A CASE STUDY OF THE CHANGE PROCESS OF INTEGRATING TECHNOLOGY INTO AN ELEMENTARY SCIENCE METHODS COURSE FROM 1997 TO 2003

A Thesis in
Instructional Systems
By
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ABSTRACT

The purpose of this qualitative case study was to provide a detailed description of the change process of technology integration into a science methods course, SCIED 458, as well as to interpret and analyze essential issues involved in the change process and examine how these factors influenced the change process. This study undertook qualitative research that employed case study research design. In-depth interviewing and review of the documents were two major data collection methods in this study. Participants included the three key faculty members in the science education program, a former graduate student who participated in writing the Link-to-Learn grant proposal, a former graduate student who taught SCIED 458, and two current graduate students who were teaching SCIED 458. A number of data analysis strategies were used in this study; these strategies included (1) coding for different periods of time and project categories and roles of people, (2) identifying themes, trends and coding for patterns, (3) reducing the data for analysis of trends and synthesizing and summarizing the data, and (4) integrating the data into one analytical framework. The findings indicated that this change process had evolved through the stages of adoption and diffusion, implementation, and institutionalization and a number of strategies facilitated the changes in individual stages, including the formation of a leadership team in the early stages, gradual adoption of technology tools, use of powerful pedagogy and methodology, the formation of a research community, and separation of technology training and subject teaching. The findings also indicated the essential factors and systems that interacted with each other and sustained the change process; these included a transformational shared leadership team, the formation of a learning and research community, reduced resistance of the elementary prospective teachers to technology, availability of university resources, involvement of the local school districts, support of the state department of education, recognition of the professional organizations, creation of partnerships with software companies, and technology advancements in society. A framework for integrating technology was presented to assist school reformers and instructional designers in initiating, implementing, and sustaining the changes due to technology integration in a systemic manner.
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Chapter 1 Introduction

1. Overview

We are living in an era full of innovations. According to Levine (1980):

Innovation combines the elements of reform and change; reform implying new and change implying different. Innovation can operationally be defined as any departure from the traditional practices of an organization. As a result, the element of newness inherent in innovations is a relative phenomenon- what is new in one place is old in the next (p. 3-4).

In other words, innovation refers to an entity or an abstract idea that was never introduced to an organization before. Innovation takes a variety of forms, such as reformed curriculum or developments of computer software and hardware. Rogers (1995) classified one kind of innovation as technology, “A design for instrumental action that reduces the uncertainty of cause-effect relationships involved in achieving a desired outcome” (p. 12).

The changes driven by innovations make our lifestyles different and also have an enormous impact on our educational system. Although innovations are prevalent in educational settings, a number of them have not been able to sustain for various reasons. Smith and Keith (1971) investigated failure of a new open-concept elementary school and concluded that the major cause of failure was that the leader was not able to adjust his vision with that of the stakeholders. Levine (1980) conducted a study to examine 14 innovative programs at the State University of New York at Buffalo and found that failure of innovations was caused by unprofitability or incompatibility. That is, some programs failed because they could not help the school generate more profits. Or the goals set by new programs were strongly against the old traditions, and a balance between the old and new ones could not be met. Micklethwait and Wooldridge (1996) pointed out that
policymakers tend to ignore the local context and culture when implementing innovations. Senge, Kleiner, Roberts, Ross, Roth, and Smith (1999) also made a statement to address the issue:

The fundamental flaw in most innovators’ strategies is that they focus on their innovations, on what they are trying to do – rather than on understanding how the larger culture, structures, and norms will react to their efforts (p. 26).

In short, innovation failure is defined as “a premature decline in the planned level of impact or influence of an innovation on the host organization” (Levine, 1980, p. 156). The change process terminates before an innovation permeates the host organization, and the causes of failure vary.

Over the past six years, from 1997 to 2003, the science education program in the Department of Curriculum and Instruction at Penn State University made endeavors to integrate technology into the course, *Teaching Science in Elementary Schools* (hereafter referred to SCIED 458). Students who major in Elementary and Kindergarten Education (EK ED) are required to take SCIED 458 with social studies and mathematics methods courses in a semester before student teaching. In light of the history of innovation failure, this case, which had been ongoing for six years, drew attention and was worthy of further examinations in order to contribute to an understanding of the technology integration process in an educational context as well as identification and understanding of the factors that lead to sustainability.

The purpose of this case study was to understand the change process of technology integration in SCIED 458 from 1997 to 2003. Perspectives of the key persons who had experienced or were experiencing the process and the relevant documents were examined. In this chapter, I provide a statement of the problem, followed by the research questions.
The significance of this study is also addressed.

