Conditions for Classroom Technology Innovations

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This article reports on a study of the complex and messy process of classroom technology integration. The main purpose of the study was to empirically address the large question of "why don't teachers innovate when they are given computers?" rather than whether computers can improve student learning. Specifically, we were interested in understanding the conditions under which technology innovation can take place in classrooms. For a year, we followed a group of K–12 teachers who attempted to carry out technology-rich projects in their classrooms. These teachers were selected from more than 100 recipients of a technology grant program for teachers.

The study found 11 salient factors that significantly impact the degree of success of classroom technology innovations. Some of these factors have been commonly mentioned in the literature, but our study found new dimensions to them. Others have not been identified in the literature. Each factor can be placed in one of three interactive domains, the teacher, the innovation, and the context. The article discusses the 11 factors in detail and proposes a model of the relationship among the different factors and their domains.

INTRODUCTION

As investment in school technology continues to increase, so does the need for more systematic, relevant, and useful research on educational technology (Education Week, 1998; Honey, McMillan, & Carrigg, 1999; Norris, Smolka, & Soloway, 1999; President's Committee of Advisors on Science and Tech-

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nology, 1997). Traditionally, studies on educational technology have been largely interested in finding out, in horserace fashion, the relative success of particular technological innovations as it affects student learning (Berliner & Calfee, 1996; Honey et al., 1999; Norris et al., 1999). As a result, after nearly 30 years and hundreds of studies, we have a list of winners and losers—what technological innovations are more or less effective than others or more or less effective than traditional instruction. However, technological advances have made most of the winners obsolete (e.g., drill-and-practice software, laser-disk-based hypermedia, or instructional television), rendering early findings largely irrelevant to today's research and development in educational technology. Because many of these technology-specific studies did not explore more fundamental issues in technology and education—issues around the interface between technology and the educational establishment—the research community is having a difficult time offering desperately needed suggestions to policy makers and practitioners (Education Week, 1998; Norris et al., 1999).

A fundamental issue around the interaction between technology and education is the conditions under which technology can be effectively used in classrooms to improve student learning. However, regardless of the claimed educational benefits, technology must be used to have any impact on learning. Despite dramatic growth in access to modern computers in American schools (Anderson & Ronnkvist, 1999; Education Week, 1999), computer usage in the classroom remains disappointingly low (Cuban, 1999; Kent & McNergney, 1999; Loveless, 1996; U.S. Congress Office of Technology Assessment, 1995). The widely recognized gap between access to and use of computers in schools begs the question why computers are not used more in classrooms. To adequately address this question we must turn our attention to the interaction between technological innovations and school realities. One obvious place to observe such interaction is the classroom, where technology integration actually takes place. However, in spite of the rich tradition of research on classroom teaching and learning (Peterson & Walberg, 1979; Richardson, in press; Wittrock, 1986), there is a conspicuous lack of attention to the complexities and intricacies of how classroom teachers actually incorporate technology in their teaching.[1] The U.S. Congress Office of Technology Assessment (1995) notes "[T]here has been relatively little research on how and why American teachers use technology" (p. 51). A preponderance of the research about teachers and technology is survey studies looking for correlates among the many variables influencing teachers' use of technology for professional and personal reasons (Becker & Ravitz, 1999; Harris & Grangenett, 1999; Honey & Moeller, 1990). These types of studies tend to neglect the messy process through which teachers struggle to negotiate a foreign and potentially disruptive innovation into their familiar environment (Cuban, 1986; Fullan, 1991; Hodas, 1993).

Although past research in educational technology has mostly ignored this issue, there are abundant a priori explanations about why computers and other technologies have not been used more in schools. The list of proposed explanations runs long: from the incompatibility between technology and the current culture of schooling to the inherent unreliability of technology, from the ill-preparedness of teachers to the poor quality of educational software, and from the predominance of conservative pedagogy to the power of standardized assessment (Collins, 1996; Cuban, 1986, 1999; Education Week, 1999; Hodas, 1993; Loveless, 1996; U.S. Congress Office of Technology Assessment, 1995; Zhao & Cziko, in press). When taken together, these explanations present a seemingly comprehensive picture. But a closer look reveals that the theoretical and practical value of these explanations is limited in a number of ways. First, most of the suggestions neither are the results of empirical studies nor have been tested empirically. Second, these explanations do not define the important characteristics of each factor, the context in which the factors operate, nor the relationships among them. Lastly, the list is simply too long. It includes virtually everything about the school and technology, making it extremely difficult for practitioners to draw any practical insights.

THE CURRENT STUDY

The current study set out to address these issues by focusing on the complex and messy process of technology integration in real classrooms. The primary purpose of the study was to better understand the conditions under which technology innovations can successfully take place in classrooms. More specifically, we aimed at identifying factors that facilitate or hinder teachers' use of technology in their classrooms. We also expected to construct a model of relationships among the factors with the hope that such a model would help provide directions for future research, policies, and practice.

METHOD

Participants

Participants of the study were a subset of the recipients of a state technology innovation grant. The objectives of this grant program were to provide resources directly to the classroom teachers so that information technology could affect student success; to support innovative educators who have successfully integrated technology into the learning environment to increase student achievement; and to encourage innovative educators who have not previously used technology tools to expand their successful teaching and learning experiences by applying technology. Unlike most federal or state grants that usually award grants to an institution, such as a school or school district, individual teachers were the intended recipients of this grant. Teachers could apply for a grant of up to $10,000 to support their efforts to use technology in their classrooms.

More than 370 applications were received. The applications were evaluated based on the following criteria: innovative use of available technology; collaboration across school, district, and organizational boundaries; potential to have major impact on curriculum and instruction to improve student learning; degree of link to the state content standards and benchmarks for student learning; potential to replicate in other learning environments; team capability to disseminate good technology integration practice; and number of students impacted. Of the 370 applications, 118 teachers or teacher teams were selected to receive a total of $601,588. The average amount per grant was $5,098. The largest grant was for $10, 000, whereas the smallest grant was $1,000.

We were contracted to evaluate the program. The evaluation collected data at three levels: 1) all grant recipients (surveys), 2) a subset of 32 (surveys and interviews), and 3) a subset of 10 (surveys, interviews, and observations).[2] Findings reported in this paper are mainly from the 10 case studies, although we used the data from the larger population as references. The 10 cases were selected based on three criteria: 1) geographical location, 2) grade level, and 3) subject matter. Geographical location was used as the first criterion because in this particular state vast differences exist among schools in terms of student population, educational achievement, and particularly technology resources as a result of their relative geographical location. Another reason for using geographical location was political—the evaluation of a statewide program must include schools located in all distinct geographical regions. Grade level and subject matter were used as criteria because they have direct impact on the type of technology projects to be implemented. Initially 12 teacher teams were selected, but two dropped out of the study for personal reasons.

Analyses show no significant differences between the selected cases and the population (all grant recipients) in terms of technology proficiency, computer anxiety, current and planned uses of technology, beliefs about computers, and pedagogical styles. It is thus reasonable to assume that the 10 cases reported in this paper are representative of all 118 project supported by the grant. Table 1 depicts the background information of the participants and a summary of their proposed projects.

