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Technology integration for preservice science teacher educators

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Technology Integration For Preservice Science Teacher Educators

by

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A thesis submitted in partial fulfillment
of the requirements for the degree of
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Technology Integration for Preservice Science Teacher Educators

Nina C. Stokes

ABSTRACT

The current state of technology integration in science teacher education programs is examined with a view to providing science teacher educators with practical information and diverse examples of technologies they can model in their own courses. Motivators and barriers to technology integration and use are discussed, and recommendations for choosing and evaluating science technologies made. A brief history of how computers, related communication technologies, and science teacher education reform "fit" together is provided. Multiple interpretations of what is meant by "technology" and associated terms (distance learning, online courses, Web-enhanced courses, simulations, authentic data sets etc.) are included to set the context.

Chapter 1

Computers, Related Communication Technologies, and Science Teacher Education

Reform: History and Background

The American Association for the Advancement of Science (AAAS) reminds us that "As long as there have been people, there has been technology." (AAAS, 1989, chap. 3). Sherman (2000) says, "Technology both shapes and reflects the values of our social enterprise." (p. 317). Science teacher educators have used computers and other information technologies as tools to increase students' learning of science in America's schools, universities and colleges for over 30 years. In 1934, the first teaching machine was invented by Sydney L. Pressey, but it was not until the 1950s that practical methods of programming were developed. In 1954, B.F. Skinner of Harvard reintroduced programmed instruction, and much of the system is based on his theory of the nature of learning. The range of teaching machines and other programmed instruction materials developed along with programming technology. Programs have been devised for the teaching of almost every subject imaginable, some being linear in concept, allowing advancement only in a particular order as the correct answer is given, while others are branching, giving additional information at the appropriate level whether a correct or incorrect answer is given (Hezfallah, 1990).

The 1960s brought with them the introduction of computer-assisted instruction (CAI). CAI was developed with the goal of aiding in the acquisition of basic skills, providing opportunities to practice these skills, and then to measure learning gains.

Patrick Suppes developed some of the first CAI at Stanford University in 1963, and set standards for subsequent instructional software. Suppes designed highly structured computer systems featuring learner feedback, lesson branching, and student record-keeping (Coburn et al., 1982).

In the late 1960s the National Science Foundation (NSF) supported the development of 30 regional computing networks, which included 300 institutions of higher education and some secondary schools, to increase computer access. In excess of 2 million students used computers in their classes by 1974. In 1963, a mere 1% of the nation's secondary school teachers used computers for instructional purposes. By 1975, 55% of the schools had access, and 23% were using computers primarily for instruction (Molnar, 1975).

In 1969, the British Open University was established as a fully autonomous degree-granting institution. The basic Open University system utilizes television courses rigorously developed by a team of content specialists and instructional designers. The British Open University broke traditional barriers to education by allowing any student to enroll regardless of previous educational experience or background. It currently serves more than 200,000 students and has enrolled more than 2 million people. It is recognized throughout the world as a prototype for current-day, non-traditional learning.

LOGO, a computer language developed by Seymour Papert and his colleagues at the Massachusetts Institute of Technology in the 1970s, provides one of the earliest examples of computer-based exploratory learning. Papert used LOGO to aid students in acquiring critical thinking and mathematical problem-solving skills (Papert, 1980).

Personal computers were ubiquitous by the end of the seventies and could be found in classrooms, offices, homes, laboratories and libraries. The computer was no longer a luxury, but a necessity for schools and universities. In 1971 the microprocessor was invented by Intel and the first e-mail messages were sent, and in 1978, the first computer Bulletin Board System (BBS) was established. In the early 1980s, low-cost personal computers allowed the use of technology in education to expand to include general-purpose tools such as word processors and spreadsheets. In addition, new technology allowed classes to be given "remotely", programs being transmitted to classrooms via cables, fiber optics and satellites. In 1984, the first such "distance learning", undergraduate courses were delivered by the New Jersey Institute of Technology. This opened the door to individuals who, because of other commitments and responsibilities (careers, children, family etc.), would have otherwise been unable to take courses, as well as people located in remote regions of the nation, and in typically underserved communities.

Telecommunication technologies have leaped forward. The Internet, a global telecommunications system that began in 1969 as a U.S. Department of Defense project, is an incredibly powerful resource, making a vast amount of information immediately accessible. It provides instant access to educational research, as well as curricula, lesson plans, discussion forums, online experts and communication tools. The World Wide Web was first developed in 1991 and provides the connections to resources on the Internet, allowing users to travel from resource to resource with the click of a mouse button. This wealth of information opens doors for collaboration, encourages alternative instructional strategies, and enhances the curriculum (Barron & Ivers, 1996). Telecomputing tools

include e-mail, electronic bulletin boards, electronic mailing lists, discussion groups, Web browsers, real-time chatting, and audio- and videoconferencing. Online resources include Web sites (including social networking sites such as My Space), and interactive environments, and remotely-operated robotic devices.

The 21st Century has brought with it many new and extremely powerful technologies that have already made their way into school and university science classrooms all over the United States. Multimedia software allows science teacher educators to teach preservice teachers (who, in turn can teach their K-12 students), concepts and skills through the use of programs that employ both sound and video. HyperStudio and other multimedia authoring tools are used to link and branch screens, making them interactive and layered with information, photos, scanned images, movies and text. PowerPoint and other slide show programs add tools for developing sequenced screens including all the elements of multimedia. "New ways of obtaining and presenting information have given students powerful new ways of analyzing and understanding the world around them." (U.S. Dept. of Education, 1996, Benefits of Technology Use section, para. 3).

Computer simulations provide teachers with tools to allow students to conduct experiments and control variables as they never could otherwise. Students can carry out virtual genetics experiments with software such as "GenScope", or analyze ecological data, simulating live data that would have taken decades or centuries to collect in the field. Computer software also allows simulations in population growth, competition and evolutionary theory to be run, exposing students to hands-on analysis of data, which reinforces the concepts they hear in their usual science classroom sessions. The Higher

Order Thinking Skills (HOTS) program designed by Stanley Pogrow of the University of Arizona, is a computer-based thinking program for disadvantaged students, that emphasizes "the basic thinking processes that underlie all learning" (Pogrow, 1987, p. 11). The project includes the utilization of computer simulations to study topics such as the dynamics of a balloon in flight, exploring the effects of different variables such as fuel, wind direction and terrain.

Students can utilize the smaller and more portable computers available now, as valuable science research tools and guides in the laboratory, and in the field. Microcomputer-based measurement and monitoring devices can be used for gathering and analyzing scientific data such as temperature, relative humidity, light intensity, pressure and voltage (Rohwedder & Alm, 1994).

Virtual dissection programs are also becoming more popular, both as valuable preparation tools, enhancements to dissections, and as a way for students who feel uncomfortable actually performing the dissection, or are physically unable to do so, to participate. It also provides a means for science teacher educators to provide preservice teachers with learning experiences that would otherwise be impossible because of lack of time, funds, or availability of materials. Researchers at Stanford University created "The Virtual Frog Project". Using the Internet to access the virtual frog, students can view and explore three dimensional renderings of the different biological systems as well as being able to make the frog's skin transparent to view a particular process, e.g. digestion, or to virtually stain an organ to facilitate viewing.

Web cams (a simple Web cam consists of a digital camera attached to a computer), can also help to bring science lessons to life allowing teachers to take their

students on virtual field trips all over the world, providing them with a bird's-eye view that serves to enhance their understanding of material studied and discussed in class. Web cams are an excellent way for information to be communicated visually over time.

