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Technologies in contexts: implications for teacher education☆,☆☆

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Abstract

This paper discusses the interaction among school and university contexts, instruction, and individual practice that occurs as telecommunications technology is integrated into teacher education programs. Data from a series of studies of such integration within one university are presented and discussed. A model to guide future research is proposed. © 2000 Published by Elsevier Science Ltd.

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1. Introduction

At this point in the evolution of instructional technologies, computer based technology is (and will become even more) a component of school and university classrooms. While we are mindful of Cuban's (1986) caution that many technologies, such as instructional television, were once heralded as innovative and later discarded, we are seeing more and more schools and universities invest in hardware, software, and computer-(and Internet) dependent course development (NCES, 1999). For the past 15 years teacher education programs in the United States have been expected continuously to increase their emphases on integrating technology with instruction (OTA, 1995; NCATE, 1997; ISTE, 1999) and to insure that program graduates meet standards for computer competence. Some programs are wealthy in terms of hardware, software, and knowledge resources. Other programs are just beginning to incorporate technology into their programs — and are struggling to find the resources to do so. As more teachers, teacher educators, and teachers-to-be work to meet these standards, it is important to understand the impact of technology on the individuals and on the contexts in which they work. In this article we discuss the evolution of

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a model to explore this impact, based on 4 years of data from a project called "Teaching Teleapprenticeships".

The Teaching Telapprenticeships project (TTa) began as a National Science Foundation-funded research and development activity to extend the traditional face-to-face apprenticeships currently used in teacher education through the use of electronic networks (Levin, Waugh, Brown, & Clift, 1994; Levin & Waugh, 1998). The project brought faculty who were interested in technology hardware, software and the applications of technology in teacher education together with faculty interested in the process of learning to teach. Thus, representatives from two professional communities were encouraged to work together and to learn from one another. Faculty from the first community tended to raise questions about the nature and frequency of network use; the nature and impact of network-based projects; and the nature and impact of various forms of distance learning (Honey & Henriquez, 1993; Waugh, 1994; Stuve, Bombardier, Secaras, & Levin, 1995). Faculty from the second community tended to ask questions about the roles of technology in bridging isolation among teachers (Merseth, 1991; Bitter & Yohe, 1989) and about the use and misuse of technology in teacher education curricula (Thomas, Clift, & Sugimoto, 1996; Thomas, Larson, Clift, & Levin, 1996).

Prior work, therefore, led us to adopt an implicit model of research on technology use that inquired into how prospective teachers used hardware and software in the process of learning to teach. Our initial research questions all related to a general theme — what kinds of students use telecommunications during coursework prior to student teaching, as well as during student teaching, for what kinds of purposes? We felt that demographic information about prospective teachers was important, as was information about their abilities and their decisions leading to any use (or lack of use) of the telecommunications. We began our work positing a rather simplistic, linear relationship among university requirements and prospective teachers' use of telecommunications (Fig. 1).

As we will document in the next section, we found that this model was far from adequate as we sought to capture the interactive nature of technology use and impact on teacher education programs and their participants.

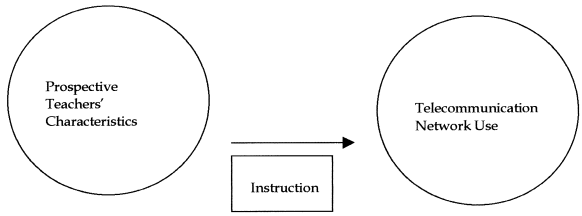

Fig. 1. An overly simple model of research on prospective teachers' use of telecommunications.

This model suggests that studying the use of telecommunication means that one is, essentially, studying individuals, with instruction serving as the primary modifier of individual practice. Researchers using this model might study people, characteristics, or instruction. Instruction in teacher education programs might be organized around individual differences and variations in instructional designs.

2. The series of studies

Over a 4-year period (from 1994 to 1998) project research teams collected and analyzed data on the evolution of the use of computer-based technology in the elementary and secondary teacher preparation programs. Four research methods were employed: surveys of students in the elementary and secondary programs (Levin, 1995; Benson, 1995); intensive interviews with elementary and secondary students (Larson, 1998); e-mail messages for students who checked out project-owned Macintosh PowerBooks (Thomas et al., 1996); and intensive case studies of students in the program (Thomas, 1998; Larson, 1998). In this section we present selected examples of each of these studies in order to support a more sophisticated model of technology use in teacher education.

2.1. Survey studies and a second model

2.1.1. Student survey data (collected from 1994 to 1996)

Over the course of this research project, we have conducted numerous surveys of students' self-rated

expertise and attitudes toward technology and its applications. These surveys have changed as technologies have changed and as the integration of technology into the teacher education courses has changed. We used the results of each survey to reshape the nature of the integration of technologies into courses. A comparison of two surveys will be presented here, to give an overview of the nature of change that occurred over the time of this research project.

One of the undergraduate groups that we studied was the Year-Long Project (YLP), an innovative elementary education student teaching program that served as the pilot for the complete redesign of our elementary education program. Forty-one students responded to surveys in 1994–1995; 49 students responded in 1995–1996. Table 1 summarizes responses to three, open-ended questions. We see a definite shift from e-mail as a focus to a broader range of software, including the World-Wide Web

Table 1
Elementary teacher education students' responses to technology instruction