Procedures and Data Sources

A variety of data were collected throughout the year. First, a survey containing six subscales was administered to all 118 recipients. The six sub-

Table 1. Participant information

Pseudonym	School	Grade	Gender	Proposed Project Summary
Henry	Large, suburban high school	10–12	Male	Have students in his advanced multimedia class work with other teachers in developing Internet lessons (topic specific lessons posted on the Web containing graphics, links, and learning activities)
Susan	Midsize, rural middle school	6	Female	Use a compost project to implement a project-based, integrated curriculum with all the students taught by her team. The project would involve researching composting on the Internet, building composters, examining the process of composting with various technologies, using technology to analyzing the results with graphs, and presenting the results in writing and multimedia.
Heather	Small, suburban elementary school	2–3 *	Female	Train 16 teachers to use an interactive, Web-based learning environment that is designed to foster a community of learners approach to literacy development. Implement this software with the second- through fifth-grade special education students and some of the nonspecial education students in Heather's district.
Anne	Midsize, urban middle school	6	Female	Have her math and social studies students create various multimedia projects, such as a multimedia display of data on students in the class and a Canadian travel brochure. A total of 10 projects were planned.
Monica and Shawn	Large, suburban elementary school	3–4	Female and male	Do a combined water quality project with Monica's fourth graders and Shawn's third graders, which integrates the teaching of science and social studies. This would involve multiage looping (Monica teaching third graders and Shawn teaching fourth graders), six field trips to rivers where data on water quality would be collected and analyzed with various technologies, and the development of a computer-generated brochure on water quality.

Four teachers at Boyleston	Midsize suburban elementary school	K–5	Female	Part 1: Create a student technology club, where selected students will become experts at certain computer programs. These students will then support teachers in the use of these programs with their own students. Part 2: Use in-services to teach third through fifth-grade teachers how to integrate technology with their curricula. Have the complete one project demonstrating the integration of technology.
Willa	Small, rural, K–12 school	K	Female	Develop moral and literacy skills by having her students use CUSeeMe to do video conferencing with students in another district. Later, have her students us AlphaSmarts to share stories and personal experiences with the students from the other district.
Kathy	Small, rural middle school	8	Female	Teach her English students to use a hypertext software program. Have them develop hypertext presentations about periods of American literature. Also, have them collaborate with students in Ghana on writing about slavery and create a hypertext presentation of the writing that could be posted on the Internet.
Jeff	Alternative high school in an urban district	9–12	Male	Engage his science students in a water quality project. Have them use various technologies (computers, Internet, water sampling technologies, microscopes, digital camera, and others) to learn about issues of water quality and test the water quality in nearby rivers.
Paul	Large, suburban elementary school	5	Male	Have his students work in groups to develop Web pages that are focused on a topic of the group's choosing and can be used by other students or teachers.

Note: Heather teaches second- and third-grade students but is the learning disabilities teacher consultant and works with many of the K–5 teachers and special education students in the district.

scales were designed to assess six constructs identified by the literature to be relevant to technology integration: technology proficiency, computer anxiety, attitudes and beliefs toward technology in education, previous and planned professional uses of technology, pedagogical styles, and experiences preparing for the grant proposal. Following the survey, a sample of 32 teachers was selected for an interview based on geographical location, grade level, and subject matter. The interviews were structured around three issues: previous experiences with technology, motivation for applying for the grant, and concerns and plans for implementing the proposed technological innovation. The interviews were 45 to 60 minutes long and were audiotaped.

We then selected 12 of the 32 interviewed grant recipients for case studies. A member of the research team visited each case monthly. During the visit the researcher observed the teacher's teaching, interviewed the teacher, and on occasion interviewed the teacher's students and colleagues. Researchers also kept records of electronic communications with the participants. At midyear, a second survey that focused on the teachers' experience with the implementation of their proposed projects was administered to all recipients, including the participants selected for this study.

Besides the surveys, observations, and interviews, we also examined the messages posted to a listserv subscribed to by all grant recipients. Additionally, as part of the grant requirement, each teacher was asked to submit a biweekly journal to the grant management Web site. The journals by the 10 teams were included as data for this study. Also included as data were the grant proposals of the 10 teams who participated in this study.

Data Analysis

At the outset we had developed a sense of factors that constitute part of the conditions for classroom technology integration based on the existing literature. We did not formulate specific hypotheses, however, because we did not feel that we had strong enough evidence to do so. Following the tradition of grounded theory (Strauss & Corbin, 1990), we adopted the constant comparison approach. When all the data came in, the research team spent a week looking through the cases for themes. The researchers wrote independent case reports for each of the 10 teachers. The writer of each case report was also asked to determine the degree of success for each case by comparing the proposed objectives and activities in the original grant proposal with what was completed by the end of the grant period. Each case was given one of three ratings: *Successful, Mixed Success*, and *Failed.* Each case was then read by the rest of the research team and discussed at team meetings. A consensus of the final characterization of degrees of success was reached through the discussions. During a period of 6 months four researchers reexamined the cases at weekly meetings. A list of themes gradually developed through this iterative process. The researchers worked to map factors suggested by previous research onto the cases, with special attention to the particular factors present or absent in each of the three categories of the cases: *Success, Mixed*, and *Failure*.

RESULTS AND DISCUSSION

Eleven salient factors seem to explain the degree of success for all 10 cases. Some of these factors have been commonly mentioned in the literature, but our study found new dimensions to them. Others have not been identified in the literature. As mentioned previously, each factor can be placed in one of three interactive domains, the innovator, the innovation, and the context (see Figure 1). In the following sections, we discuss the way in which each domain and its related factors are associated with successful technology integration.

THE INNOVATOR

The teacher is naturally the first person one can look to factors that affect classroom technology uses. Three factors associated with the teacher have been found to contribute significantly to the success of classroom technology innovations: technology proficiency, pedagogical compatibility, and social awareness.

TECHNOLOGY PROFICIENCY

The study confirmed the assumption that teachers' technology proficiency plays a major role in classroom technology innovations. Moreover, it added a new dimension to the variable. Traditionally, technology proficiency has been understood as the ability to operate a piece of equipment or use a software application. However, our observations suggested that an additional dimension of technology proficiency plays an equally important part: knowledge of the enabling conditions for a technology—that is, knowing what else is necessary to use a specific technology in teaching. Modern computers and computer-related technologies are dependent on many contextual factors to function. For instance, an activity as simple as having students exchange writings using e-mail requires access to a functional network, networked computers, e-mail software, and perhaps even filter software. Simple knowledge about how to send and read e-mail with a single e-mail program only works when everything else functions perfectly. This is seldom the case with classroom technology. This is not to suggest that teachers need to know