In addition to being more powerful, new technologies are also more user-friendly and accessible. Adaptive technologies ensure that students with disabilities are no longer precluded from computer use. Physically disabled individuals can use modified joysticks, keyboards and head pointers (Day (Ed.), 1995), while the speech impaired "talk" through the computer by typing words which are translated into speech by text-to-speech translators (Middleton & Means, 1991). Visually impaired students can use speech-enabled products such as talking watches, calculators and computers, as well as products with Braille feedback.

In today's technological world, it is essential that science teacher educators furnish preservice teachers with the skills and knowledge necessary for them to utilize the wealth of resources that technology offers. As stated in the report, "Getting America's Students Ready for the 21st Century", "Success as a nation will depend substantially on our students' ability to acquire the skills and knowledge necessary for high-technology work and informed citizenship." (U.S. Department of Education, 1996, The Technology Literacy Challenge section, para. 1). It follows then, that science teacher educators have the responsibility for ensuring future science teachers are prepared and experienced enough to go into the classroom feeling confident and comfortable integrating and using technology in their science instruction. As Gillingham and Topper (1999) emphasize "We need a clear sense of our own expectations for technology-using educators if we are to prepare future teachers for appropriate use of technology in their classrooms," (p. 305).

Their definition of technology literacy focuses on educator beliefs and knowledge about using technology in instruction and learning, and on “having the skill and dispositions to use technology in flexible and adaptive ways for the purposes of classroom instruction and professional development.” (p. 305). Science teacher educators need to open preservice science teachers’ eyes to the important role technology can play in providing a real-world context in which they can ground their instruction. Technology, if used appropriately, can greatly enhance the educational experience and lead to deeper, more meaningful learning. It is not enough to furnish classrooms with numerous computers and vast arrays of software packages – the fact that the technology works has already been established. The big question is, when does it work and under what circumstances. Technology is no different from any other educational tool – teachers must come up with an effective strategy or pedagogy to make it work.

Chapter 2

How Technology and the Reform “fit” Together

Technology and reform do not necessarily go hand in hand, as illustrated by technologies that were expected to revolutionize the classroom, such as television in the 1960s, computers in the 1970s and videodisc and artificial intelligence in the 1980s. The revolution didn't happen (U.S. Department of Education, 1993). Studies of specific school sites that spent substantial amounts on technology, aiming to change the school, only to discover that the equipment sat unused in closets gathering dust, or that teachers used the technology to teach in the same way they had always done (Oakes & Schneider, 1984; U.S. Department of Education, 1993), also illustrate this fact. On the flip side, there are also many instances where technology and school reform were partnered successfully (Sheingold & Tucker (Eds.), 1990; Stearns, Hanson, Ringstaff & Schneider, 1991; Zorfass, 1991) and from these successes, it has become evident that technology often produces unexpected benefits for teachers and students (Stearns et al., 1991). The failures illustrate that successful implementation of technology requires extensive and thoughtful planning, as well as sustained support. In a review of educational reform, Fullan (2000), points out that because technology is everywhere, the issue is how we contend with it, not whether we do. As technology becomes more powerful, good teachers will become increasingly invaluable.

Millar and Osborne (1998), report that the traditional form of science education, where emphasis is on transmitting science content through lectures and cookbook labs,

does not prepare students to function effectively in today's rapidly evolving society where citizens are expected to understand science and technology issues. Science teacher educators must focus on preparing preservice science teachers to teach in our technological world, ensuring they are well equipped and knowledgeable about the huge diversity of instructional and learning opportunities provided by using technology in the science classroom. The National Science Education Standards state "The current reform effort requires a substantive change in how science is taught; an equally substantive change is needed in professional development practices." (NRC, 1995, p. 4). Current national standards for technology in teacher preparation stress the importance of developing skills and competencies for using technology (International Society for Technology in Education [ISTE], 2008).

Reports on curricular reform (National Association of Secondary School Principals, 1996; National Council of Teachers of Mathematics [NCTM], 1989; National Research Council [NRC], 1995; National Science Teachers Association [NSTA], 1990), highlight the change from the traditional, didactic, transmission teaching mode to a constructivist, learner-centered instructional method. Unfortunately adoption and use of reform-based instructional techniques is often hindered by the fact that many of today's preservice and inservice science teachers were taught in the traditional, teacher-directed manner and tend to adopt the same methods in their own classrooms (Stofflett & Stoddart, 1994). Battista (1994) reports that as a result of being students in didactic classrooms, these individuals tend to interpret reform-oriented activities in light of their previous school experiences, adapting constructivist practices that fit with the didactic pedagogy with which they are already familiar and feel comfortable using. Teachers are

the ones who determine how technology gets implemented in the classroom and despite the assumptions of many policymakers and administrators, Niederhauser, Salem and Fields (1999) report, “there is nothing inherent in technology that ensures reform-oriented uses. To date, many teachers continue to hold traditional beliefs about instruction and have incorporated technology in didactic ways.” (p. 156). This problem can be solved only by helping teachers to change their underlying beliefs about teaching and learning. They must be given opportunities to analyze their own learning under a variety of instructional conditions to understand fully the relationships between teaching and learning. In addition, teacher educators must model effective integration of technology in their courses. One of the specific objectives of the National Council for Accreditation of Teacher Education (NCATE) standards is "to prepare candidates who can integrate technology into instruction to enhance student learning" (NCATE, 2008, p. 4). NCATE standards also "expect teacher educators to model effective teaching. The traditional lecture alone is inadequate. Teacher educators must use strategies they expect their candidates to use. Why? Teachers teach as they are taught. Teacher educators should model expert teaching." (Wise, 2000).

In a presidential report on the use of technology in K-12 education, the authors argue that technology supports the constructivist teaching paradigm, and list uses of computers and computer networks by teachers to support constructivist learning. Although the report is general in scope, the technology uses listed are all directly applicable to science education:

1. Monitor, guide, and assess the progress of their students.
2. Maintain portfolios of student work.

3. Prepare (both computer-based and conventional) materials for use in the classroom.
4. Communicate with students, parents and administrators.
5. Exchange ideas, experiences, and curricular materials with other teachers.
6. Consult with experts in a variety of fields.
7. Access remote databases and acquire educational software over the Internet.
8. Further expand their own knowledge and professional capabilities.

(President's Committee of Advisors on Science and Technology, 1997, p. 17).

This report goes on to stress that “colleges of education have a valuable opportunity to introduce future teachers to the use of educational technology before the demands of an actual teaching position begin to impinge on the time available for such training” (p. 53). New and innovative technologies provide empowering tools to support the science education reform, and in order for us to produce technology-literate science teachers, science teacher educators will also have to be technology-literate. Science teacher education programs are the key to ensure that new science teachers are fully aware of the huge potential of technology, and how it can be used both in their own professional development, and in their classrooms.

Dexter, Anderson, and Becker (1999), report that, “The research on technology-using teachers characterizes different ways teachers employ technology in instruction. Data from this literature suggest that technology-using teachers range along a

continuum of instructional styles from instruction to construction.” (p. 221). Examples of technology-using teachers who fall at every point along this instruction--construction continuum can be found, but research on exemplary technology use suggests that expert technology-using teachers (do or should) fall on the constructivist side of the continuum (Becker, 1994; Dede, 1998; Dexter et al., 1999). Studies on classroom practice in general (Brown, 1997; Bruer, 1994) and technology use within that practice (Becker, 1994; Berg, Benz, Lasley II, & Raisch, 1998; Hadley & Sheingold, 1993) have tended to define exemplary in terms of the extent to which teachers’ instructional methods embody a constructivist teaching philosophy.