	1994–1995 Elementary students	1995–1996 Elementary students
What was the most useful thing that you learned from the Technology Component of the C&I block?	How to use: e-mail (21) Gopher (4) Word processing (2) Spreadsheets/databases (2) Awareness of: The variety of software available (10) Multimedia/CD-ROMs (3) Access to: Macintosh PowerBooks (5)	How to use: "Netscape" (11) "Scanner" (5) e-mail (8) "presentation graphics" (2) Awareness of: The variety of software available (13) Multimedia/CD-ROMs (7) Access to: Macintosh PowerBooks (3)
What was the least useful thing that you learned?	Course requirements: Accessing ERIC (7) Accessing preservice teacher list serve (5) Software: spreadsheets (4) databases (3) Gopher (2) Instruction not enough time (3) Too basic (2)	Already knew how to use: e-mail (4) word processing (2) Presentation format: lectures/large group instruction (4)
What suggestions would you make for changes next semester?	Content: more connection to actual K-12 uses (7) CD-ROM and other educational applications (2) Presentation format: form small ability-level groups (7) more hands-on learning (7) teach at a different time (4) make it optional (2) Instructional level: too simple (6) too complex (3)	Content: more relevant to classroom use (6) Presentation format: more hands on (7) shorter or fewer technology sessions (5) more structured technology sessions (3) Instructional level: ability group the class or allow choice of attending technology sessions (4)

(WWW). This was due, in part, to the rapid development of the Web over the course of the intervening year. It also reflects that, within just 1 year, students entering the program had become more proficient with technology on their own. Students' greater acceptance of technology is seen in their responses to "least useful learning". The most striking difference between the 2 years is the much smaller number of responses for the 1995–1996 group. There were 19 blank responses and four explicit non-negative responses ("all good things", "nothing", "n/a" and "nothing was useless"). So almost half (49%) of the responding students in 1995–1996 did not respond to this question with a negative comment. In contrast, for the 1994–1995 group, there were about one-third (32%) non-negative responses (13 blank and two "Don't know").

2.1.2. Suggestions for change

Unlike the other two questions, there is a consistent pattern of responses for both years to this question. Students wanted to see more explicit connections between technology and its use in actual K-12 settings, and they wanted more "hands-on" experience during their learning. It is also clear that there was quite a range of technological expertise: some thought that the technology strand was too simple and several thought it was too advanced. The suggestion of small ability-level groups came out in both years. At this point in the program, there was no evidence that students were tapping into different ability levels in order to learn from one another. We will return to this point in a later section.

These results had a direct impact on program revision. During Spring 1996, the technology component was modified to provide several, simultaneous small groups that students could join, each of which was held in a computer lab so that students would have hands-on experience. This multiple small-group, hands-on instruction required much more in terms of resources, i.e., more instructors with technological expertise, graduate assistants who could be available on an as needed basis, and multiple lesson preparations that matched technology with content and grade level.

2.1.3. A second research model

At the end of the first year of the project we found that we needed to develop a more sophisticated model to guide our research. We drew from Rogers' general theory of diffusion of innovations (Rogers, 1983) and Markus' (1987) critical mass theory of media adoption. The former, diffusion of innovations, suggests that early users are seen to benefit from adopting a particular innovation (in our case, electronic mail) and that others follow suit either to stay competitive or because they are persuaded to adopt the innovation by significant (and often powerful) others. Critical mass theory suggests that using a new interactive medium (such as telecommunication) is considered beneficial only if there are a sufficient number of innovators and if universal access to interactive media is assured. With universal access, users may be able to employ the medium more efficiently than alternatives and an interdependence among users develops over time.

With this model we predicted that the work setting and the prospective teachers' perceptions of that setting would affect and be affected by their individual characteristics and their preferred modes of communication, as well as the communication media available to them. We also predicted that the ease with which the prospective teachers could access these media and their perceptions of the practical importance of the media would affect and be affected by individual characteristics. This second model also acknowledged the importance of context as it influenced students' perceptions.

Unlike the earlier model, this one suggests that not only are individual characteristics important, but also researchers must take perceptions into account (Fig. 2). Furthermore, the context in which those individuals work should not be ignored. In addition to people, characteristics, or instruction, research questions might address how people's thoughts and feelings affect their use of telecommunications and other technologies. It might also be important to study how the context promotes or inhibits access to technology. Instruction in teacher education programs might be organized to challenge perceptions that inhibit technology use and might seek to ease access to various forms of technology.

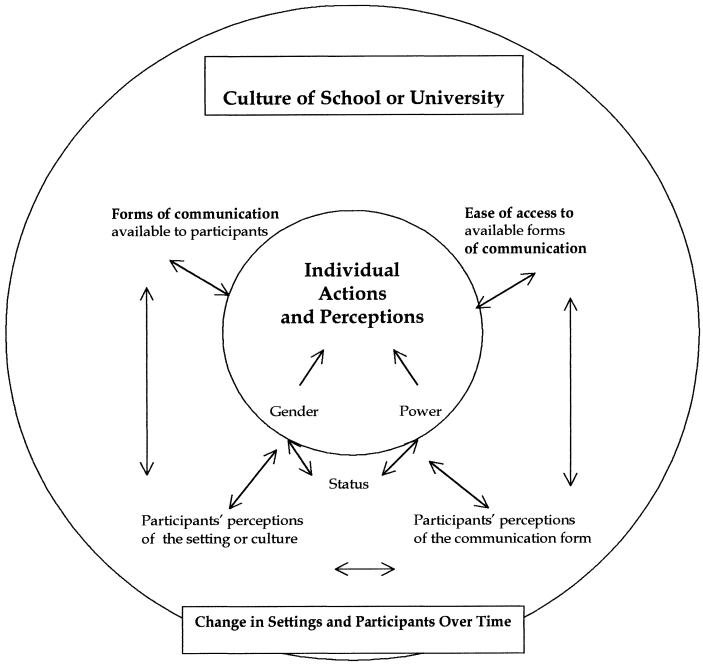

Fig. 2. A second model of research on prospective teachers' use of telecommunications.

2.2. E-mail and interview studies

2.2.1. Prospective secondary English teachers' data (collected from 1994 to 1995)

Eleven secondary teacher education students who were preparing to teach English agreed to give us access to three sources of data: (a) all e-mail messages sent and received on Macintosh PowerBooks (with personal, private messages deleted by the students); (b) interviews with all participants conducted at the end of the semester; and (c) responses to a survey distributed to all student participants. The participants were told beforehand that the messages would be read only by the researchers. They were also told that they had the right to delete the messages that they did not want to share.