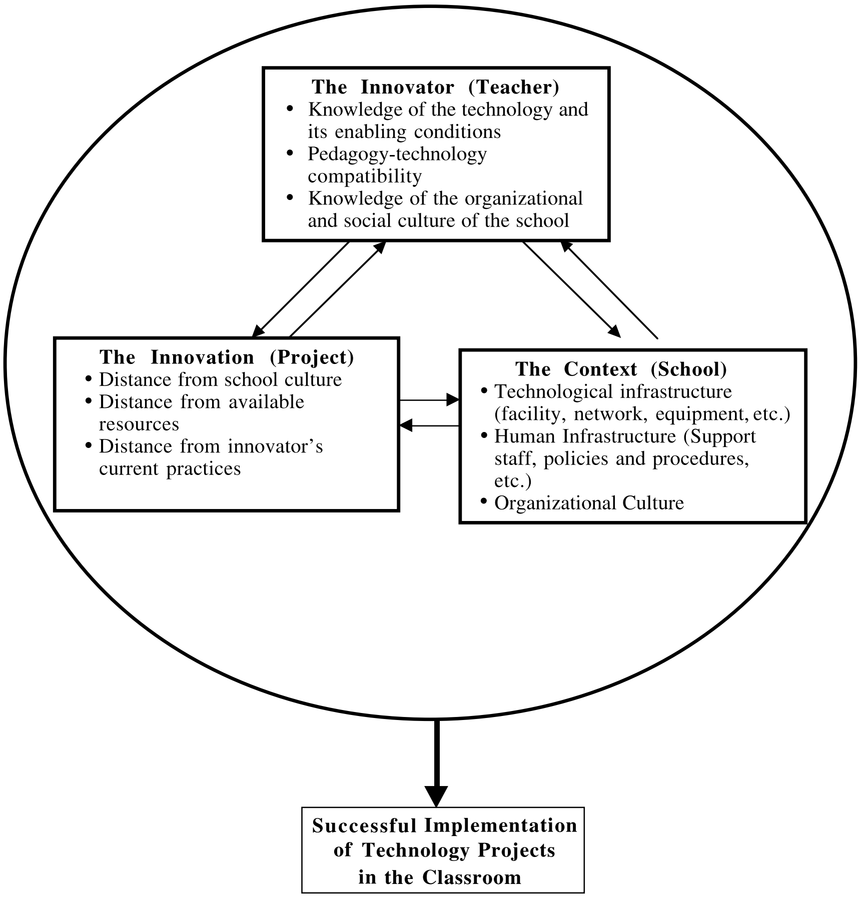

Figure 1. Conditions for classroom technology innovations.

how to manage computer networks or install software, but it is essential that they understand the enabling conditions of certain technologies. The following cases illustrate the importance of comprehensive technology knowledge.

Willa proposed to use computer video conferencing to connect her third graders with students from other places to develop literacy through authentic oral communication and writing. Although Willa knew which software she needed to use, she had little knowledge about the technological infrastructure needed to set up the whole system—such as a fairly high-speed Internet connection and digital cameras. It took her a long time to find out and order what she needed. Her project was never implemented.

In contrast, Jeff, one of the most successful cases, was a science teacher at an alternative high school. His proposed project was to engage students in authentic scientific inquiry through collecting, analyzing, and communicating data about water quality from a local river. The project required an elaborate technological setup involving probes, videos, computers, networks, and servers. However, Jeff had extensive knowledge about the various technologies involved in this complex project. Our data suggest that this comprehensive understanding was a significant factor in the successful implementation of his project.

The case of Anne, whose goal was to have her students conduct and present 10 multimedia projects connecting mathematics and social studies, further exemplified the critical role of a broader understanding of technology—knowledge beyond the actual application. Instead of purchasing new computers, Anne decided to upgrade the existing technology she was previously using. This decision seriously limited her project, enabling only 5 (instead of 10) integrated projects during the school year. On reflection Anne commented that had she known more about technology, she would have simply bought new computers:

> But if I were to add the upgrades that I already had done, plus the close to $300 upgrade that I still need to have done, I could have bought a new, bought or almost bought another new computer that can do more . . . do more than what I've got with all the upgrade stuff.

In retrospect, Anne' decision to upgrade cost her time, money, and opportunities to go beyond the goals of her project. The lack of knowledge and awareness of technology did not entirely sabotage Anne's project, but it hindered her ability to successfully accomplish all that she had envisioned.

The above cases are illustrative examples of how a teacher's expertise with the technology he or she hopes to integrate into the classroom can help or hinder a project. The surveys suggested similar trends. What is interesting is that although most teachers reported to be proficient in basic computing applications (especially those that do not involve the understanding of the broader computing system), there were significant differences on measures of more advanced applications that require operations of more than one component (Zhao et al., 2001).

COMPATIBILITY BETWEEN TEACHER PEDAGOGICAL BELIEFS AND THE TECHNOLOGY

In carrying out daily activities and classroom lessons, teachers draw on their own beliefs and collected knowledge to successfully negotiate the busy ecology of the classroom (Huberman, 1983). Studies of teaching and teachers' beliefs have shown that teachers who are more reflective and aware of their own pedagogical beliefs are generally more adaptive and flexible teachers (Clark & Peterson, 1986). Analysis of the case studies suggests that successful implementation of technology innovation into the classroom is more likely when teachers are highly reflective about their own teaching practice and goals, in the sense that they consciously use technology in a manner consistent with their pedagogical beliefs. We found that when a teacher's pedagogical approach to teaching was consistent with the technology she or he chose to use, the efforts to use technology were more likely to yield positive results. This is because technology is not functionally neutral, as some have argued (Means, 1994). Although at a generic level modern computing technology is quite versatile, capable of supporting a variety of uses, specific technological applications have their own affordances and constraints (Bromley, 1998; Bruce & Hogan, 1998); certain technologies are simply better suited for some tasks than others. When teachers choose a technology that is compatible with their pedagogical orientation, the integration goes much more smoothly. We found that when teachers' pedagogical beliefs conflicted with the technology they were attempting to incorporate into their classroom, they struggled to successfully accomplish the goals of their proposed project. In these cases, projects were postponed, severely modified, or simply canceled.

Additionally, we found that successful implementation of classroom technology was more likely to occur when teachers viewed technology as the means to an end, rather than an end itself, and when they saw an intimate connection between technology and the curriculum. When the value of technology was limited to peripheral functions, such as adding novelty to teaching, the likelihood of success was greatly reduced.

Several teachers exemplified these findings. An illustrative example of the connection between pedagogy and technology can be seen in Kathy, an eighth-grade English and social studies teacher. Kathy's successfully implemented project involved having students build a hypertext of American history. Kathy had a very explicit theory of mind underlying her view of how technology could best be used to support student learning. Regarding the congruency between the human mind and the technology involved in her project, Kathy states,

> The idea of multilinear and the idea of intertextual stuff isn't new. It's how human beings think. We now have technology that comes closer to mirroring how we think. And that's what hypertext is. And so my goal for my students is to really think deliberately. My goal for my students is to, is to think deliberately about hyper, about hypertext. To think about that relationship between one piece of text and another.

In this interview, Kathy states clearly that she believes technology has finally caught up to the way humans think. The technology she selected for use in her classroom, in this case a hypertext writing software application, enables the kind of thinking she wants students to develop.

In contrast to Kathy is Willa, whose pedagogical beliefs were not consistent with her project. Her project originated from one in-service seminar. The seminar inspired Willa to think about using video conferencing technology as an innovative way to develop students' oral skills and enhance their literacy development. Thus, Willa found a technology that fit a particular pedagogical orientation—the centrality of oral language to the development of literacy. However, prior to the seminar, using oral skills to develop literacy had not been a significant part of her pedagogical practice or beliefs. Rather, she simply found the idea and the technology interesting and decided to try it. However, as the project started, she began to lose sight of the pedagogical basis for the technology. Rather than focusing on the development of literacy through developing oral skill, she began to focus on how the technology might afford the development of social skills such as listening to and respecting others.

Prior to the beginning of the school year, Willa was asked what she hoped her project might accomplish with her students, and she said,

> Well, I guess I just wanta provide them opportunities to speak and maybe in their realization that somebody is talking to them, that they have to listen also. That, you know, if they're talking, they expect you to listen so if you're talking into a camera or a computer and there's someone on that other end, and you, you're telling them something, it's your responsibility then to listen to what that person says back.

Willa's comments suggest that she is at least as interested in teaching her students how to sit and listen as she is in teaching them oral language or cognitive skills. Hence, she did not seem to be strongly and consistently committed to using the technology to achieve a particular goal related to a particular pedagogical belief.