In the research literature, there is some indication that over time, technology-using teachers will evolve into constructivist teachers (Fisher, Dwyer, & Yocam, 1996; Hadley & Sheingold, 1993; Sandholtz, Ringstaff, & Dwyer, 1997). The supposition is that the use and integration of technology into practice actually prompts teachers to change their methods so that they are more student-centered. Dexter et al. (1999) noted that if this were true then, “This makes the issue one of time. That is, given enough time, the variety of approaches to using technology will homogenize into a constructivist approach.” (p. 222). On the other hand, some researchers (Miller and Olson, 1994; Hativa & Lesgold, 1996; Kerr, 1996) disagree, believing that just because teachers have new technologies available for utilization in their classrooms, does not mean that they will become constructivists. Pedagogical beliefs explain how teachers teach, with or without the use of technology, and these beliefs go much deeper than technological capability or accessibility. Changing beliefs is no easy task and usually takes a significant amount of time (Cuban, 1993; Ertmer, 1999; Ertmer & Hruskocy, 1999). In spite of the fact that

research studies have shown that most teachers today understand the importance of using technology in their classrooms (Beichner, 1993; Fulton, 1993), Robyler (1993) reports that they don't know how to utilize technology to support educational best practices. Technological tools change every day, as do current opinions on how teachers should use these technologies in schools. Technology best practice is still evolving and individual teachers may have significantly contrasting ideas of what exactly exemplary technology integration and use entails. This is echoed by Ertmer, Gopalakrishnan and Ross (2001) who suggest, "it is quite possible that today's practitioners and researchers have very different beliefs about what constitutes exemplary classroom technology use." (, p.1). As Earle (2002), points out, "Teaching with technology causes teachers to confront their established beliefs about instruction and their traditional roles as classroom teachers." (p. 8).

The International Society for Technology in Education (ISTE) published the National Educational Technology Standards for students (NETS•S), in 1998, and they have been subsequently reviewed and refreshed. The NETS•S (2007) describe what students at each grade level should know about technology and what they should be able to do with it, as well as outlining how technology should be used throughout the curriculum. Educational technology standards for students are divided into six categories: (1) creativity and innovation; (2) communication and collaboration; (3) research and information fluency; (4) critical thinking, problem solving, and decision making; (5) digital citizenship; and (6) technology operations and concepts. Categories provide a framework for linking performance indicators found within the profiles for technology-literate students. Together, the standards and profiles guide educators in their planning of

technology-based activities "in which students achieve success in learning, communication, and life skills." (ISTE, 1998, Technology Foundations for All Students section, para. 1).

The ISTE also developed NETS for Teachers (NETS•T) in 2000. These standards focus on preservice teacher education, and define the fundamental concepts, knowledge, skills, and attitudes for applying technology in educational settings. They state that " Effective teachers model and apply the National Educational Technology Standards for Students (NETS•S) as they design, implement, and assess learning experiences to engage students and improve learning; enrich professional practice; and provide positive models for students, colleagues, and the community." (ISTE, 2008, Educational Technology Standards for Teachers section, para. 1). They list five standards areas with performance indicators designed to be general enough to be customized to fit state, university, or district guidelines, and yet specific enough to define the scope of the topic. Performance indicators for each standard provide specific outcomes to be measured when developing a set of assessment tools. Teachers: (1) facilitate and inspire student learning and creativity; (2) design and develop Digital-Age learning experiences and assessments; (3) model Digital-Age work and learning; (4) promote and model digital citizenship and responsibility; and (5) engage in professional growth and leadership. ISTE reported that as of September 2008, every U.S. state and many countries have adopted, adapted or referenced at least one set of ISTE standards in their technology plans or other official state documents. ISTE's 2008-2009 Annual Report stresses that the "next generation (of NETS) focuses more on using technology to learn and less on learning to use the tools." (p. 4).

Chapter 3

What is Meant by Technology and Associated Terms?

The word technology has several meanings. The term is derived from the Greek words, tekhnē, which refers to an art or a craft, and logia meaning an area of study, so, literally, technology means the study, or science, of crafting. Besides computer technology, also called educational technology or instructional technology, there is technology education. In this sense, technology “refers to the diverse collection of processes and knowledge that people use to extend human abilities and to satisfy human needs and wants.” (International Technology Education Association [ITEA] 2000, p. 2). Technology does this by identifying and solving problems that people face. Technology education involves teaching people to solve problems and satisfy human needs and wants in a practical way. A wide range of factors must be considered simultaneously to determine just what these needs and wants are. Thus technology meshes, or integrates, many different subject areas. It forms the interface between learning about the natural world and solving societal problems. The ITEA captures the science educator's idea of technology in their logo, "Technology is human innovation in action!" (Technology for All Americans Project, 1996, p. 16).

In Benchmarks for Science Literacy (AAAS, 1993), technology is described as being "an overworked term". The authors go on to say that:

It [technology] once meant knowing how to do things - the practical arts or the study of the practical arts. But it has also come to mean innovations such as

pencils, television, aspirin, microscopes etc., that people use for specific purposes, and it refers to human activities such as agriculture or manufacturing and even processes such as animal breeding or voting or war that change certain aspects of the world. Further, technology sometimes refers to the industrial and military institutions and know-how. In any other senses, technology has economic, social, ethical, and aesthetic ramifications that depend on where it is used and on people's attitudes towards its use. (p. 43)

As noted by the ITEA (2000), there are three commonly occurring misconceptions regarding technology. The first is that technology is applied science. “The lack of technological literacy is compounded by one prevalent misconception: When asked to define technology, most individuals reply with the archaic and mostly erroneous idea that "technology is applied science” (Bybee, 2000, p. 23). This is illustrated clearly by the following definition for technology taken from the "American Heritage Dictionary" which defines technology as “The application of science, esp. to industrial or commercial objectives.” (Berube et al. (Eds.). p. 1248). In fact, the history of technology is older than the history of science as we know it. Technology has been around since the appearance of the human species on Earth. The second misconception concerns people’s tendency to equate technology education with teaching computers and information technology, and the third, the confusion of the term “technology” with “technical”.

Carnevale (2000), reports on an Internet survey of 2,227 learning-and-training professionals, conducted by a learning and technology research group (the Masie Center, based in Saratoga Springs, N.Y.), which goes a long way towards illustrating the multiple

interpretations of technology in education. Individuals were asked what term they would use to describe "learning with technology". The respondents were given a list of possible terms, as well as the opportunity to write their own choices. The results showed a wide range of responses as well as significant differences between individuals who take online courses, and vendors who offer course material. Forty percent of people who work for institutions and vendors offering online course material, responded with the term, "e-learning", while of the people who take online courses, "computer-based training" was the number one response, closely followed by "Web-based training". The Director of Development for the Masie Center believes the inconsistency probably stems from the swift development of learning technology, which has caused a rhetorical rift between those who stay current with the technology industry, and those who do not follow it.

Distance education or distance learning is terms that have been applied interchangeably to a huge variety of programs, providers, audiences and media. Its characteristics are the separation of teacher and learners in space, and/or time (Perraton, 1987), the conscious control of learning by the student rather than the distant instructor (Jonassen, 1992), and noncontiguous communication between student and instructor, mediated by print or some form of technology (Keegan, 1986; Garrison & Shale, 1987). Carnevale (2000) quotes the director of a business providing computer-certification courses using distance education, who states that the rapidly increasing number of terms causes a great deal of confusion. This individual earned her Ph.D. in adult education and found, during the course of doing her dissertation research that, within the distance education community, different meanings are attached to the same terms and concepts by different individuals. Some students assume that distance education involves technology,

while others still think of correspondence schools where communication between instructor and student is via mail. Even some of those who expect a technology component assume that they will use a CD-ROM and don't immediately understand the practice of taking a course on the Internet.