Analysis of the e-mail messages (complete details are provided in Thomas et al., 1996) indicated that while telecommunication served as a convenient medium for meeting task demands, it also served as a filter of information. If the subject line in an e-mail message indicated that a particular message was not immediately relevant to either personal or instrumental concerns, it was often unread. Seldom was reading e-mail seen as an important professional exchange of information, but writing e-mail (a program requirement) was seen as an aid to reflection by some of the student teachers. This was corroborated by the interview data.

When the student teachers experienced extreme stress, however, e-mail only served as a quick way to send a "help" message. Telephone calls and face-to-face communication were identified as more personal and often more helpful than e-mail. For these 11 students, the electronic medium served as an impersonal, but efficient, way of accomplishing work-related tasks. Telecommunication was perceived to be a cool, impersonal medium. Students' purposes for using e-mail were less often self-motivated discoveries and were more often responses to instructors' recommendations for using telecommunications media. The data we collected led us to conclude that the university task demands had a major impact on prospective teachers' use of e-mail, if not other forms of telecommunication. We also learned that the status/power imbalance between instructors and students led some students to

perceive that messages from instructors were more important than messages between students — regardless of message content. In other words, use of telecommunications did not automatically foster students' abilities to engage in professional reflective activity with one another.

Based on our analysis of e-mail messages, we developed a more complex interview protocol to increase our understanding of communication choice during student teaching. The first set of questions addressed the participants' biographies, specifics about the courses they were taking, responsibilities during student teaching, and current, as well as prior experience with computer technology. The second set focused on a typical teaching day, in that each student teacher described their interactions with people working at their site for student teaching and with people working at the university. We asked them to focus on the people with whom they communicated about their teaching and to discuss where this communication took place. The final set of interview questions addressed each student teacher's perception of communication media and the role each medium played in their teaching and communications about their teaching. We interviewed prospective secondary teachers from the content areas of English, mathematics, and science as well as prospective elementary teachers.

All interviews were transcribed and responses were categorized under each specific interview question. For the purpose of this article we focus on the third section of the interview protocol, the section related to media choice. We developed a communication choice profile in relation to purpose of choice for each student and then worked as a team to identify themes that crossed individuals. We then began to study unique instances that provided insight into how some students did not fit the dominant pattern. We used this discrepant analysis to modify and refine our categories and themes.

2.2.2. *Secondary student teachers in English, Mathematics, and Science (collected from 1995 to 1996)*

The secondary students we interviewed emphasized the importance of face-to-face communication with people who served as resources for lesson planning and implementation. Such interactions included seminars and team meetings, as well as conversations with supervisors, cooperating teachers, and other student teachers. The telephone also served as a resource to connect students to important persons who could provide professional input. We were particularly interested in noting that student teachers' parents were mentioned as professional as well as personal resources. E-mail served as a relatively "cool" medium for connecting students back to the campus and to one another, in that it was considered much less personal than a telephone or talking face to face.

We found some differences across content areas, with students preparing to teach English only using e-mail to help with logistical arrangements with their methods instructor, not discussing ideas about instructional content or pedagogy. Neither did they avail themselves of resources such as the World Wide Web. The science student teachers reported more use of Internet resources than did the English student teachers, but the greatest use of telecommunication for gathering professional resources was reported by the mathematics student teachers. Two reported using e-mail to send attachments of lesson ideas to other students, something not mentioned in the other two groups. One reported being on Prodigy and getting "tons of suggestions and answers to problems"; another received information from a methods instructor on "Geoboards" and communicated with her brother on another campus about mathematical proofs and rounding. The two consistent themes across all of the secondary students were that e-mail saved time and that they saw little use of electronic communications or the Internet in their field experiences.

2.2.3. *Elementary student teachers' data (collected from 1995 to 1996)*

Unlike their secondary counterparts, the elementary student teachers reported using electronic communications for social interactions as well as for professional exchanges. They also reported numerous interactions (that we classified as support seeking) through telephone and face-to-face communications. Parents and friends were contacted by telephone and, whenever possible, were visited in person. Like their secondary counterparts, the

elementary student teachers reported that electronic mail served as a way of staying connected to people on the university campus. Interestingly, they also noted that e-mail enabled them to discuss sensitive issues such as racism in a safer environment than a face-to-face environment afforded.

The elementary student teachers did not report using Internet resources to plan and implement lessons or to access materials. They did report being aware of such resources. Few reported using Internet activities with their students. Interestingly, several students reported that their teachers were beginning to incorporate Internet activities into their work. One young man surfaced as someone who built on his cooperating teacher's use of the Internet to plan a school-wide participation in the "TeleOlympics," in which students competed in selected track and field events with counterparts all over the world. Times and distances were recorded at a given school site and then sent to a central location. This project provided instruction in physical education, mathematics, and social studies.

The interview studies led us to more closely examine the varied contexts that impacted students' learning to use technology. In order to get a detailed picture we conducted case studies of elementary and secondary students. Four of these studies are summarized below.

2.3. Four case studies

Two of the co-authors of this paper conducted extensive, year-long case studies of students and the teacher education programs in which they studied. One study was of elementary students (Larson, 1998) and one was of secondary students (Thomas, 1998). The data for these studies were collected and analyzed 1996–1998 and 1997–1998, respectively. We have selected and abbreviated two of the case studies from each of two dissertations in order to illustrate similarities and differences between students in and across programs.

2.3.1. Katia

At the time the data were collected, Katia was a 21-year old white female who came into the program already skilled in using computer technology. Her parents, scientists, used telecommunications in their work and Katia always had access to a computer in her home. She described herself as a voracious Internet user on campus, although mainly for individual and recreational time as opposed to academic purposes. She liked to "hang out" in the computer lab where there was access to computers 24 hours a day.