Willa' s case is particularly interesting because of the way it highlights challenges with regard to the implementation of technology in the classroom. In the beginning, Willa appears to have been inspired to use computers in her classroom in an innovative manner. Attending an in-service provided an introduction to new ideas about teaching. However, a single exposure to these new ideas may not have been enough to support the long-term and consistent application in the classroom (Berliner & Calfee, 1996). Without a full understanding of these new curricular goals, in this case about links between oral language and literacy, the goals of a project may be subverted or deflected. Although the lack of success experienced by Willa cannot be solely attributed to her pedagogical beliefs, it may have contributed to her readiness to continually postpone confrontations with the barriers she encountered while trying to implement her project.

SOCIAL AWARENESS

Among the qualities of a teacher that appeared to make a project more or less successful was her or his understanding of and ability to negotiate the social aspects of the school culture. Our analyses suggest that socially savvy teachers were more likely to implement their projects successfully. These teachers knew the social dynamics of the school, were aware of where to go for what type of support, and were attentive to their peers. Technology-based classroom innovations, although sharing many qualities with other types of innovations (Fullan, 1991), require teachers to be more socially sophisticated than other types of innovations for a number of reasons. First, today's technology, especially network-based computers, often requires resources beyond the teacher's control. To make computers work teachers often need to continuously interact with technicians and administrators, two groups of people teachers have not traditionally had close relationships with. Thus teachers have to discover which individuals in the school or district can provide the help they need, and they have to know how to work effectively with those individuals. Second, technology-based projects can make traditionally private classroom activities public and can expose students to an environment beyond the classroom walls, disturbing well-established school patterns. This disturbance can often result in anxious parents and administrators. Socially savvy teachers are much more aware of the potential for problems and can frequently negotiate compromises among the various parties that smooth the way for successful class technology experiences. Furthermore, technology means money and attention in today's schools. In an egalitarian place with limited resources such as schools, the extra resources technology projects receive or require can easily disturb the social harmony among peers. Thus, knowledge of school resources and sensitivity to the needs and priority of colleagues is helpful for successful technology integration efforts.

As an example of how familiarity with the school context and the demands of others enable an innovator to be successful, Kathy provides a telling case. At the time of her grant award, Kathy's school had a single computer lab for all of the teachers to share. When they wanted to use the lab, teachers had to sign up. Kathy's project required frequent uses of the lab, which could potentially draw her into conflict with the demands of other teachers. However, this proved not to be a problem because Kathy knew and understood how much her colleagues might use the computer lab. Knowing the school-wide demand for the computer lab, Kathy could plan her lessons appropriately.

In contrast, Susan's case highlights the impact of a lack of social awareness on technology implementation. Susan's attempts to implement innovative uses of technology in her classroom were, in part, hindered by other teachers' reluctance to fully integrate a composting project into their classroom curriculum. This resistance to innovation has been a source of disagreement between Susan and her colleagues in the past. Susan, however, consistently ignores the actions of her colleagues:

> On my team I usually have a clear vision which my teammates support and say they understand, but then when it comes to actually implementing it, they lose the glimpse of what it could be and keep wanting the comfort of that with which they are familiar . . . Right now we are wrestling with this again. I say again because every year we begin, come close, then they slide back into a more traditional approach.

As implied in these comments, the compost project was affected by the differences in perspectives. Susan thought it should be fully integrated with their regular curriculum, but the other teachers felt it was difficult to make this actually happen once they started planning out the curriculum for the year. The result was that the project became more of an add-on to the curriculum than an integrated part of it. The realization that the project was becoming an add-on occurred gradually for Susan. After the project had been underway for about a month, she commented,

> Well, my intention when I wrote [the grant] was that [the project] would be just the math, science, language, social studies [instruction] for a period of time and then it would be sort of an ongoing project that would be a side project. The way it's turned out is that it's been sort of an additional project. And part of that is because of, you know, and different viewpoints of how you can do things.

In the end, despite Susan's attempts to better integrate the compost project into the classroom curriculum, the project remained on the sidelines and became more of a specialty project for a smaller group of students. Susan's inability to fully accomplish her stated goals for the project is due, in part, to her lack of coordination and perhaps understanding of the teachers she works with. Without the cooperation of the other teachers, Susan's project could never be more than partially successful. Successful projects, as illustrated by Susan's case, require that the innovator understand which innovations the social context will constrain and which ones it will afford.

One of the important ingredients to the successful integration of innovative uses of technology in schools is the teacher. Teachers vary on a wide range of qualities and attributes, some of which appear to be particularly relevant when discussing technology integration in classrooms. We found that the way an individual's pedagogical beliefs interacted with the technology they know and decide to use affected the likelihood of successful technology integration. Teachers' technology proficiency played an important role as well, as did teacher's social awareness. These characteristics did not operate in isolation. They interacted with one another and with aspects of the innovation itself. In the following section, we report our findings of significant factors associated with the second domain, the innovations themselves—the projects that teachers attempted to carry out.

THE INNOVATION

A prime determinant of whether a project succeeded or not was the nature of the innovation itself. Simply put, some innovations appeared much more difficult to implement than others. Specifically, we found that innovations varied along two dimensions, distance and dependence, and that success was related to these two dimensions. Distance refers to how much the innovation deviated from the status quo. We found distance to be important in three areas: distance from the existing school culture, distance from existing practice, and distance from available technological resources. Dependence refers to the degree that an innovation relies on other people or resources—particularly people and resources beyond the innovator's immediate control. For example, we rated innovations that only involved a teacher's own students and technology (i.e., technologies that the teacher controlled in his or her own classroom) as less dependent than innovations that required the involvement of other teachers, administrators, or outside technologies, such as a computer lab or district network server. We found a close relationship between where the innovations fell along these dimensions and the degree of success of those innovations. In the following sections, these dimensions are discussed in more detail.

DISTANCE FROM SCHOOL CULTURE

Distance from school culture refers to the degree that an innovation differs or deviates from the dominant set of values, pedagogical beliefs, and practices of the teachers and administrators in a school. In most of the cases, distance from the school culture was not a salient issue because these innovations were not very different from the existing beliefs and practices at the school where they were implemented. For example, Anne's innovation involved having students do multimedia math presentations. This project fit well with the school culture. Other teachers, in a variety of subject areas, liked the idea of having students do presentations (multimedia or otherwise) and also tried to have their own students do such presentations. In addition, the team of teachers with whom Anne worked, as well as the principal, was excited about this use of technology.

Henry's innovation is an example of an innovation with a moderate level of distance. His project involved having other teachers work with students to design Internet-based lessons. These teachers had never developed lessons for the Internet before, and some had not used the Internet much with their students. Thus, the project went beyond what other teachers normally did. However, the project closely paralleled some of the things that the teachers had been used to doing. Teachers were used to writing worksheets to guide students in looking up information on topics in a textbook or in the library. Henry's project was similar to this activity, asking teachers to design a Web-based worksheet that would guide students in researching a topic on the Internet. Both Anne's and Henry's innovations were able to achieve a good level of success.

In a few cases, the innovations were very distant from the school culture. For those projects, the result was often quite negative. Distance from the school culture leads to significant, sometimes insurmountable, roadblocks to a project's success. For instance, Susan's innovation of doing interdisciplinary science projects was quite distant from the culture of her school—and from the culture of schooling in general. Her project was progressive in the sense that it challenged the traditional "grammar" of schooling (Tyack & Cuban, 1995). Susan's school, in a new building, was designed so that teachers could work collaboratively as teams and have open classrooms where integrated teaching took place. In reality, all of the teams except Susan's used partitions to divide their open spaces into individual classrooms. Additionally, although the teachers did collaborate as a team, for the most part the students were still taught individual subjects by individual teachers. Susan's project challenged this culture by requiring subjects to be integrated and teachers to teach in coordination with one another. Susan had many problems trying to implement her innovation. In the end, she had to transform her innovation into a separate composting project that fit more closely with the school culture and the traditional grammar of school.