Jackson (2001) reports having “several problems talking with colleagues about 'online courses' as the term seems to be used in radically (and confusingly) different ways by different people.” (p. 3, Defining eLearning section). He uses a “definitional dichotomy” to help clarify meanings: Technology-enhanced learning versus technology-delivered learning. The former includes courses in which the students have frequent opportunities to meet face-to-face with the instructor, and in which technology is used as a supplement to classes held face-to-face in classrooms. Technology-enhanced courses are those in which information (typically the syllabus, readings, reference list etc.) usually given to students in shrink-wrap course kits purchased from copy centers, is instead posted online for the students to access and print out. Online communication is typically asynchronous through either a Web editor or an asynchronous course system. In contrast, students are never, or only very rarely, in the physical presence of the instructor in technology-delivered learning, the more usual, teacher-directed instruction being perhaps limited to the first and last classes of the semester, or eliminated all together and sometimes replaced with real-time virtual classrooms. According to Jackson (2001), technology-delivered learning has the same meaning as the terms distance learning, distributed education, and distance education. Instruction can be delivered through blend of synchronous (traditional classroom, face-to-face activity, real-time virtual classrooms, live Web-casts, live online discussions) and asynchronous (e.g. e-mail, voice mail,

comments from threaded discussions) technologies. He stresses that combinations of both technology-enhanced, and technology-delivered methods of instruction and delivery often represent the ideal program structure resulting in the most learning.

Hefzallah (1999) talks about two types of interactive learning environments made possible by new learning and telecommunications technologies: (a) face-to-face, and (b) mediated interactions. These overlap and blend with Jackson's categories in many ways. During face-to-face interactions, both the student and the instructor are present in the learning environment, whereas mediated interaction "occurs when space and/or time separates the source of information or the teaching program or material from the student" (p.59). He outlines three types of mediated interaction: (a) live mediated interaction where there is immediate feedback between the student and instructor and the only separation is space. This would include audio interaction, visually augmented audio interaction, live video interaction and computer-interaction-synchronous mode; (b) computer interactions in the asynchronous mode. In this type of interaction, students and teacher are separated by space and time. Examples of this type of interaction would be e-mail, discussion groups and electronic mailing lists; (c) totally mediated interaction in which there is an absence of feedback. Again the student and instructor are separated by space and time. Examples would be multimedia CD-ROM programs, interactive video programs and multimedia-assisted instruction, where feedback is indirect. For example, a teacher might recommend a particular interactive video or CD-ROM program to another teacher.

Chapter 4

Integration of Technology in Science Education

As Rakow (1999) states, "The sciences are a natural place for the integration of instructional technologies to improve teaching and learning." The challenge lies in integrating technology into classrooms and in making it an integral tool for learning within the context of science and science education. Technology use needs to match teachers' instructional goals (Strehle, Whatley, Kurz, & Hausfather, 2001; Windschitl & Sahl, 2002; Zhao, Pugh & Sheldon, 2002). Science and technological knowledge are constantly changing and increasing in complexity and it is essential for educators to keep current and abreast of changes and new developments.

Teachers must have the ability "to make choices about technology integration without becoming technocentric by placing undue emphasis on technology for its own sake without connections to learning and the curriculum." (Earle, 2002). Preservice (and inservice), teachers must be given opportunities to experience and observe technology integration in action, time to reflect on their ideas and experiences with colleagues and peers, and to collaborate with other educators to try out new ideas and methodologies (Ertmer, 1999). Continuous training and practice are essential.

According to The National Center for Education Statistics (NCES, 2005), the percentage of public schools with Internet access increased from 35 to 99 percent, between 1994 and 2002. Additionally, in 2001-2002, 87 percent of public schools with Internet access reported that professional development focusing on how to integrate the

use of the Internet into the curriculum was offered to teachers (Kleiner and Lewis 2003). Hattler (1999) stresses that professors in teacher education programs are responsible for integrating information technology into courses necessary for, and leading to, certification. “By adding technological assignments via the Internet into our teachers’ certification courses, preservice teachers can be better prepared to meet the technological challenges present in the classrooms of tomorrow.” (p. 327). More and more states are starting to include new technologies in learning standards for all disciplines, increasing the urgency for teacher competence in this area. If technology is to be integrated successfully into classroom instruction, teacher educators must be able to exhibit successful technology use in preservice course work (Beichner, 1993).

Levin (1994) outlines the three main foci embodied in the guidelines developed by the ISTE and National Council for Accreditation of Teacher Education (NCATE) for teacher education programs to ensure that preservice teachers are furnished with the know-how, skills and attitudes necessary for them to use technology effectively in their own future classrooms.

1. Use technology for personal and professional productivity.
2. Acquire both the content and pedagogical understanding needed to teach with computer-based technologies.
3. Gain knowledge about the impact of technology on schools and society.

(p.13)

These foci are echoed by Yerrick and Hoving (1999) who stress that,

In order to incorporate appropriate technology applications and teach in ways consistent with National Science Education Standards (NRC, 1996), teachers

need, among other things, to be proficient in ways of speaking, thinking, and interacting with science content and microcomputers. To teach constructively via technology takes special knowledge of microcomputer capabilities and skills. It also requires teachers to think broadly across all content areas and about the many areas of available technological resources (Greenberg, Raphael, Keller, & Tobias, 1998; Scardamalia & Bereiter, 1989). (p. 292).

In recent years a number of research studies focusing on barriers to technology infusion and strategies to break down these barriers have been conducted. During a discussion at the 2003 Association for the Education of Teachers in Science (AETS) Conference, motivators and barriers to the infusion of technology into the science curriculum were examined with a view to discovering how technology might "act as an amplifier for and catalyst of the pedagogical revolution we seek in science education, rather than as a vehicle for the entrenchment of traditional practices?" (Gess-Newsome, J., Clark, J., & Menasco, J., 2003, Discussion section, para. 1). These included personal factors, contextual factors and teacher thinking.

Personal factors affecting teachers' technology use were age, gender, teaching experience, background and experience in technology use, content area or grade level, and quality of professional development experienced. Becker (1994) reported on a 1989 national survey of 516 teachers in grades 3-12, five percent of whom were categorized as exemplary users of technology (i.e. they used technology for exemplary teaching practices such as inquiry and problem-solving). Exemplary users were found to be mostly males, with backgrounds in content discipline, holding advanced degrees, having had formal training in computer use, and using computers at home more often than non-

exemplary users. Recent research studies however, indicate that demographic characteristics including exposure to technology are not particularly useful in explaining technology integration (Cuban, Kilpatrick & Peck, 2001).

Research demonstrates that teachers with greater teaching experience are more likely to use technology in their teaching (Becker, 1994; Pierson, 2001), and that teachers' level of expertise in using technology determines their level of understanding of the potential of the technologies, how effectively they use them in classrooms, and how effectively they overcome barriers (Atkins & Vasso, 2000; Friedrichsen, Dana & Zembal-Saul, 2001; Germann & Sasse, 1997; Jaber & Moore, 1999; Zhao, Pugh & Sheldon, 2002).