Despite her proficiency, Katia was not a strong contributor to the use of computers in the elementary education program. On many occasions Katia was impatient with the technology component of the program. She felt that she had little need for what was accomplished in the class sessions. She did not see it as her role to help others learn about computers and often asked to go home or to the computer lab to work on her own. Katia believed that she taught herself more about using computers than did the teacher education curriculum. Her peers who were not equally proficient both admired her independence and were intimidated by it as they observed her going beyond the curriculum to develop an electronic portfolio or a plan for her classroom layout.

But Katia's proficiency did not mean that she was always prepared in her assignments. It was as if practical, "teacher uses", for the computer were not worthwhile enough. For example, Katia would push herself to think of elaborate ways to use the computer, but she would not succeed in doing what she wanted because the complex ideas were not translated into implementation strategies. Consequently, she would accomplish even less than other students who recognized their place on a learning curve, sought to accomplish defined tasks and objectives, and produced products that demonstrated they had learned some practical skills for integrating computers in their teaching. We concluded that Katia viewed the environment for computer technology use in the College of Education and in the university portion of her teacher education program as being at a lower level than other colleges and programs on campus. This perception may have caused her to pull back from some of the opportunities and experiences with computers in the program.

In her field work, Katia learned how to use software in making items for the walls and bulletin boards of her classroom from her cooperating

teacher. She also worked near a teacher who had written a large grant for integrating computers in his classroom and expressed admiration for his willingness to help other teachers and share his expertise about computers. Katia was curious about ways to use software in the classroom curriculum. She was particularly interested in language and literacy applications. For example, she used word processing with her very young students to write stories.

Katia was also concerned about the ways computer technology affected social interactions. For example, she talked at length about e-mail and how individuals could "construct false identities" with e-mail and in electronic chat rooms.

> E-mail is a dangerous thing that way. Because it allows you to be someone you're not. And I think that … it depends on the kind of person you are. If you're a verbal person in writing, rather than speaking, I think it can be dangerous. Because you can just use this persona. I see that so much in my friends' crowds. They try to write these things that look so cool … so mysterious and dark and all that. And you can think through what you want to say. And you can erase something and not send it. And you can be selective. And you can be more open because you're not writing to anything. It's not a "real" person. You're not judging their reactions. And they have time to digest the thought. So I keep that in mind now. From learning the hard way, I think. This past year with e-mail … People need to learn that it [e-mail] is not the same thing as having a conversation.

This reflection, and others, reveal that Katia thought deeply about both the positive and negative influences of new technology on people. She identified some roles with which she was not comfortable (lurker, voyeur); she also thought about the relationship of computer technology to schools and society. She expressed some concerns about how computers seem to be "accessible to kids who have all the privileges anyway … " and inaccessible to those who do not. She was concerned that schools could not "level the field" because her students would come to their learning experiences in classrooms with biographies that informed their skills and proficiency levels for all kinds of learning, computers included. Her reflections about issues of equity also led to reflections on her own experiences with computers in learning settings. She talked about not realizing what privileges she had with education, computers, and support systems until she came to the teacher education program.

From Katia we learned that prior experiences with computer technology did not necessarily create beneficial lenses for viewing ways in which computers can be tapped for learning in elementary schools. Neither did expertise mean that the more experienced teacher education student would happily share that experience in helping others acquire skills or in designing age or grade appropriate instruction. We also learned that prior experiences, particularly with chat rooms, may heighten students' awareness of the ways in which technology may change social interactions — and that such changes were not always seen as desirable.

2.3.2. Syrie

Like Katia, Syrie was a 21-year old white female who was from an upper middle class, two-parent family. Syrie, however, did not come into the teacher education program already proficient in technology use. She did not prefer to use the computer for writing in many circumstances, nor did she prefer e-mail as an important means of communicating with others in the program. Syrie needed to believe that computer use for a specific assignment or task was required or expected. She believed that this expectation gave her more confidence as she increased her knowledge about using computers.

Syrie valued the technology component in the teacher education program and she was able to identify several areas in which she learned specific skills from the program. She was especially pleased that she had access to a Macintosh PowerBook, although she was often frustrated by technical problems associated with its use. Syrie was not averse to seeking help, however, and she often sought the support and expertise of others who would help her solve technical problems.

We concluded that Syrie was pragmatic in her approach to using a computer for class

assignments. When the benefits for using computers were clear in Syrie's mind, she used the PowerBook. When the benefits were not clear, and costs were higher than benefits, she chose not to use the computer and completed the assignment in another form. She was less pragmatic in her decisions to use e-mail to keep in touch with friends with whom she had lost touch. She talked enthusiastically about these conversations with her "retrieved" friends, while at the same time she revealed that she barely had enough time to get her university work and her preparation for teaching accomplished. She felt that requirements to communicate by e-mail were often an "extra" and, therefore, stressful thing to do.

Syrie used computers less in her field work than in the university context or in her individual practice. She did have the opportunity to observe computers being used in instruction. She reported that in one of her first field placements one of her cooperating teachers used "some kindergarten-type programs with the children". The other cooperating teacher used technology "a great deal … She had programs set up for kids to use … many different kinds of programs … She typed up stories kids gave her". In her second placement her cooperating teacher had "a computer center. She had a math software program in her classroom and spelling programs … Roving computers came to the classroom [along with] volunteers for extra assistance". Syrie felt that she observed many practical examples of computer use in her field placements.

Syrie did not spend much time reflecting on the connections between computers and society. Technical problems and practical classroom applications were her greatest concern as she discussed the importance of using computers and new technologies in her professional work. She recognized the potential for applications and was a creative and energetic teacher. She was particularly interested in how computers might be used to teach writing and mathematics in the elementary classroom. The disparity between having and not having computers in the university vs. the schools was not of as much concern to Syrie as it was to other Year-Long Project students — even though she experienced this disparity across her field placements. For example, she worried about the children in her classroom who would come from impoverished homes — although she seemed ready to accept that these students might learn at lower levels because of their life circumstances or biographies.