Monica and Shawn's case provides another example of an innovation highly distant from the school culture. Their innovation involved multigrade looping and project-based collaborative teaching. This contrasted strongly with the wider school culture Monica described as driven by textbooks and statewide standard tests:

> Our school is, by and large, textbook driven. We have textbooks in every subject and most teachers do lesson one, followed by lesson two, followed by lesson three, and so on. . . . We're very MEAP [the State's standardized tests—authors] driven, MEAP conscious. We're trying to get North Central accreditation. So our district is starting to look at the MEAP tests and state documents and design curriculum to that.

Thus the school culture places an emphasis on a structure and sequence that would progressively lead students to perform well on the state assessment. Monica and Shawn's project came into conflict with this goal. First, the multigrade looping and collaborative teaching undercut the structured sequence of instruction emphasized in the school. In fact, some of the other teachers complained about the project for this reason. According to Monica,

> [T]he big thing now is taking my third graders on study trips with the fourth graders. Some of the third graders are now going on, quote unquote, fourth grade study trips. . . . Some of the fourth grade teachers were upset because that's a, quote unquote, fourth grade field trip. They shouldn't be taking that because next year, when they're fourth graders, it won't be a big thing for them. It won't be a, you know, surprise. It won't be a novelty.

Also, the project-based approached and the looping undercut the principal's goal of a unified curriculum. Monica and Shawn simply were not doing the same thing as the other teachers, and what they were doing did not directly relate to preparation for the state test. As a result, the principal was not very supportive of the project. An additional problem was that Shawn left in the middle of the year. This meant Monica would have to do the multigrade looping and collaborative teaching with a new person. However, the new teacher did not want to get involved in the project because it was a radical departure from what she was used to. This, combined with the lack of the principal's support, was a primary reason why almost none of Monica and Shawn's goals were accomplished.

DISTANCE FROM EXISTING PRACTICE

Distance from practice refers to the degree to which an innovation differs from the prior educational practices of the teacher. Although related to the role of teachers' pedagogical beliefs discussed previously, this refers more specifically to the teacher's particular practical experiences. The most successful projects generally involved an innovation that was a variation of a project previously completed by the teacher. For example, Kathy and Jeff had both previously completed projects very similar to their proposed one. Or the new project simply involved expanding the breadth of the project or adding a technology component to it. For example, Paul's innovation to have his elementary students develop Web pages was a modest adaptation of a previous project. The innovation simply involved extending what he had done the year before to include all of his students, another teacher, and her class.

Other projects involved more significant deviations from prior practices. The added distance on occasion hindered the implementation of some projects. For example, Susan's innovation required making a fundamental transformation from a standard curriculum to an integrated curriculum. For about 5 years Susan and her team engaged in joint teaching, where they combined their classes and taught as a team. However, this joint teaching did not really involve an integrated curriculum because the teachers would take turns teaching their subject area specialties (i.e., math, social studies, language arts, science), although occasionally they worked on some projects together. However, Susan's project required that the team take a much larger step toward collaboration. It required that the teaching of the different subject areas be integrated within a single project for a period of time. Hence, each teacher would have to fundamentally reorganize her approach to teaching the subject. The teachers resisted making this change, as discussed earlier. As a result of these difficulties, one aspect of her innovation, the goal of doing an integrated project, had to be largely abandoned.

DISTANCE FROM AVAILABLE TECHNOLOGICAL RESOURCES

Distance from existing technological resources refers to the amount of new technologies (hardware, software, accessories, connectivity, etc.) needed for successful completion of the innovation. Again, the most successful projects were not very distant—they either required no new technology or minimal purchases or installations. For instance, Kathy's project simply required the purchase of additional licenses for a piece of software she had been using. Jeff only had to purchase more sensors for an existing technology system.

Other projects were more distant from the existing technological resources. Our analysis revealed that a high proportion of those innovations that required the purchase or installation of new technologies experienced significant delays or complete failure in getting the required equipment and software. For example, Susan's project required a number of things: computers with Internet access, probes, a graphing calculator, a video microscope, and various software programs. The arrival of many of these technologies was significantly delayed. The computers and most of the other technologies were not obtained until halfway through the school year. The computers were never connected to the Internet, despite teachers being told that the computers would be installed and made Internet-ready before the school year started. As a result, Susan had to drop some of the technology aspects of her project. After explaining the delays, she commented,

> Consequently I have not been able to implement instruction or build skills in construction of a multimedia database or even simple graph production of the temperature data. There has been no word processing skills practiced and nothing composed. No Power Point or Hyperstudio stacks produced for presentations. No computers to work with.

DEPENDENCE ON OTHERS

Dependence on others refers to the degree that the innovation required the cooperation, participation, or support of people not under the innovator's authority. Those innovations with a low level of dependence were most successful. For instance, Jeff's, Kathy's, and Paul's innovations were highly successful and largely self-contained (i.e., they only involved their own classrooms and students).

However, the level of success often dropped as innovations became more dependent on others. For instance, the project of the teachers at Boyleston had two components. The first component was developing a computer club with students. It was successfully completed. The second component involved conducting training of other teachers (who were not under the authority of the innovators) and was only partially successful. In other cases, such as those of Henry, Susan, and Heather, the entire project was dependent on others because they required the participation and cooperation of other teachers. These latter projects experienced some difficulties in getting the teachers to fulfill their responsibilities, which hindered the success of the projects.

Monica and Shawn's case represents an innovation that was dependent in a different way. Although the innovation appears self-contained in that it only involved their classrooms, it required the support and cooperation of the principal and other teachers. Perhaps all projects require this support to some degree, but Monica and Shawn's project was more dependent on this support because their multiage looping and project-based approach came into conflict with the established school structure. For the project to succeed, other teachers needed to be willing to adjust some of the structures of their classes, and the principal had to be willing adjust his plan for the school. Because these parties were unwilling, the project was not successful.

DEPENDENCE ON TECHNOLOGICAL RESOURCES

Dependence on technological resources refers to the degree that innovations require the use of technological resources beyond the control of the teacher. The projects we analyzed varied widely in the degree to which the teacher had control over the resources and the degree to which the technology was central to the project. Innovations where the essence of the project required significant amounts of technology beyond the innovators' immediate control were considered highly dependent.

The most successful projects tended to be less dependent. For instance, both Jeff and Paul had high levels of success and high levels of control over the needed technological resources. They both had Internet-capable computers, software, and a few other technologies in their own room. Further, Jeff was the technology person for his school, and he was able to make sure he had control over any resources he needed:

> [B]ecause of the role I play in the school, and the assets that I have available, I foresaw that I wanted to be able to control that particular aspect [the technology] and made sure—as much as I could—that that wouldn't be problem.

Other innovations, such as Anne's, Kathy's, and Heather's, also required Internet-capable computers with particular software packages but had to rely on computer labs where they had less control of the resources. For Kathy, this proved not to be a problem. But Anne found that availability of the lab was limited, and as a result she didn't have time to complete all of her project goals. Heather ran into the biggest problem. Although her project required Macintosh computers, the district decided to purchase only computers that run on the Windows platform. Because she did not have control over this decision, the success of her project was impossible.

