertheless be revealing of actions that should be taken to ensure better investment of the valuable fiscal and human capital resources that will be allocated in the future to enhance technology use by teachers and improve educational outcomes for students.

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