From Syrie we learned that, for certain students, the absence of prior experience with computers may actually be an asset. The concurrent struggle to learn, to apply that learning, and to think about lesson design may result in a synthesis of purpose or instructional intent, provided that the teacher education curriculum encourages such synthesis. We also learned that students are very aware of the cost/benefit ratio when choosing to use computers for their own assignments. This pragmatic approach, in some cases, might actually inhibit learning because the goal was to just get the assignment done, not to explore alternative approaches and the impact of those approaches on the final product. Finally, while we were encouraged by Syrie's early awareness of the disparate access to computers by students from different economic background, we were troubled by her apparent acceptance of that condition. It seemed to us that Syrie was not prepared to think about how schools (and teachers) might provide more equitable opportunities for students.

2.3.3. Janee

When we began interviewing Janee, she was an academically successful 20-year old junior who was just beginning her course work in teacher education. Janee's favorite teacher was her former geometry, trigonometry, and calculus teacher in high school. Her opportunities for working with computers began in the fourth grade, when her parents enrolled her in a basic programming class in the home of a local university professor. As a high school senior she took a word processing class, but reported limited opportunities for access and integration of computers in other classrooms. For example, although she was encouraged to purchase a graphing calculator while in a trigonometry class in high school, the math teacher at the time did not emphasize how to use it, except to check one's evaluation of an integral. In addition she had access to a home computer, used for word processing, games, and spreadsheets, which she attributed to

her parents' demand that she and her sister keep a budget while students at the university.

Games represented some of her earliest recollections of using a computer. She described a variety of computer games, many math related, such as Alien Edition and Hunt the Wumpus. She also discussed more complex games, similar to activities in MUDs and MOOs[1], where players take on various identities with lists of tasks to accomplish. One game, called The Cave, required players to work through a cave using words only and on occasion included the death and reincarnation of its players.

While in university-required general education courses, Janee used a variety of computer technologies for course completion. From her personal computer, she hooked up to NovaNet in order to access quizzes and print out quizzes. She also accessed a campus computing laboratory in order to run programs for her computer science class. This computer science class used class newsgroups to post the required machine problems and as places for students to post questions about the problems along with example answers to class assignments. Her chemistry class posted lessons for review and many other classes posted course lecture notes on the World Wide Web.

The first field component of her mathematics methods course took place in a middle school eighth grade mathematics class located in the same town as the university. Her cooperating teacher had attended summer computer workshops given by the university. Janee did not observe her cooperating teacher using computer technologies for instructional purposes, however. When describing the computers available in the classroom, Janee reported that her cooperating teacher had a laptop but did not use it in front of the students. The only time Janee saw her use the computer was when she demonstrated a project that she had completed for a summer class at the university to Janee and other preservice students. During her field assignment Janee and the other prospective teachers were asked to take the students to the computer lab for an Internet search. Her role was to make sure that they were on track. "I felt like I was more of a resource for the computer and the Internet than a math teacher, and I'm studying to be a math teacher."

In the second semester field experience Janee was placed in a special education resource room, where the students were allowed to play computer games (action games) or access the Internet after their work in study hall was completed. The Internet sites she saw the students access were those they had seen on television. She saw no examples of incorporating the Internet into instruction. When comparing both of her field placements, she commented that she saw more direct use of technology during the first semester (the middle school mathematics class). Technology during the second semester was used for non-instructional time. Based on what she saw and experienced in her field placements, Janee summarized the use of computer technologies as a "fun break."

Janee shared that she felt there would not be much difference between the role she imagined for herself and the role of the mathematics teachers 10 years ago. She did see, however, that there might be different tools, such as the computer, the graphing calculator, or standard calculator. Janee lamented about the over-reliance on calculators for computation based on observations from her field experience. She went on to describe this student over-reliance on calculators as forcing the classroom teacher to gear the problems more toward the calculator, "if you know they are going to use it, you may as well [gear problems that way]". Yet when asked to give a metaphor for the computer she answered,

> It's like a friend to help you do things much more quickly than before. I could never hack doing papers on a typewriter. You can't revise or look at things clearly. Seeing my mom using it for her checkbook now. It is so much easier. It takes two minutes to balance your checkbook instead of adding all this stuff up by hand. It is a waste of time especially when you are adding 100 numbers, you are bound to make a mistake.

[1] MUDs are Multi-User Domains, computer-based environments that allow multiple people to interact within a shared virtual world. MOOs (MUDs Object Oriented) are MUDs that can be modified by users.

When asked, "If you had one computer in your room with an Internet connection, what site might you use and how would you employ it?", Janee responded that she had heard of a website that hosted lessons posted from other math teachers and would use this site as a resource to get new ideas about how to present things to see if they worked or not. At that time, her image of the Web was for teacher use. At the time of the study she did not think in terms of the students exploring the Web for their own learning purposes.

From Janee we learned that not only do prior experiences with computers serve as filters for thinking about how to incorporate technology into instruction, but images of good teaching do so as well. Janee, at that point in her preparation program, had not been able to get away from a traditional view of mathematics instruction. We also learned that the teacher education program (both field and course requirements) had not helped this student (and others as well) to develop a coherent view of what it means to incorporate technology into mathematics instruction.

2.3.4. Chris

Of all of the students we studied intensively, Chris, a 20-year old junior studying mathematics education, was the most technologically sophisticated. One of the reasons he decided to teach secondary mathematics was because those teachers often teach computer applications. His experience with computer technologies began when he was 5-years old with access to an Apple II + and a few basic programming books. His elementary school had 5 Apple IIe's on which five students would play math games or work on typing skills each week. His junior high curriculum included a BASIC programming class. In high school he enrolled in additional programming classes, including Pascal and HyperCard. Some of the applications he used on his personal computer were Microsoft Office, PowerPoint, and Mathematica, as well as word processing, e-mail and games.