Henry's innovation is an example of project that was dependent on a larger group of technologies. First of all, it was dependent on a set of computers with a wide variety of software packages, on a number of network servers, and on a local server, all of which he controlled. However, it was also dependent on district servers. His project ran into problems with the district servers (for more details, see the sections on the human and technological infrastructure that follow). Upon reflection, Henry decided he should have and could have been less dependent on technology beyond his control. He commented,

> I needed to create a system that's totally independent, non-dependent upon anything else. . . . I relied too much on what was in place last year, thinking it would remain, and stay consistent. And I shouldn't have made myself dependent. I should have controlled the assets that I needed . . . You need to be in control of the assets . . . and I wasn't. I let other people take control of it. And looking back on it now, I should have gone to GeoCities [a commercial free Web-hosting service—authors], got a site, hosted it on the GeoCities site. I would have been independent of the school.

Susan's innovation also required a wide variety of technologies. As mentioned before, most of these technologies were delayed in being obtained, and some were never available. Susan's project experienced a little success only because the essence of the project didn't require technology. The essence of the project was studying and doing composting, whereas the technology merely provided additional tools for studying the composting process. Hence, even though her project involved a variety of technologies, it was not highly dependent on them for the success of the project. In contrast, Willa's innovation could not be completed in any form without the technologies. Hence, when she didn't get the needed computers, she was unable to accomplish her most basic goals.

Overall, the more successful innovations had a lower degree of distance, dependence, or both, whereas the less successful innovations had a higher degree of distance, dependence, or both. The relationship between success and either distance or dependence is not always direct and involves complex interactions between various aspects of distance and dependence. In particular, the success of an innovation is mediated by the interaction between its dependence on others and its distance from both the school culture and existing practice. In addition, success appears to be mediated by the interaction between an innovation's distance from existing technological resources and it's dependence on technological resources. Furthermore, the characteristics of innovations (distance and dependence) interact with those of the innovator (pedagogy, technology proficiency, and social awareness) and with contextual factors, which we now turn to in the following section.

THE CONTEXT

The third domain that we found to have a strong mediating effect on the success of technological innovations is the context in which the innovations take place. We identified three aspects of the school context that were of central importance to the success or failure of an innovation: 1) the human infrastructure, 2) the technological infrastructure, and 3) social support.

HUMAN INFRASTRUCTURE

We use the term *human infrastructure* here to mean the organizational arrangement to support technology integration in the classroom. A healthy human infrastructure would include a flexible and responsive technical staff, a knowledgeable and communicative group of "translators," or people who can who can help the teacher understand and use technologies for his or her own classroom needs and a supportive and informed administrative staff. A healthy human infrastructure would also include institutionalized policies and procedures related to technology issues, such as hardware and software purchases, professional development, and student access to computers and the Internet.

Even more than other innovations, technology innovations require institutional support because the resources and knowledge required for using any modern computing technology often lie beyond an individual's immediate reach. For example, having students exchange e-mails with each other in the classroom, a simple and common activity, requires computers being installed, electric outlets wired or rewired, network connections established, student e-mail accounts (which often require district permission, parental agreement, and the establishment of acceptable use policies). A teacher cannot accomplish any of these actions or gain access to resources unless she or he interacts with the administration and a wide range of support personnel. It is also very common that teachers need to access Web sites that are filtered out by the district server or purchase and install software that is not available on the district server. To act on teachers' requests, a district needs to have a very responsive and easy communication channel. Most teachers in our study could have benefited from a stronger human infrastructure. They often required the presence of people who could assist them with the financial aspects of their grants, the purchase of new materials and technology, the maintenance of technologies, and the use of the technologies.

When an adequate human infrastructure is in place, it largely goes unnoticed. In our research, it only became salient when the innovators ran into problems. However, one aspect of the human infrastructure did stand out even in innovations that didn't experience problems. This aspect is the presence of what we call a translator, a person who can help the teacher understand and use technologies for his or her own classroom needs.

Henry's case demonstrates the hindrances and deep frustrations that can arise when the human infrastructure is problematic. Henry's project was quite dependent on a variety of technological resources, some of which were operated at a district level and required a human infrastructure at the district level that would be supportive of his project. Unfortunately, he found that the human infrastructure was faulty in two areas: communication and trust. This seriously hindered the project, eventually causing Henry to abandon the attempted innovation.

To understand Henry's problems, one first needs to understand the existing technological context. Henry worked in a multimedia lab at a high school with computers connected to a server through the local district, which was connected through an intermediate school district (ISD), which in turn was connected through a consortium of ISDs in conjunction with a local university. An obvious problem with this arrangement, Henry discovered, was that difficulties with a server at any of the levels impinged on his computer use. During the semester that Henry was initiating his innovation, the district and ISD servers were being upgraded. As result, the servers would be down, sometimes for a day or weeks, and Henry's students were prevented from using the computers to participate in the project.

Although the work being done on the servers was a serious obstacle, the greatest hindrance to a successful program for Henry was the lack of communication about the situation. According to Henry, nobody ever communicated what work was going to be done, when it would occur, and how the work would affect his computers and class. He commented at one point, "I understand things need to be done, but you need to communicate with people what's going on." At another interview he explained his frustration, "they make these changes and don't tell people it's coming so I can prepare for it. . . . Nobody bothered to say to anyone this is what we're gonna do, this is what you should do to prevent any problems. I don't even think they were aware of what the problem was." To further add to his frustrations, Henry didn't know whom to talk to because he wasn't informed about who was in charge. He commented, "I know we have a director of technology but, I don't think he's making the decisions per se. Maybe he is. I don't know. We've never been, the whole time we've been doing all this stuff, staff has never been briefed on what the plan is."

As a result of the poor communication channels, Henry began to feel that he was not important and not trusted by the leadership in the district and human infrastructure. This feeling boiled over when access to the district Web server was cut off. The district wanted to limit access to the server and to control the material posted to the district Web site. Henry was not given access to the district server, which he interpreted as a sign of distrust. A veteran, Henry uses the military as a comparison in his comments:

> In the military, the bosses said this is what we want done. You're gonna do it. Now how you're gonna do it, that's up to you. . . . you do it the way you think it needs to be done. It maybe will not be the way I chose to do it. But that's part of being a leader is saying I'm gonna let you do the job, taking a risk. But I think that's a big problem we have in education is leadership isn't leadership. It's administration. And there's a big difference between leadership and administration. I'm tired of being administered. I'd like to be led for a change.

As a result of this experience, Henry became disenchanted with his project and even withdrew from his work in the multimedia lab. Rather, he planned to go back to teaching social studies full-time, where he would incorporate some technology into his teaching there. Interestingly, upon reflecting on the project, Henry did not identify the solution to his problems as improvement of the human infrastructure. Rather, his proposed solution for the future was to make himself independent of the human infrastructure. In essence, Henry's solution was to reduce the dependence of his innovation on others.

TECHNOLOGICAL INFRASTRUCTURE

All of the innovations required some type of technological infrastructure. Overall, we found that most of the technological infrastructures were inadequate, especially in cases where much of it needed to be put in place (i.e., innovations distant from existing technological resources). For instance, Frances's innovation required frequent access to the computer lab, but because of popular demand of the lab, her opportunities to use it were somewhat limited. Paul felt that the technologies were overly controlled by administrators and that he couldn't use them as freely as he needed.

Susan's case illustrates the problems of assuming that plans for a technology infrastructure would be put into place. To be fully successful, her project required a set of computers, with Internet access, in the room. These computers were supposed to be installed and Internet-ready at the beginning of the school year. However, the computers she needed didn't arrive until December. Then only 3 computers arrived instead of the expected 15. The rest of the computers didn't arrive until spring, and none of the computers were ever connected to the Internet because the school was still writing up an acceptable use policy. Monica and Shawn had similar problems. They also needed an Internet-ready computer and were promised that one would be installed at the beginning of the year. However, there was a change in administration, and they were not able to get a computer until the end of the year.