Teachers want additional professional development in technology use and infusion (Clark, 2002; Jaber & Moore, 1999), and attendance at technology infusion-related professional development activities (inservice and methods classes) has been shown to increase integration into practice (Adams, 2000; Beyerback, Walsh, & Vanatta, 2001). In spite of the fact that technology use in the classroom increased following professional development, uses were often limited to didactic presentation modes, word processing and data access, or class management (Mullen, 2001; Sandholtz, 2001). By modeling technology integration in constructivist classroom settings, science teacher educators can provide future science teachers with examples of effective technology use that develops students' higher order thinking skills and focuses on science inquiry.

Contextual factors affecting teachers' technology use were defined as being either structural (availability and reliability of hardware, how easy the software is to use and its educational appropriateness, teachers' preparedness/willingness to infuse technology in

their curricula), or cultural. Cultural factors would include threats to technology infusion such as lack of administrative and technical support and time for teacher learning and planning.

Research has shown that technology infusion is rare, even in cases where contextual factors have been mitigated. Although computer access issues have decreased, neither the frequency in use of computers for science instruction, nor the frequency of students doing hands-on/laboratory activities have changed (Horizon Research, Inc., 2002). Cuban et al. (2001) and Norton, McRobbie and Cooper (2000), report that access to equipment rarely led to widespread teacher and student use. Access to technology is not an issue for science educators' infusion of technology, but "Because technology is constantly changing, keeping current is a full time job in itself." (Pederson & Yerrick, 2000, p. 144).

Teacher thinking is the third factor that Gess-Newsome et al. (2003) discuss as affecting the infusion of technology into the science curriculum, proposing that research has shown that teacher thinking acts as the most consistent predictor of the success of infusion (Woodbury & Gess-Newsome, 2002). The likelihood of a science teacher using technology in the classroom and how that technology is used depends largely on his/her knowledge and beliefs about teaching and how students learn. This is demonstrated in studies by Ertmer, Addison and Lane (1999), and Windschitl and Sahl (2002), who found that teachers' basic beliefs about teaching and learning were more powerful predictors of teacher classroom instruction than attempts to reform their teaching, and studies by Germann and Sasse (1997), Strehle et al. (2001), and, Zhao and Cziko (2001), indicating that teacher beliefs about teaching efficiency and effectiveness are more critical to the

infusion of technology than the availability of technological resources. Past research indicates that teachers' opinions of teaching with technology corresponded with their views of teaching as either a didactic or active process (Hakkarainen et al., 2001; Friedrichsen et al. 2001; Mullen, 2001; Norton, McRobbie & Cooper, 2000). In their study of use of technology in high school classrooms, Cuban et al. reported that teachers adapted the technology to fit their customary patterns of traditional, teacher-centered instruction, so computers sustained, rather than altered existing teaching methods. Technology use, if partnered with teachers' commitment to change, dissatisfaction with current practices, or reflection, can function as a catalyst for the change to more constructivist teaching methods (Dexter, Anderson & Becker, 1999; Greenburg, Raphael, Keller, & Tobias, 1998; Holland, 2001; Strehle et al. 2001; Windschitl & Sahl, 2002). Some research studies indicate that the most powerful predictor of technology infusion is the presence of other teachers who are attempting to do the same and willing to work with others (Becker, 1994; Holland, 2001; Hunter, 2001, Windschitl & Sahl, 2002).

Barriers to technology infusion and strategies to break down those barriers were also discussed at the Florida Educational Technology Conference (FETC) in February 2003, where the International Society for Technology in Education facilitated a session designed to gather comments and suggestions for the National Education Technology Plan (NETP). Attendees included representatives from schools, districts and teacher education programs, and although the discussion was general in scope, the barriers to technology infusion and strategies to overcome them are all applicable to science teacher education.

Barriers to technology infusion fell into eleven categories:

- 1) Access/Equity (getting a chance to use a computer)
- 2) Collaboration (with business and community partners)
- 3) Funding/Resources (infrastructure, hardware, software)
- 4) Leadership
- 5) Motivation/Incentives/Time
- 6) Professional Development/Training
- 7) Planning
- 8) Research/Information Gathering/Dissemination
- 9) Standards/Accountability/Evaluation
- 10) Technology Facilitation/Technical Assistance
- 11) Technology Integration/Curriculum/Teaching and Learning Strategies

(ISTE NETS FETC Forum, 2003)

The group as a whole, listed Funding/Resources (infrastructure, hardware, software, connectivity, other) as the number one barrier to technology integration, followed closely by the Motivation/Incentives/Time and Professional Development categories. The Teacher Education group (consisting of teacher educators, teacher candidates, and administrators) identified the Motivation/Incentives/Time category as being the number one barrier (interesting to note that this differs from the Gess-Newsome et al. (2003) proposal that research has shown teacher thinking acts as the most consistent predictor of the success of infusion). The Teacher Education group identified the following strategies as being most pertinent strategies for addressing the barriers identified:

- Support for ISTE NETS-type structure

- Include funding for higher education faculty, administrators, and leaders
- Include content-focus, learning styles, sharing of models, effective research
- Collaboration among teacher education faculty and others outside teacher education
- Include tenure requirements and incentives/rewards for teacher educators using technology effectively
- NCLB [No Child Left Behind] should ensure that teacher preservice preparation/administration/preservice teachers are not left out of the funding, structure, and model sharing
- Structure funding for effective model sharing and dissemination of lessons learned in currently funded teacher preparation programs (ISTE NETS FETC Forum, 2003, Strategies section)

Research studies such as these have identified numerous road blocks hindering the integration of technology, as well as strategies for surmounting them. It is clear that science teacher education programs play a key role in successful technology infusion. As Kent and McNergney (1999) emphasize,

the use of technology by school children necessarily depends on the ability of teachers to integrate technology into their teaching. Preservice education can provide rising teachers with the confidence and knowledge required to use the technological tools available to them” (p. 4).

The current education of preservice science teachers will be a determining factor in the future part technology plays in science education, and it follows that for them to learn

how to infuse technology into their own science classrooms, first it must be integrated into their professional education course work. As Bell (2001) states:

Technology access and skills are necessary but insufficient steps toward using technology effectively in science instruction. Rather science educators should explicitly instruct preservice teachers on ways to integrate technology into their instructional practice. Such instruction will require science educators to provide conceptual frameworks for technology integration, and opportunities for preservice teachers to develop and practice teaching lessons that appropriately integrate technology. Like most worthwhile goals, such explicit instruction is inherently more difficult to achieve, but much more likely to produce desired results. (p. 5).

In the next ten years, more than two thirds of the nation's teachers will be replaced by new teachers so it is critical to ensure that this new generation of teachers is equipped with the knowledge and skills necessary to meet this challenge successfully. A study by the Milken Exchange on Education Technology (1999), and the International Society for Technology in Education found that, "in general, teacher-training programs do not provide future teachers with the kinds of experiences necessary to prepare them to use technology effectively in their classrooms." (p. i, para. 4). It emphasized that since the United States will need a projected 2.2 million new teachers over the next decade, "the time to examine and re-engineer our teacher preparation programs is now." (p. i, para. 4).

Examples of Technologies Currently Being Used in Science Education

There are a plethora of different applications of technology being used in science teacher education programs today. Educational technologies consist of many different

combinations of hardware and software and may employ many different combinations of audio channels, code, data, text, graphics or video. Technology applications are usually characterized in terms of their most obvious hardware feature (e.g. a VCR or computer), but for educators, it is the nature of the instruction delivered that is important not the equipment delivering it.