Chris used e-mail everyday for course related and personal purposes. During Fall 1996, Chris reported that he used the Web to examine sites selling computer hardware and to buy a new motherboard for his computer. Chris described the computer as "like a student and the user is the teacher. The computer is not going to do anything that it is not told to do. It is like a perfect student because it will only do what you tell it to".

Like Janee, Chris was required to use a variety of computer technologies for requirements in university courses across campus. For a physics class he logged on to NovaNet to access the homework assignments. Chemistry classes required the same. Computer science classes required programming with Mathematica. Another physics class required the students to access the course homepage for the homework, where the work was also to be sent when finished. Chris reported that no computer technologies were used in the educational psychology course he took. He also noted that because course notes were made available on the Web for the educational policy course, he did not attend lectures — opting to download the course notes.

The mathematics methods course, which he was taking when we began interviewing him, required the use of e-mail, accessing the Web for mathematics specific resources, and the creation of a personal homepage. During the spring semester, a second course in education required that e-mail be sent to a class reflector, as well as a subscription to a professional listserv of interest to the student and following the conversation on that listserv for at least 2 months. In addition, this course required researching the Web for resources appropriate for a secondary classroom, previewing and critiquing of multimedia software, and included the option to create a personal portfolio in electronic form. Chris reported that for the remainder of his second semester courses, word processing was required, but not many more technology requirements were expected, particularly in his mathematics courses.

Chris felt strongly that computer technology was a tool that could and should be utilized more in classrooms. He imagined his future classroom to house at least one computer with an LCD panel for using HyperCard or PowerPoint. He wanted to experiment with having "lessons made up on there that I could just go through on my computer. I think that would almost be a necessity for me". He felt that programs like PowerPoint could be effective because of the attractive presentation, and the ability to plan out the lesson before class so that

time is not wasted writing on an overhead or chalkboard. Additionally, lessons prepared on PowerPoint were ready for a substitute teacher in the computer lab. He hoped that computer technologies would open the students' minds to the fact that math is a lot more than a textbook and a sheet of paper.

When he was asked, "If you had one computer in your room with an Internet connection, what site might you use and how would you employ it?", Chris responded that he would use the "Puzzle of the Day" web page, "because I think I could hook up the computer to an LCD display. It would make fun warm-up exercises or if there is ever 10 minutes left in the class period, I could do that".

Chris's fall classroom placement was at a high school in the same town as the university. He was assigned to observe two classrooms: a lower level pre-algebra class, in which 12 of the 16 students were African-American; and a sophomore geometry class, which was primarily white, with one African-American student. His cooperating teacher, a graduate of the mathematics education program from Chris's university, was currently enrolled in the Master's degree program. In cooperation with the Davea Career Center in northern Illinois, the high school geometry students in this class were "hired" as subcontractors for a "Base Plate Project" by a company producing a new video game. The product was manufactured at the Davea Career Center and the students were to correspond with the Center via e-mail after down loading the blueprints from the Davea Web Page.

A key element in this project was the use of Macintosh-based mathematical software called Geometer's Sketchpad. Chris and his colleagues were given this software on the Macintosh PowerBook laptops loaned out for the semester. Chris was assigned to work with one of the base plate production teams. In further interviews with Chris, there was no reference to how he might use such a project with his own students. We concluded that, like Janee, he had not abandoned a traditional view of teaching and the role of the teacher.

Chris' second field placement was at a local high school in a special education classroom. This classroom held only five students and was a more relaxed atmosphere. Every so often the cooperating teacher let the students play chess, and Chris played with them. The classroom housed an Apple IIe. One particular student in the class wrote letters on it. Chris was not sure about the degree to which his cooperating teacher relied on computer technology.

> The only time I've seen him use a computer is when we took the class to the library to the computer lab and did an Internet search on tornadoes. They were supposed to look for how many people died and where the tornadoes hit.

Chris felt that none of his courses or his field experiences introduced him to any computer software that would be used in basic math classes. He did not feel prepared to incorporate computer technologies with lower track students or students with special needs. He did note that, "you can always find ways of using stuff you are familiar with until you can find new stuff".

Before his year in the teacher education curriculum, Chris had never considered the computer for instructional purposes. He began to feel that the "lecture style" mathematics classroom was outdated and that computer technology could be a useful tool—for the teacher. His image of computer as information giver only put a modern spin on what we often refer to as "chalk and talk" instruction.

From Chris we learned that even though a field experience demonstrated technology use in a novel and innovative manner, this was insufficiently powerful to overcome a teacher-centered view of teaching—at least initially. While Chris eagerly adapted his instruction to take advantage of computers, this advantage did not extend to student use. We were especially concerned with Chris' apparent views that technology use was appropriate for high track students, but not for students in the lower tracks in the high school where he was observing.

2.4. A third model

At this point we began to look across the data we had collected in order to develop a third model that acknowledged the inferences we had made based

on our various analyses. We began with acknowledging that in our project, the university setting exerted a powerful and intentional force on many of the prospective teachers by infusing telecommunications use and technology use throughout the curriculum. The program (and our project in particular) made technology available on and off the campus. Thus, for these prospective teachers, issues of access and available communication forms were not as important as they would be for students who are working in university contexts that are not as technology rich. Table 2 summarizes our conclusions.

We do *not* argue that our data are illustrative of all, or even most, teacher preparation institutions. We also recognize that as times, people, and technologies rapidly change (which has happened since we submitted this article for review), our conclusions will not necessarily continue to hold for our own programs, much less for any others. One concern of any study concerning new technologies is whether the conclusions will remain relevant over time given the rapid rate of change in technology. A study whose findings were dependent on the details of particular ways of interacting with technologies, with the specifics of computer speed or the limitations of communication bandwidth at a particular moment in time may not be relevant as those specific features change radically over a few years. We *do* argue that our findings can inform both program design and future research as technology becomes more and more important in education and in teacher education. In our work we have attempted to focus on those aspects of technology use that are less impacted by the specifics of the software or hardware and, hopefully, less sensitive to the changes in technology.