Delayed installation of computers caused other delays as well. For instance, Susan couldn't order software because the software committee at the school didn't want to order software until the computers arrived, even though Susan had a few older computers on which she could have used the programs. As a result, Susan had to alter certain aspects of her project. A breakdown in one aspect of the technological infrastructure often had ramifications across several aspects of a project.

SOCIAL SUPPORT

Another important factor in the successful implementation of innovations was the degree to which peers supported or discouraged the innovators. Examples of support were demonstrated in the cases of Anne and Henry. Anne worked with a team of teachers who were excited about using technology in teaching. One of these teachers, who ended up doing the project with Anne, commented,

> We are using a lot [of technology] . . . We're kinda going with what Anne did put down for the grant. And I'm just gladly following it because I love it. . . . We enjoy it, I like it. . . . We both enjoy working with technology and so it's really fun. . . . it's really fun to work with somebody that wants to, to move onward and upward and be on the cutting edge, if we could be.

Anne also commented that the project was much easier to do because of the technology orientation of her team. She comments,

> I just think it was just so easy here because [Sheri's] right into it. [Dorothy's] into it. You know, we pulled, kind of pushed, nudged [Bart] into it and you know, like I said, [Meg] is starting to so within our team, our team is, I would say, is probably the most . . . technology oriented, literate.

The team was also highly collaborative and supportive. One of the other teachers explained that the group of teachers who comprise this team even collaborated together last year, when they were at different schools. All of this support further helped Anne to achieve as much as she could, despite the other difficulties she had.

In contrast, the teachers at Boyleston also had an innovation dependent on others, but they did not receive much support from their peers. Part of their innovation involved conducting in-services for other teachers. Unfortunately the other teachers were not too enthused about participating in the workshops. Initially, a significant group of teachers (about 11) attended the workshops, but this group quickly dropped down to a group of 5. Two of these five teachers later dropped out, and only three teachers ultimately stayed with the program. The innovators at Boyleston were disappointed and frustrated by this lack of participation, and one of them commented at the end of the project, "The biggest problem was lack of staff enthusiasm. This is something I hadn't really counted on, but should have foreseen." Another Boyleston teacher stated, "We didn't get as much participation as we wanted."

Overall, it appears that adequate infrastructures for technology innovation do not seem to be in place yet. In most cases, critical human or technological resources did not exist or did not function as they should have. One of the key results we found is that the teachers often distrust administrators when it comes to technology issues. Promises for the purchase or installation of technology were often broken or delayed. In addition, there was often a lack of communication between administrators and teachers with regard to technology. This was most evident in Henry's case, but other teachers had similar experiences and feelings. For instance, Susan expressed her frustrations about never being told what was going on with the computers the school was expecting: "I am the district curriculum coordinator for technology K–12, but I have to find out things accidentally or seek and find because I really am not supposed to know anything because I am a teacher and not administrator."

Finally, social support seems to be most important for innovations that are highly dependent on others. Further, the level of support a particular innovation receives is likely the result of an interaction between the innovator and social context. For instance, an innovator who is a respected leader, such as Henry, can often garner more support from peers. An evaluation of the context and the degree to which it provides technical and human support is essential to the implementation of technology in the classroom.

THE RELATIONSHIPS AMONG INNOVATION, INNOVATOR, AND THE CONTEXT

Thus far we have discussed the three domains and their associated factors needed for successful classroom technology integration. Although we have described each domain separately, the interactive relationships among these domains and the factors within the domains are particularly important. We now turn to the relationships among these factors. The discussion of the interactions will be presented at two levels. First, we examine the relationships among the three domains: innovator, innovation, and context. We then take this analysis one level deeper into the specific interactions among the various factors within and across the domains.

INTERACTIONS AMONG THE DOMAINS

Although we identified three domains that contribute significantly to the success of classroom technology integration, the contribution of each domain was not equal. Factors associated with the innovator, the teacher in our study, appeared to play a more significant role than the other domains. That is, when the teacher was strong, the projects seemed to have a better chance to succeed, even with innovations that exhibited a high degree of distance and dependence and less-than-supportive contexts, although the latter two apparently limited the degree of success in some cases. For a teacher like Jeff, who was technologically proficient, used technology that was consistent with his pedagogical approach, had a fairly high status in the school and district, and was socially savvy, the context did not seem to be an insurmountable barrier. On the other hand, a teacher like Willa, who was not very strong in terms of technology proficiency, pedagogy-technology compatibility, and social awareness, could not accomplish much in the face of a project that is distant from her existing practices and resources within a context that did not have strong human and technology infrastructures.

However we should not underestimate the effect of the factors associated with innovations. We found that the qualities of projects significantly influence the possibilities of success. Even a very competent innovator may struggle if the project is quite distant from and dependent on the existing school culture, practice, and technological resources. For instance, Susan was quite strong in some of the qualities. She had a very well-developed pedagogical belief (importance of an integrated, project-based curriculum) and a project that fit closely with this belief. She was also quite technologically proficient. In addition, she was experienced at trying out innovative projects, and, although she seemed to lack some social awareness in regard to the teachers on her team, she was well respected by these teachers and viewed as a leader. However, the project was so distant from the existing practice and school culture that these teachers struggled to support the project, and Susan struggled to implement it. The distance from the existing technological resources contributed to the problems.

Although the context may not solely determine the degree of success of classroom innovations, it can definitely impact how far teachers can push the innovation. In an environment where there is good technical and human support, projects that are more innovative and distant from the school culture and resources can still be successful. A strong context can also compensate, to some extent, for teacher weaknesses: With good support and easy access, even teachers who are not pedagogically, technically, or socially strong can carry out classroom technology innovations. For example, Anne did not have a strong technology background and did not have much experience as an innovator (technologically or otherwise). However, she was part of a very supportive peer culture and had the assistance of a very supportive technology person in the computer lab. These people seemed to contribute greatly to Anne' success. Likewise, the presence of a translator compensated for Paul's lack of technical knowledge and experience.

INTERACTIONS WITHIN THE DOMAINS

Moving one level deeper, we found more intricate interactions among the different factors within each of the three domains. We use the interactive relationships among the factors of the innovation domain as an example (see Table 2).

One of the most obvious patterns in Table 2 is that all of the innovations that fall in the low-low quadrant are among the most successful, and all of the least successful innovations fall in the high-high quadrant. This pattern can be understood by looking at how distance and dependence are related in this interaction.

Table 2. Degrees of success and dependence of innovation

		Dependence on Others	
		High	Low
Distance from school culture and existing practice	High	*Susan* *Monica & Shawn* Willa Heather	Kathy *Boyleston?*
	Low	*Henry*	Jeff Paul Anne

Note: Underlined cases had a high or very high level of success. Italic cases had a low level of success or no success.

Innovations low in distance and dependence are logically the simplest and easiest to implement—hence, the reason for their high level of success. But as distance and dependence begin to increase, potential obstacles to success arise. If the distance and dependence increase asymmetrically (i.e., one increases but the other does not), then these obstacles can perhaps be overcome to some extent. For instance, Kathy's innovation was highly distant from the existing school culture. It was based on her postmodern beliefs about the nonlinear nature of learning, and her project involved having students develop hypertext. Others in the school did not share her beliefs. However, her project never came into significant contact with the school culture. The project only involved her students, and it didn't affect other teachers or administrators. As a result, distance from school culture was not really an issue. Henry's innovation represents a complementary example. His project had a fairly high level of dependence in that it required the participation and cooperation of other teachers. However, as explained earlier, his project did not require these teachers to do something radically new; it didn't require them to do something that was highly distant from their existing practice and culture. As a result, he was able to garner their cooperation and achieve a moderate level of success on the project. By the end of the year, the teachers Henry worked with were very active in the project and looked forward to continuing it the next year.