In the U.S. Department of Education's 1993 report, "Using Technology to Support Education Reform", the authors classified educational technologies into four categories based on their different uses: tutorial, exploratory, application, and communication. They explain, "Our categories are designed to highlight differences in the instructional purposes of various technology applications, but we recognize that purposes are not always distinct, and a particular application, may in fact be used in several of these ways." (Educational Technologies section, para. 1). Although their classification scheme is general in scope, it provides a concise and useful guide for science teacher educators and preservice science teachers.

Tutorial uses are those in which technology does the teaching and controls the material presented to students. The format is usually lecture or workbook. Exploratory uses of technology allow students to explore freely the information presented in a particular medium, while application uses provide students with tools to help them complete various educational tasks such as data analysis and writing. Finally, communication uses allow students and teachers to communicate with each other and with others through networks or other technologies. Table 1 summarizes the technology classification scheme giving definitions and examples of each of the four categories of educational technology use.

Table 1 Classification of Education Technologies

Category	Definition	Examples
Tutorial	Systems designed to teach by providing information, demonstrations, or simulations in a sequence determined by the system. Tutorial systems may provide for expository learning (the system displays a phenomenon or procedure) and practice (the system requires the student to answer or questions or solve problems).	Computer-assisted instruction (CAI) Intelligent CAI Instructional television Some videodisc/ multimedia systems
Exploratory	Systems designed to facilitate student learning by providing information, demonstrations, or simulations when requested to do so by the student. Under student control, the system provides the context for discovery (or guided discovery) of facts, concepts, or procedures.	Microcomputer-based laboratories Microworlds/Simulations Some videodisc/multimedia systems

Table 1 (Continued)

Category	Definition	Examples
Application	General-purpose tools for accomplishing tasks such as composition, data storage, or data analysis.	Word processing software Spreadsheet software Database software Desktop publishing systems Video recording and editing equipment
Communication	Systems that allow groups of teachers and students to send information and data to each other through networks or other technologies.	Local area networks Wide area networks Interactive distance learning

Note. From "Using Technology to Support Education Reform," U.S. Department of Education, 1993. Retrieved May 20, 2003, from <http://www.ed.gov/pubs/EdReformstudies/TechReforms/chap2a.html>

The state-of-the-art in technology changes almost constantly, but there are many uses of technology in science education that support science education reform and what we know about how students learn best. The ISTE, in an effort to implement the NETS for Teachers across universities, has identified and described many methods and strategies for successfully integrating technology and state, "having a set of generic models and strategies that are multipurpose in application assists teacher candidates in quickly developing technology-rich lessons" (ISTE, 2002, p. 31). In ISTE's "NETS for

Teachers: Preparing Teachers to use Technology" publication, examples of proven effective strategies for integrating technology into teaching for Web-based lessons, multimedia presentations, telecomputing projects and online discussions are given. These examples provide a wonderful resource for science teacher educators looking for explicit ways to instruct preservice teachers on how to integrate technology into their practice.

WebQuests provide an example of Web-based lessons. They utilize information exclusively from the Web. They are inquiry-oriented activities designed to use learners' time efficiently by focusing on using information rather than searching for it, supporting higher order thinking skills: analysis, synthesis, and evaluation (Dodge, 1997). The WebQuest model was developed in early 1995 at San Diego State University by Bernie Dodge with Tom March. WebQuests are reflective, fluid, and dynamic. They provide teachers with the opportunity to integrate Internet technology into the course curriculum by allowing students to experience learning as they construct perceptions, beliefs, and values out of their experiences (Beane, 1997).

The Internet offers such an incredible wealth of information, teachers can become frustrated and overwhelmed spending hours searching for the best resources to support a particular classroom activity or unit. The WebQuest model provides the option of reviewing and selecting Web-based lessons structured in a lesson-type format, hence cutting down on the time needed for a specific search and allowing more focus on student learning. Diverse examples of science WebQuests can be found on the WebQuest site. Tasks range from genetically altering a plant or animal, to learning about the people and

culture of a particular geographic area, while simulating the work of a team of epidemiologists.

A WebQuest comprises of 6 sections or 'blocks': introduction, task, process, resources, evaluation and conclusion. The introduction serves to orient the learner and peak their interest in the subject. The task block in a WebQuest describes what the learner should have accomplished at the completion of the exercise. This could take the form of a verbal presentation, such as the student being able to explain a particular topic, or a product such as a PowerPoint presentation or HyperStudio stack. The teacher suggests the steps that students should follow to complete the task in the process block. Depending on the task, these might include descriptions of roles to be played, or strategies for dividing the task into smaller, more manageable subtasks. The resources block lists the Web pages identified by the teacher to aid the student in accomplishing the task, and since these resources are preselected, learners can focus on the topic, rather than on searching. Resources may include audio conferences with distant experts, videotapes, or the hard copy of a report--they are by no means limited to Web pages. The evaluation block is a recent addition to the model and involves the use of rubrics for evaluators (e.g. teachers, parents, or peers) to evaluate accomplishments. The conclusion section of a WebQuest allows the experience to be summarized, and encourages reflection about the process, so that learning can be extended and generalized.

Science teacher educators may design their own WebQuests, or require their preservice students to design a WebQuest as a course assignment. Topics that mesh with the science curriculum, and for which there are appropriate online materials, are identified. Teachers then follow the specific WebQuest design steps and/or utilize a

template to create their own WebQuest (Dodge, 1997). "The WebQuest teaching strategy provides an excellent framework for teacher candidates designing technology-rich experiences for students." (ISTE, 2002, p. 33). WebQuests provide preservice teachers with valuable opportunities to become comfortable with aspects of technology within the context of their preparation for the profession of teaching (Stinson, 2003). WebQuests can be especially useful for teachers who are inexperienced in technology use in that they offer prepackaged, self-contained lessons ready for implementation. The WebQuest site contains lessons, rubrics, and teaching tips, all of which aid teachers in making an easier transition into using Internet technology (Watson, 1999).

Multimedia represents and conveys information through combinations of text, graphics, video, animation and sound. Multimedia presentation software such as PowerPoint and HyperStudio provide an easily updateable way to produce artistic presentations in which the learner controls the order and pace of the presentation. PowerPoint also allows the establishment of links between any object on the slide and objects on another page, or in another presentation. Slides may also be linked with Internet sites, CD, or Laser disc players. Teachers have found that multimedia projects motivate students to learn, as illustrated in a study by Cradler and Cradler (1999), in which students and teachers reported a positive change in student motivation for class assignments when the use of multimedia was incorporated into classroom instruction. According to ISTE (2002), "Exemplary project-based learning with multimedia is anchored in core curriculum, multidisciplinary, demonstrates sustained effort over time, promotes student decision making, supports collaborative group work, exhibits a

real-world connection, utilizes systemic assessment, both along the way and for the end product, and employs multimedia as a communication tool." (p. 36).

Another dimension is provided by publishing students' multimedia products (e.g. Web pages, sites, computer presentations created with PowerPoint or computer-generated movies) over the Internet so that they can be viewed by distant audiences. Research has shown that the quality of student work increases significantly when students realize their work will be viewed by an audience other than teachers and students at their school (Coley, Cradler, & Engel, 1997).

The CyberFair sponsored by Mankato, MN schools allows third through sixth grade students to share their science projects on the Internet, while Brentwood School in California has a virtual science fair in which projects competing in the school-wide science fair have no printed reports or display. Preservice science students can visit these Web sites and see examples of student science projects ranging from "Which tile cleaner removes soap scum best?" to studies of carnivorous plants! These projects engage students in learning and teach them educational technology skills, while supporting standard-based coursework. They serve to connect students to their local communities through collaborations with local leaders, businesses, special populations and increase environmental awareness. In addition they increase real-world, transferable skills and involve students in peer evaluation.