As we reflected on our own work, plus our knowledge of the varied university contexts that supported students' learning to use technology, we found that, not surprisingly, university instructors differed in the expectations for students and in the support they provided. We also found that different groups of students evolved their own, unstated norms for what were and were not useful practices related to telecommunications. The model we have since developed to guide our research, shown in Fig. 3, expands the concept of contextual factors

Table 2
Summary of conclusions across data sources

	Surveys	Interviews	Case studies
Individual practice is shaped by the culture/setting in which the individual works		X	X
Different settings encourage different practices in the same individual.		X	X
Purpose for communication also impacts individual practice	X	X	X
Different communication options are used, based on purpose for communication and on the ease with which they can be accessed.	X	X	X
Ease of access depends, in part, on individual perceptions of such ease.		X	X
Purpose and task demands may override individual characteristics when using technology and telecommunications	X	X	X
The differential power and status relations between instructors and prospective teachers can have a strong effect on perceptions of both task demands and purposes.	X	X	X
The university and school settings differ greatly with regard to the ability to access technology and, therefore, the communications options available to prospective teachers.		X	X
The university and school settings differ greatly with regard to the group norms that encourage technology use.		X	X
Across the university, departments also vary with regard to the group norms that encourage technology use.			X
Students can handle the variation among the contexts, but do not actively transfer learning about computer use from context to context.			X
Students are only beginning to be aware that telecommunications technology implies social as well as pedagogical changes.			X
Students do not necessarily view technology as a way to ameliorate economic disparities as they impact school work.			X

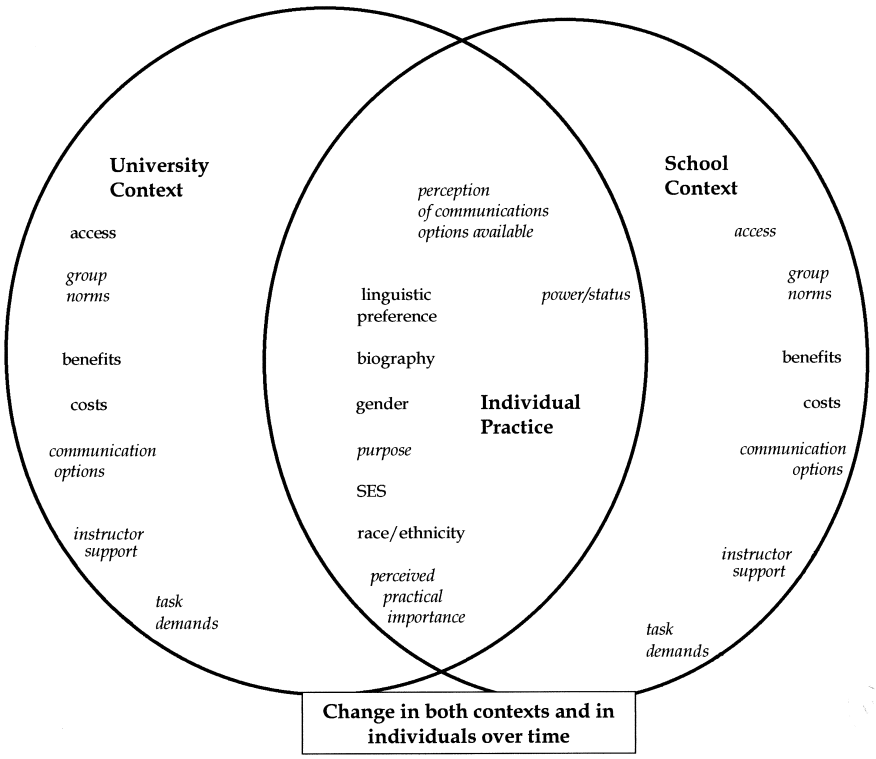

Fig. 3. Technologies in contexts — a model to guide future research.

from our previous model and separates the university context from the school context. In referring to the visual representation of the model as a framework, the inner circle of the model represents individual practice in three distinct, but overlapping, settings: (1) the culture of the schools in which field experiences are situated; (2) the culture of the university at large, in which students have been a member for 4–5 years; and (3) individual practice which includes strands of biography, purpose, socioeconomic status, and linguistic preference. For example, some preservice teachers come to the university following consistent experiences with computer technology in their homes or in their high schools. Others come to the university having had little exposure or opportunity to use computers as part of their personal biographies or in their high schools. However, by the time these students become preservice teachers, their individual practices are informed and modified by their university experiences, and later, in their teacher education program by their school experiences.

Inside the school setting, the university setting, and within individual practice are multiple contexts in which preservice students' experiences with technology emerge, are perceived, and are interpreted — each of which contributes to an emerging knowledge base. Within and between the school and university settings, the model represents ways preservice students might experience and perceive computer technology as: (1) a form of communication in that setting; (2) a form of communication that is practical, accessible, or easy to use in that setting, (or that it is not); and (3) a form of communication that relates to issues of access, group norms, costs and benefits, communication options, instructor and mentor teacher support, and task demands in each setting. Each of these categories informs the others as preservice teachers move beyond technical skills to thinking through meaning and

interpretation of technology use in their individual practice and in the contexts in which they work.

The italicized features, within both the school and university context and within the domain of individual practice, are features that our data have led us to believe are important for thinking about how telecommunications technology interacts with other forms of communication as one is learning to teach. We would not argue that those features in plain text are unimportant, we instead note that the data we have collected to date do not address these issues specifically.