2. Problem statement

In the last two decades, science education has embarked on major reform in order to support children’s scientific inquiry (American Association for the Advancement of Science, 1989, 1993; National Research Council, 1996, 2000, 2001a, 2001b; National Science Teachers Association, 1991, 1996). From the reform documents, statements, and policies, technology has been advocated as a desirable tool to facilitate science learning because, with the help of technology tools, children can be encouraged to explore, simulate, and visualize various scientific phenomena that only can be observed in laboratories.

Studies have shown that elementary prospective teachers struggle to make appropriate use of technology to teach science to children (Willis & Mehlinger, 1996; US Congress, 1995) because of a variety of reasons. The main factor is that elementary prospective teachers’ personal experience as science learners from K to 12 resulted in their fear of science learning and teaching. In addition to their experience, college-level science courses offered by science education programs appear to be another reason for inadequately preparing prospective teachers for teaching science in that the courses do not include appropriate curriculum (American Association for the Advancement of Science, 1990; Arons, 1990; Carter, Heppner, Saigo, Twitty, and Walker, 1990; Coble and Koballa, 1996; National Research Council, 1989, 1995, 1999). Also, the courses do not coordinate well with other aspects of science education programs for them to practice what they have learned, and are not taught by competent faculty (Barrow, 1987; Raizen & Michelsohn, 1994). Therefore, after graduation, elementary prospective teachers do not
have much confidence in teaching science to children.

Moreover, it has become more difficult for elementary prospective teachers to teach science with technology. Research indicates that the science education programs fail to equip them with appropriate instructional strategies in teaching science with technology (Novak, 1991), and fail to assist them in realizing their roles in implementing technology to enhance science learning (Whetstone & Carr-Chellman, 2001). In addition to poor curriculum (Beaver, 1990; Bork, 1991; Huang, 1994; Main & Roberts, 1990; Scheffield, 1994), other barriers to integrate technology into science education include insufficient funding, training, software, and hardware.

In order to equip elementary prospective teachers with the ability to make connections between technology and science teaching, the science education program in the Department of Curriculum and Instruction at the Pennsylvania State University had undergone a major change over the past six years, 1997 to 2003, in the elementary science methods course, SCIED 458, to address the National Science Education Standards (National Research Council, 1996, 2000). Various types of technology tools had been integrated into SCIED 458 and each of them had evolved to varying degrees. SCIED 458 had been restructured to cope with technology integration accordingly and the course continues to successfully teach prospective teachers to integrate technology with science learning and teaching. Therefore, this change process is the major focus of this study.

Based on the literature review, the change process of educational technology consists of a sequence of the stages of adoption and diffusion, implementation, and institutionalization (Surry & Ely, 2001). The stages of adoption and diffusion involve
how people form the initial decisions to use technology innovations (Rogers, 1995). Fullan (1996) defined implementation as “the actual use of an innovation in practice” (p.273). Institutionalization means that an innovation is stable and routinely used in an organization (Eiseman, Felming, & Roody, 1990). Although there have been numerous research studies related to adoption and diffusion (Keeler, 1976; Rogers, 1995; Ryan & Gross, 1943; Sekon, 1968; Surry, 1993; Surry & Brennan, 1998), few studies focus on the aspects of implementation and institutionalization of technology integration (Eiseman, Fleming, & Roody, 1990; Fullan & Pomfret, 1977; Yin & Quick, 1978). Furthermore, little or no literature explores how a process of technology integration has evolved through the sequence of these stages. This study intended to contribute to a deeper understanding of various factors of technology integration in a sequence of the stages of diffusion and adoption, implementation, and institutionalization in an educational setting.

Research has affirmed that well-designed instructional innovations do not necessarily lead people to adoption since a variety of social, personal, organizational, and economic factors can create resistance to innovations (Levine, 1980; Micklethwait & Wooldridge, 1996; Smith & Keith, 1971; Senge et al., 1999). In order to investigate the complex interrelationships of numerous factors, systems inquiry comes into play. Systems inquiry assists researchers in examining how essential factors depend on and influence each other (Banathy 1987, 1996, 2001; Brethower, 1999). Thus, a systemic change perspective was applied to examine what stages the change process had experienced and explore what factors contributed to the sustainability. The findings suggested the factors that an educator, an instructional designer, a policymaker, or a program innovator should consider when introducing technology innovations in an educational context.
3. Research questions

The purpose of this study was to develop a framework for understanding the factors that contributed to the change and sustaining the change in the process of technology integration in SCIED 458 over the past six years, from 1997 to 2003. The major research questions were:

1. What is the current state of technology integration in SCIED 458?
2. What have been major attempts to integrate technology into SCIED 458 over the past six years?

Some sub-questions under this question are:
   2a. What factors were responsible for initiating the changes?
   2b. What factors appeared to influence the changes positively and negatively?
   2c. To what extent have attempts to integrate technology in SCIED 458 over the past six years been maintained?
   2d. What are the factors that influenced the sustainability of the changes?
3. What model of change has emerged?