ThinkQuests are another example of multimedia projects. ThinkQuest Programs provide a highly motivating opportunity for students and educators to work collaboratively in teams to learn as they create Web-based learning materials, and teach others about a huge variety of different topics. Students (Grades 4 through 12), can

collaborate on Web projects hosted on a searchable library at the ThinkQuest Web site. ThinkQuest programs also provide electronic meeting places designed for educational collaboration. Teachers can expand their professional development while learning a student-centered model of education, and experimenting with the potential of the Internet. They can examine modes of learning and interact with students to obtain a true understanding of how young people want to learn. Students in California created a ThinkQuest project focusing on the plight of threatened Southern sea otters. As well as including a wealth of information about sea otters, (e.g. life cycle, habitat, population counts, and range), the site includes live streaming video of sea otters housed at the Monterey Bay Aquarium, and an audio interview with a marine mammal trainer.

Telecomputing projects utilize Internet communication tools as essential resources. Tools include e-mail, electronic mailing lists, electronic bulletin boards, discussion groups, Web browsers, real-time chatting, and audio- and videoconferencing. Harris (1994) identifies three different general classes of educational telecomputing activities: interpersonal exchanges (incorporating the use of interpersonal resources), information collections (involves students collecting, organizing, and sharing information), and problem-solving projects. Each category of activities includes five, six or seven different activity structures, and for each structure, an example activity that has been classroom-tested and shared by telecomputing teachers is provided.

Interpersonal exchanges involve individuals or groups communicating via e-mail electronically with other individuals or groups. According to Harris (1994), these types of educational telecomputing activities are the most popular. Teachers and students may also use newsgroups and Internet-connected bulletin boards for projects such as

"Keypals" which involves student-student communication. Harris notes that student-student exchanges involves the transfer and processing of multiple e-mail messages sent to a single account, and may prove to be too time consuming for the teacher. Global classrooms, in which two or more classrooms located anywhere in the world, study a common topic together, sharing their new knowledge about that topic during a previously-specified time period, are easier to manage. Other activity structures for interpersonal exchanges include electronic appearances (a special guest is hosted, students corresponding with him/her either asynchronously, or real-time), electronic mentoring (students can mentor other students, or experts from universities, businesses, government, or other schools can serve as electronic mentors), and impersonations (participants communicate with each other "in character").

Activity structures falling within the information collection category of educational telecomputing are information exchanges, electronic publishing, database creation, tele-fieldtrips, and pooled data analysis. Information exchanges provide students with the opportunity to become both the creators and consumers of the information that they are sharing and have resulted in students collecting a wide variety of topic-specific data from around the world. Some examples are: local agricultural information, biome data, water usage information, recycling practices, and personal health information. KidsNetwork (developed by the Technical Education Research Centers [TERC], and funded by the National Science Foundation [NSF] and the National Geographic Society) is a telecommunication-based science curriculum for elementary and middle school students in the United States, Canada, Israel, and Argentina. Participants focus on a number of real-world issues, examples of which include acid rain,

weather and health. This project provides an exciting and innovative way to bring inquiry-based learning to students. Students perform experiments, gather data, and analyze trends and patterns on topics of current social, scientific and geographic interest. E-mail is used to communicate with each other and with participating scientists who help students review the data and make interpretations. The data and findings are then shared with other participating schools, and there have been several significant instances in which students' findings led to the discovery that school drinking water and air pollution standards were not being met. In 1991, KidsNet units were used in more than 6,000 classrooms in 72 countries. More than 90% of teachers using KidsNet reported that students' interest in science increased significantly, and that their classes spent almost twice the amount of time on science than they otherwise did (TERC, 1991).

A great example of an electronic publishing project is provided by the Global Schoolhouse's NewsDay project in which students write articles about a variety of issues and topics including science and technology, and post them on an electronically shared newswire. Different schools publish different newspapers locally but also read and choose articles from other schools to download and include in their own newspaper.

Some information exchange projects involve database creation where students not only collect data, but organize it into databases that project participants and other students can use for study. Harris (1994) notes that "successful projects of this genre are well-structured; they have a definite time schedule, requirements for participation are clearly stated, and teachers are asked (often by filling out a registration form) to commit to following these guidelines." (Database Creation section, last para.).

Tele-field trips allow sharing of experiences and observations of local field trips to museums, zoos, aquariums etc. with students and teachers all over the world via the Internet. These informal science centers house an incredible wealth of information that can be used to support science learning in the classroom. Access is usually limited because of travel expenses or time limitations, but through the Internet, students can learn about the work of Benjamin Franklin at the Franklin Institute, or participate in science experiments online from the Exploratorium in San Francisco. Some tele-fieldtrips can be taken either directly or vicariously via a variety of telecommunications networks, using robotic devices that can be controlled remotely via the Internet.

The JASON Project™ is a multidisciplinary, real-time science teaching and learning program that enhances the curriculum by exposing students to experts and leading scientists who work with them to examine the biological and geological development of Earth. The JASON Project™ has been a pioneer in the field of Virtual Field Trips. Students can journey to the bottom of the Atlantic Ocean in search of the wreck of the RMS Titanic, view rain forests, volcanoes, or journey to Polar Regions. Through the JASON Academy™, teachers can take content-rich, continuing education science courses anytime, anywhere via the Internet. There are no text materials involved in the courses, instead hot-linked references and many classroom applications with demonstrations and hands-on activities are utilized.

Pooled data analysis involves students collecting data at multiple sites, and combining them for analyses. The simplest of these types of activities involve students sending out a survey electronically, collecting the responses, analyzing the results, and reporting their findings to all participants. Water acidity projects, in which rainwater or

stream water is collected at different sites, tested for acidity, then examined for patterns over time and distance provides an example of a pooled data analysis project. WaterNet (developed by Berger and Wolfe at the University of Michigan and funded by the Department of Education), is a telecommunication-based water pollution study involving high schools in the United States, West Germany, and Australia. Students gathered water quality data from their local rivers and stored the information in a database. Through data sharing, it is hoped that students will gain a deeper understanding of the problems of water pollution and develop an interest in solving these social problems (Roberts, Blakeslee, Brown, & Lenk, 1990).

Problem-solving projects include information searches (students are provided with clues, and must use electronic or hard copy reference sources to solve problems), electronic process writing, sequential creations (in which participants progressively create either a common written text or a shared visual image), parallel problem-solving (a similar problem is presented to students in several locations, solved separately at each site, and their successful problem-solving methods shared electronically), simulations, and social action projects.

Online discussions allow students to communicate with peers, teachers, and experts worldwide either asynchronously (via electronic bulletin boards, e-mail) or in real-time (via chat groups). Asynchronous communication allows students time to reflect before responding and also allows for time differences in different geographic areas, while real-time communication provides students with immediate feedback. TAPPED IN™ is an excellent online resource for professional development. It is "the online workplace of an international community of education professionals. K-12 teachers and

librarians, professional development staff, teacher education faculty and students, and researchers engage in professional development programs and informal collaboration with colleagues." (SRI, para. 1). Science teachers can participate in After School Online science teacher forums which are discussions designed for science educators on various topics related to the field of science education. In addition, TAPPED IN™ offers e-mail groups to locate and communicate with others who have shared interests or expertise. Examples of online activities conducted by other teachers can also be viewed.