As we analyzed our data we learned that individuals were also affected by evolving norms within university classes, and within the school settings, that made a powerful impact on the students. In some classes, *not* using technology and telecommunications was simply not an option. In such settings, individual practice was shaped by these groups' norms, which seemed to be constructed jointly by students and instructors. In other classes, wherein use of technology or telecommunications was not emphasized, use of technology varied more from individual to individual. We predict that this will hold in school and in university settings — for faculty as well as for students.

Our data indicated that students' options for communicating with others, including their cooperating teachers and others in the field, were tapped for differing purposes. That is, students availed themselves of numerous forms of communication while learning about teaching. Internet-based communication was only one such option. We also noted that when prospective teachers entered field settings with teachers who were interested in technology use, but not necessarily experienced, the student teachers served as teachers of teachers. This leads us to wonder about the potential of technology to encourage communities of learners in which issues of status and power are downplayed more than they are when technology use is not an issue. It also leads us to wonder if prospective teachers can become partial change agents unless they are actively invited and encouraged to do so by experienced teachers and administrators in school settings.

This model, our most sophisticated to date, recognizes that there are many contextual factors that impact upon inhabitants' use of technology, not simply access or resource allocation. Equally important are additional, less easily measured factors such as group norms for technology use and the costs or benefits the context assigns to its use. The model also emphasizes that in order to understand the congruence or dissonance between settings, it is important to examine the settings separately. Likewise, teacher education programs should alert students to the possible differences between campus and field settings — and then strive to minimize any problematic disparity, possibly providing a series of professional development opportunities for practicing teachers.

3. Final observations and conclusions

From our work to date we offer the following thoughts concerning teacher education program design and for further research on the impact of technology on teaching and learning to teach.

3.1. The importance of "just in time support" or support on demand.

Our work has led us to conclude that coursework in technology and telecommunication is not nearly as important as embedding technology and telecommunication use throughout the university curriculum — in and out of education courses. Indeed, this finding has formed the basis for the redesign of our teacher education programs for elementary and secondary students. This conclusion has been confirmed by a national survey of teacher education conducted by the International Society for Technology in Education (1999) and by other research (Zhao, Rop, Banghart, Hou, & Topper, 1998; Thurston, Stuve, Secaras, & Thomas, 1998). Embedding, however, requires that faculty and cooperating teachers be technologically proficient.

3.2. The importance of support for all teacher education participants

Although our data focus mainly on teacher education students' learning, our students often commented on the teacher education program,

which necessarily means the teacher education faculty. Our Teaching Teleapprenticeships project offered some support to interested faculty, but only provided systematic support to one elementary education professor. At this point we note that there is insufficient research on how faculty learn to incorporate technology into their instruction (Handler, Strudler, & Falba, 1998). We suspect that by supporting instructors' use of technology, and by also supporting cooperating teachers' uses of technology, we will see a dynamic change in the degree to which both the university and the school contexts support technology use. Through workshops, easily accessible consultants, and sharing of information, we will most likely influence teacher educators' use of telecommunications and that of their prospective teachers. This teaching of teachers function has not typically been the role of teacher education, but we agree with others who have reached the same conclusion and advocate the expansion of such a role (Roberts & Ferris, 1994).

3.3. The potential of preservice teacher education as change agent in school settings

The concept of prospective teachers serving as change agents within the schools in which they are placed is discussed for many instructional innovations, despite the research on student teaching that emphasizes the low power status of prospective teachers and the degree to which they conform to their cooperating teachers' pedagogical styles (Clift, Meng, & Eggerding, 1994). While our work confirms the existence of social pressures exerted by the field settings (Loveless, 1998), we note that there were occasions when a prospective teacher served as a teacher educator. We advocate for more deliberate program designs in which occasions for mutual learning and the sharing of expertise are emphasized. We also note that the university can support such learning by making technology resources available when the school context cannot.

3.4. The absence of shared knowledge among students of differing abilities

The previous recommendation was made even with the knowledge that much of our data suggest that teacher education students with expertise do not share that expertise with others. When we juxtapose this against research on cooperative learning, we are led to conclude that program designers should deliberately create contexts in which prospective teachers share their abilities with one another. At the same time, we also advocate more research on intentional and unintentional learning when teacher education students with mixed abilities work together on projects designed to encourage such sharing.

3.5. The awareness of purpose in communication choice as a factor in course design

Our students reported that sometimes the requirement to use telecommunications was more frustrating than helpful, but sometimes it was a tremendous asset. When communicating with people who were hard to reach in person or by telephone, technology was perceived as helpful. Based on our analysis we have concluded that asynchronous telecommunication technology is particularly helpful when one does not need or want a rapid interchange. But when rapid interchange is important, particularly in times of emotional stress, asynchronous telecommunication is not valued. The delays between the time a message is sent and a reply is received are too long. Furthermore, prospective teachers often want the visual reassurance that face-to-face communication can provide.

We have also found that some individuals are using technology as a distancing mechanism when they do not wish to be overburdened with others' expressed thoughts or feelings. Busy students or busy professors can use e-mail as a way of avoiding communication with one another, just as they can use it as a means of increasing communication with one another. The same holds for communications with field-based teacher educators. It is much easier to avoid an electronic message than it is to avoid a telephone call or someone's presence in your office or classroom. We believe that further research involving communication choice will be helpful to program designers, particularly as programs experiment with forms of distance education.

Our final thought is based on the reflection and the revisiting of data that occurred as we prepared

this article. The Teaching Teleapprenticeship project supported practice, practical learning, and research. Without the ongoing collections of data and analyses we would not have learned about the interaction among individual characteristics and contexts. Without a project team comprising individuals with different areas of expertise and different research agendas, we would not have raised the multiplicity of issues found in this article, nor would we have modified our own separate views based on the sharing of data and data analyses. We strongly advocate that ongoing research conducted in mixed ability teams can and should be a primary component of teacher education program design and modification.

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