Susan's case provides an interesting contrast to both Kathy's and Henry's cases. Like Kathy's project, Susan's project was distant from the existing school culture. However, unlike Kathy's, Susan's project was dependent on other teachers who were part of that culture. Moreover, Susan's project required that these teachers fundamentally transform their practice. Monica and Shawn's case was similar to Susan's.

Again, looking at Table 3, we can see that the most successful innovations were low in terms of their distance from, and dependence on, tech-

Table 3. Degrees of success and dependence on technology

		Dependence on Tech.	
		High	Low
Distance from existing tech.	High	*Willa* *Heather*	Susan Shawn & Monica
	Low	*Henry* *Boyleston*	Jeff Kathy Paul Anne

Note: Underlined cases had a high or very high level of success. Italic cases had a low level of success or no success.

nological resources. For the most part, these innovations did not encounter any obstacles related to technology. But as the distance and dependence began to increase, more obstacles arose. Once more, these problems were overcome to some degree as the distance and dependence increased asymmetrically. For instance, both Susan's and Monica and Shawn's innovations had a high level of distance from existing technological resources. However, in both cases, the essence of the project was not highly dependent on these technologies. Thus, when the needed technologies were delayed or not obtained, the projects could be completed in a less technological form than if they hadn't encountered other problems.

Henry's case again provides a complementary example. His project was highly dependent on a number of technological resources, but most of these already in place. Henry didn't encounter any technological problems until the district started doing work on the servers. As explained above, this caused Henry a number of headaches and led to delays in the project. His case demonstrates that distance is not a stable characteristic. Technological resources that are already installed and working are not necessarily going to stay that way. Willa's case provides a contrast to Susan's, Monica and Shawn's, and Henry's. Her project not only was highly distant from the existing resources, but it was also highly dependent on those resources. As a result, when she was unable to obtain the needed technologies, she was unable to do the project at all.

CONCLUSIONS

By carefully studying teachers' experiences with using technology to support teaching in ordinary schools throughout a school year, we were able to develop a fairly good understanding of the conditions under which technology integration can happen. The conditions include factors located in three domains: the teacher, the project, and the context. In this final section, we recap the findings and discuss their implications for research and practice.

TEACHERS AND TECHNOLOGY: ISSUES OF PROFESSIONAL DEVELOPMENT

To integrate technology in teaching, teachers need to know the affordances and constraints of various technologies and how specific technologies might support their own teaching practices and curricular goals. They also need to know how to use the technologies. Moreover, teachers need to be aware of the enabling conditions of the technology they plan to use—what contextual factors make it work. Furthermore, teachers need to realize that technology integration requires support from others, even people with whom they have not interacted traditionally (e.g., technicians or technology coordinators).

The findings from this study point out serious problems with the current efforts to prepare teachers to use technology. Most of the current efforts take a very narrow view of what teachers need to use technology—some technical skills and a good attitude. Many in-service workshops often take the format of motivational speeches by a forward-looking visionary plus sessions on how to use a piece of software. Few pay much attention to the pedagogical or curricular connection (Education Week, 1998). Even fewer attempt to help teachers develop their knowledge of the social and organizational aspects of the school. Teachers need to look carefully, not only within themselves but also at their technological and social environments before they begin to implement innovative uses of technology in their own classrooms and teaching.

What follows naturally as a suggestion is to expand the view of what teachers need to effectively integrate technology. The national movement toward developing technology standards for teachers (Handler & Strudler, 1997; International Society for Technology in Education, 2000; National Council for Accreditation of Teacher Education, 1997) has generated many technology standards for teachers (U.S. Congress Office of Technology Assessment, 1995; Zhao & Kandall, 2001), most of which focus on the technical aspect of educational technology. In light of the findings from this study, we suggest technology standards be expanded to include the social and pedagogical contexts and implications of technology. We also encourage teacher education institutions and other teacher professional development programs to broaden their views of the kind of preparation and support preservice and in-service teachers need to thoughtfully and effectively integrate technology in their teaching. Teacher education programs that direct individuals to reflect on their own beliefs about teaching and technology, as well as to consider the real-world limits that exist in today's classrooms, may be working in this direction.

REVOLUTION OR EVOLUTION: ISUES OF CLASSROOM TECHNOLOGY

It is popular to talk about the "technology revolution." It might be attractive to think that teachers should engage in innovations that make dramatic changes in existing practices and school culture. Additionally, one might assume that the innovations that include a wide range of people and resources within the school would be the most likely to have the greatest impact on other teachers and the school culture. However, this research found these ideas to be unreliable. Innovations that were the most distant from the teachers' existing practices and school culture were less likely to succeed, as were those innovations that were more dependent on other people and resources. For instance, some innovations that were highly self-contained (i.e., low on dependence on others) still had a significant impact on other teachers. Also, in some cases the impact of a self-contained innovation on others was greater than the impact on others of an innovation designed to influence others. For example, Anne's innovation was designed to be self-contained, but it had a large influence on other teachers. They saw what she was doing and wanted to get involved. In fact, so many other teachers have become interested that now Anne's opportunity to use the computer lab has become seriously restricted.

Given these findings, we argue that teachers should take an evolutionary rather than a revolutionary approach to change. It is likely that teachers will experience more success and less frustration if they take small, but progressive steps toward change. Moreover, they are likely to benefit from carefully balancing distance and dependence so that the two dimensions might compensate for each other.

ACCESS OR EASY ACCESS: ISSUES OF SUPPORT AND TECHNOLOGY

The study found that a supportive school environment is important for successful technology integration. Teachers need access to a healthy human infrastructure and a functional and convenient technical infrastructure. Although in recent years there is great progress in bringing computers and networks to schools, we found that in many schools teachers did not have easy access to either of the two infrastructures. There are major differences between *access* and *easy access*. For example, in a school where computers are housed in labs, teachers can be said to have access to computers, but they may not have easy access to them—if they have to schedule lab time far in advance, compete with other teachers, or spend significant time trouble shooting. Similarly, a teacher can be said to have access to the Internet. But that access is by no means easy if the teacher has only one computer connected to the Internet and the district technology professional controls what content and functions the teacher can access.

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Notes

1 An exception would be the Apple Classrooms of Tomorrow Project (ACOT) (Dwyer, Ringstaff, & Sandholtz, 1991; Fisher, Dwyer, & Yocam, 1996).

2 Because in some cases the grant was awarded to a team of teachers, the 10 cases actually involved a total of 14 individual teachers.

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The benefits of technology in the classroom. Learn how technology improves tasks like attendance-taking and standards-based lesson planning while preparing students for the future. How to use technology in the classroom. Discover the power of devices for more engaging, interactive lessons for students of all ages. Technology grants. How to find, apply for, and obtain grants for using technology in the classroom. Assistive technology in the classroom. See how technology can expand access to learning for special-needs students. Using technology for differentiated instruction. Leverage classroom The uses of technology are widespread. Technology is not meant to replace the teacher. Rather, the idea is to create a flexible learning environment that breeds innovation. It shifts the classroom experience from the â€˜sage-on-a-stageâ€™ approach to a more collaborative learning environment. The success of such endeavors will ultimately depend upon how technology is applied to keep students engaged.