The emergence of social networking technologies and evolution of digital games and simulations have significant implications for education. These technologies have been utilized for decades by institutions including government, medicine and business, mainly for training purposes, but as reported by Klopfer, Osterweil, Groff and Haas, 2009, digital simulations, games and social networking technologies provide deeper educational benefits. Security issues and possible dangers of using social networking sites definitely raise significant concerns that must be addressed, but Klopfer et. Al (2009) take the position that “these technologies are safe, valuable tools schools must take seriously.” (p.2). Green and Hannon (2007) discuss the fact that the newest generation of K-12 students has been completely normalized by digital technologies – these technologies are a fully integrated part of their lives. Teachers and teacher educators must appreciate and realize that students sitting in today’s classrooms have a very different perspective on the world, and experiment with new ways to connect with students through these technologies. Research is supporting this kind of work illustrating that “multimedia education improves both comprehension of the lesson material and students’ interest in the lesson topic” (Brady, 2004).

These examples represent only a fraction of the many creative and reform-oriented ways technology can be infused into the science curriculum. By modeling best practices in technology integration (such as the in examples previously discussed), and by providing preservice science teachers opportunities to develop and practice teaching lessons that appropriately integrate technology, science teacher educators can aid them in reforming their instructional practice (Yerrick & Hoving, 1999).

Recommendations for Choosing and Evaluating Science Technologies

Technology should be examined in the same way that any other material or tool being considered for use in the classroom would be, with how students' learning will be enhanced through its use, being the primary focus. Bernhard, Mellissions Lernhardt, and Miranda-Decker (1999) stress that in considering a particular technology for use in the classroom, whether it aids students in understanding technology's role and importance in the real world should be a major consideration. The technology should have the ability to engage student interest and make use of computer capabilities. This is echoed by Jones, Valdez, Nowakowski, and Rasmussem, (1995), who report that successful use of technology in the classroom is characterized by student engagement.

Reed and McNergney (2000) review how educators can evaluate technology-based curriculum materials for use in the classroom stating that "Only through evaluation of technology-based curricula can educators make informed decisions about the purchase and use of technology, and ultimately about the wisdom of their investments." (Conclusion section, para. 1). The first concept they identify as being key in evaluating technology-based curriculum materials are authenticity. This concept gives rise to questions such as: Does the technology help students learn by utilizing real-world

examples? Do such examples integrate technology and subject matter to enhance conceptual understanding of complex, naturally-occurring phenomena? Does the technology encourage students to learn actively (i.e. by doing, interacting, and exploring) rather than focusing on passive activities such as listening or watching? These are excellent questions for science teacher educators to ask about a technology they are considering for use in their courses.

Educators can construct their own evaluation framework by defining the instructional context, establishing who the learners are, what constitutes the learning environment (of which the instructor is a part), and determining the nature of any technical limitations (Comer and Geissler, 1998). Once this context has been established, aspects of the curriculum such as content, required technology and instructional tools, learning assessment, and teacher support can be evaluated (Bernhard et al., 1999).

Educators must evaluate digital content to ensure that it emphasizes open-ended exploration rather than drill-and-practice (Zehr, 1999). Learning can be promoted through the effective integration of digital content by educators, providing students with opportunities to search and manipulate digital information in collaborative, creative and engaging ways (CEO Forum, 2000). McKenzie (1999) reports that "successful searching and efficient electronic investigations must rest upon a carefully developed, structured foundation of information literacy skills that would include solid questioning, prospecting, translating and inventive abilities." (p. 17). WebQuests are a perfect example of how students can be guided through the information-gathering process and their searching abilities improved (Dodge, 2000). Students themselves also become content-producers, products taking a multitude of different forms ranging from Web sites and e-

mail, to computer simulations and streamed discussions. The ThinkQuest site provides visitors with insight into what kinds of products today's students can create.

Bell (2001) summarized questions pertinent to educators' reluctance to embrace technology raised by participants in a National Technology Leadership Retreat that brought together the leaders of a dozen national education associations. Specific to science teacher preparation, Bell reports on the concerns of representatives from the Association for Education of Teachers of Science (AETS):

- Does technology help students accomplish the recommendations of the science education standards?
- If we teach preservice teachers to use appropriate technology, will they teach more in the way we want them to teach?
- Does technology enable students to ask questions they would not thought of asking before?
- Do students learn science differently with technology? Is the quality, nature, or efficiency of learning improved?
- Are students learning different science content or concepts with the technology than they would have otherwise?
- Does technology enhance inquiry learning? Can technology provide an inquiry environment?
- If science educators determine that technology is worthwhile, what do they need to do, or what experiences do they need to provide, to convince preservice teachers of its benefits?
- What are the stages teachers have to go through to appropriately use

technology in learning? (Some take the technology and teach in the same old way.)

- Can technology help educators maintain an ongoing relationship between education faculty and new teachers in the classroom? (p. 13).

When considering a particular technology for use in their classroom, science teacher educators can apply these suggestions to determine whether it aligns with the standards, supports scientific inquiry, advances student learning and/or surpasses the possibilities of less advanced technologies. If the answer to these questions is affirmative, then they can be reasonably assured that the technology is worth implementing. As Odom, Settlage, and Pedersen (2002) point out, "The varieties of technology that could be potentially be incorporated into science instruction and teacher preparation seem to be increasing at a rapid rate. Given the impossibility of adopting every new gizmo, individually and organizationally, we should be wiser and more selective about the technological routes we pursue." (p. 395).

Chapter 5

Implications for the Future

As Thornburg (1999) asserts, "Just because an educational task can be conducted using technology doesn't mean it should be." (p. 7). Face-to-face meetings are always better than videoconferencing and, "no portable display device on the market is as cheap, or has the image quality of the printed page." (p. 7). The key is to look for opportunities where technology can be used to accomplish tasks that without it would be impossible. Technology should not be taught merely for its own sake in the preparation of science teachers. Science teacher education programs obviously play a key role in ensuring that new science teachers enter the classroom as technologically-literate individuals, able to implement and use varied technologies as part of their instructional methods. As emphasized in the U.S. Department of Education (1996) report, "Getting America's Students Ready for the 21st Century", teacher preparation programs can make a significant difference "by focusing on teaching with technology, not merely teaching about it." (Supporting Professional Development section, para. 1), and also by Flick and Bell (2000) who stress that,

Technology modeled in science education courses should take advantage of the capabilities of technology and extend instruction beyond or significantly enhance what can be done without technology. New teachers should experience technology as a means of helping students explore topics in more depth and in more interactive ways. (Proposed Guidelines section).

Flick and Bell go on to propose the following guidelines for using technology in the preparation of science teachers:

1. Technology should be introduced in the context of science content.
2. Technology should address worthwhile science with appropriate pedagogy.
3. Technology instruction in science should take advantage of the unique features of technology.
4. Technology should make scientific views more accessible.
5. Technology instruction should develop students' understanding of the relationship between technology and science. (Proposed Guidelines section).

To many, technological development means change, and change is uncomfortable, unsafe. This is why so often, people are negative and resistant to learning about, and using new technology. Science teacher educators are responsible for helping future science teachers push through that initial resistance, so that they can learn enough about the ideas that guide the use of technology to realize its massive potential as a teaching and learning tool.

If the educational system is viewed as a series of waves, continually breaking on the shore, gently changing the beach landscape--each wave represents a different component or facet of the educational system, and although the waves all leave their own impression, changes in the beach are small. Technology is like a tidal wave breaking on the beach. In a matter of seconds, the whole topography of the shore is totally altered.

The education system of the future based in the context of an information society --an environment rich in technology and information, demands that teachers make radical shifts in their instructional and learning paradigms. In order for this to occur, intensive, continuing technology education will be needed, in addition to a sustained support structure teachers can turn to for help and advice.

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