Question 1 intends to provide descriptions of types of technology tools that were currently utilized in class by the instructors and the elementary prospective teachers, examine the applications of the technology tools in science teaching and learning, and investigate their influence on SCIED 458. Question 2a looks for various factors, such as people, tools, and processes, which had brought forth technology integration in SCIED 458 over time and identifies types of technology tools that were being or had been utilized. Question 2b explores what positive and negative factors had contributed to each technology tool in continuing or terminating. Question 2c intends to find out what technology tools had been sustained and examines the extent to which they had evolved over time. Question 2d explores the factors that had contributed to the sustainability of these technology tools. Question 3 attempts to find out if there is any framework
informing the changes in this particular educational context.

4. Methodology

This study used a qualitative research methodology that employs case study research design. I conducted in-depth interviews with persons who had experienced or were experiencing the change process, including three faculty members in the science education program, a former graduate student who participated in writing Link-to-Learn grant proposal, a former graduate student who taught SCIED 458, and two graduate students who were teaching SCIED 458. Documents, including publications, presentations, a grant proposal, SCIED 458 syllabi, theses, dissertations, and the internet resources for the course, were reviewed and examined. Data analysis followed the guidelines suggested by Strauss and Corbin (1998) and Miles and Huberman (1994), utilizing different levels of coding schemes. This study adopted triangulation, member check, peer debriefing, and thick description to ensure the validity of the data. A log that recorded the logistics of this study, my reflections on data collection and analysis, and methodological decisions were also used to ensure the reliability of this study. Overall, the writing of this study followed Stake’s (1995) guidelines for case study.

5. Significance of the study

This study made contributions to scholarly research in the areas of systems inquiry, the change process, and technology integration in elementary science education. First, Banathy (1996) pointed out that systems inquiry, consisting of systems theory, systems philosophy, and systems methodology, is applied in a variety of fields such as business, health services, and engineering, but not in education. He strongly suggested that educators should embrace systems inquiry to ensure the successful school reform that the
U.S. has called for in recent years. In 1988, Banathy also described a comprehensive system of educational system and categorized it into four components: (1) the analysis and description of educational systems; (2) the design and redesign of systems; (3) systems development, implementation, and institutionalization; and (4) systems management and the management of change.

A number of models and methods (AcKoff, 1981; Checkland, 1981; Nadler, 1981) have contributed to the first and second areas. This study intended to contribute to the third and fourth areas. That is, in order to strengthen the notion of systems implementation and institutionalization, this study was meant to inform researchers and practitioners about how the types of technology tools integrated into SCIED 458 and the process of integration unfolded over six years. In order to enhance the notion of change management, the factors that had been involved in sustaining or terminating technology tools in SCIED 458 were examined. Thus, research on systems inquiry was extended.

Second, this study contributed a new perspective of the change process in an educational setting. Surry and Ely (2001) illustrated that the change process is composed of the stages of diffusion and adoption, implementation, and institutionalization. The literature indicates that numerous studies have discussed the stages of adoption and diffusion such as Rogers’ (1995) comprehensive book, *Diffusion of Innovations* (4th Ed.). This study sought to gain an in-depth understanding of the stages of implementation and institutionalization and, furthermore, the complete change process. Holloway (1996) pointed out that the research designs of most case studies about integrating technology into organizations are limited to short time spans such as one or two years. By studying the change process of six years, this study provided detailed descriptive and analytical
Third, this study was responsive to the National Science Education Standards (National Research Council, 1996, 2000, 2001a, 2001b), particularly to the Science and Technology Standard under the Science Content Standards, the Science Education Program Standards, and the Science Education System Standards. That is, this study explored how technology had been integrated to enhance science teaching and learning and how the science education program has structured the course to maximize the use of technology. As Kiefer (1991) noted, information technology is a tool for reform. The use of educational technology should be specific to a particular subject area and curriculum should be modified because of technology integration, which requires more attention. Thus, this study attempted to focus on technology tools particularly used in elementary science education and also to learn how an elementary science methods course, SCIED 458, had been transformed over time. Moreover, this study employed a systemic view to examine how factors interrelated and interacted with each other within the program, which is in itself a form of educational system.
Chapter 2 Literature Review

In this chapter, I provide the history of reform in science education that emphasizes teaching science as inquiry in the United States. I describe a number of major types of technology tools that have potential to support reform efforts. Nowadays, these technology tools are still rarely seen in classroom. Because teacher preparation education plays an important role of shaping the practice in school, I explain the challenges of preparing elementary prospective teachers to support science teaching and possible approaches. In light of these challenges, I provide a rationale for focusing this study on the technology integration change process in the elementary science methods course at Penn State. Furthermore, in order to gain a deep understanding of the technology integration change process, the literature from systems and change theories is addressed.

1. Reform in science education

In the last two decades, the United States has called for reform on science education in response to children’s poor performance and lack of interest in science. A number of professional scientific societies and organizations have taken the initiative in reforming science education. In 1986, the American Association for the Advancement of Science (AAAS) initiated Project 2061, resulting in the publication of Science for All Americans (1989) that articulated AAAS’ vision for scientific literacy. It proposed the meaningful learning of science for K-12 students. Specifically, it aimed at building an in-depth understanding of science concepts, integrating other disciplines such as technology, and fostering scientific ways of thinking such as creativity. It also emphasized that reformers of K-12 science education should consider all aspects and components within the
By the end of the 1980s, the National Science Teachers Association (NSTA) developed a new approach teaching science, which recommended that students in grades 9-12 should be exposed to every science subject each year (NSTA, 1996). In 1991, the National Science Teachers Association Position Statement: Elementary School Science provided basic guidelines for elementary science (NSTA, 1991). The guidelines stressed that, when learning science, students should explore broad concepts rather than isolated facts, should be able to think critically, solve problems, and make informed decisions from analyzing the data, and, ultimately, should be capable of applying science and technology to everyday life.

In 1993, Benchmarks for Science Literacy (AAAS) offered goals and objectives for what U.S. students should know and be able to do in science. Furthermore, the National Research Council with the assistance of the National Academy of Sciences developed the National Science Education Standards (National Research Council, 1996). The goals addressed the standards for teaching science and science education programs. Based on the standards, science teaching should take an inquiry-based approach and be adapted to meet the interests, abilities, and experiences of students; inquiry refers to “approaches and strategies for teaching and learning that enable learners to master scientific concepts as a result of carrying out scientific investigation” (National Research Council, 2001a, p. 187). Science teachers should be able to create an environment to enhance science understanding by encouraging students to communicate ideas with a community of learners. The standards for science and technology focus on the connections between science and invention. The standards specify the roles of colleges and universities in
preparing teachers for implementing curricula that are consistent with the content standards.

In 2000 and 2001, the National Research Council continued to explicate the detailed guidelines to implement inquiry-based science and classroom assessment (National Research Council, 2000, 2001b). In inquiry-based science, teachers serve as facilitators who set up a number of conditions for students to explore and investigate problems. Assessment becomes an integral part of science teaching and learning rather than a standalone activity.

With the increasing awareness of the importance of teaching quality, the National Academies established the Committee on Science and Mathematics Teacher Preparation (CSMTP) to identify critical issues in existing practices and policies for K-12 teacher preparation in science and mathematics in 1998. In 2001, *Educating Teachers of Science, Mathematics, and Technology* presented detailed recommendations for improving science teacher education from a systemic view based on extensive research and careful examinations of practical experiences conducted by the committee.

From these reform documents, statements, and policies, four distinct characteristics can be concluded to form the basis of reformed science education:

(1) Science teaching should employ an inquiry-based approach;

(2) Assessment attempts to ensure the quality of teaching and enhance the effectiveness of learning;

(3) Integrating other disciplines with science is necessary; and

(4) Applications of technology tools into science teaching and learning have grown gradually.
2. Technology tools that have potential to support reform efforts

The use of technology tools in science teaching and learning as inquiry has gained growing attention with the advent of emerging technology innovations. The literature has addressed three major types of technology tools, referred to as inquiry empowering technologies (Krajcik, Blumenfeld, Marx, & Soloway, 2000; Zembal-Saul, Munford, & Friedrichsen, 2002) that are commonly used to assist elementary students in inquiring scientific understanding, carrying out investigation, communicating, and developing products. Three types of technologies were synthesized by the elementary science education group at Penn State (Zembal-Saul et al., 2002)

2.1 Tools that allow students to engage in sciencing

In microcomputer-based laboratories (MBLs), students can observe graphs being produced by a microcomputer while the experiment is conducted at the same time. Nakhlen (1994) defined MBLs as “software which uses an electronic probe to collect information about a physical system and convert that information to a graphical system in approximately real time” (p. 368). One example is probes, a microcomputer-based tool that can detect temperature, voltage, light intensity, sound, distance, dissolved oxygen and so on.

By using probes, students are shown to develop science concepts, collect and analyze real time data, and visualize the data much more quickly (Mokros & Tinker, 1987). Probes enable students to perform investigations that were difficult or impossible to do (Bannasch, 2001; Krajcik & Layman, 1992). In addition, probes purport to strengthen students’ graphing science process and problem solving skills (Linn, Layman, & Nachmias, 1987; Linn, 1998) because probes possess the capability of simultaneously
collecting and graphing data (Brasell, 1987). In short, probes encourage students’ active engagement with phenomenon, like scientists, because of these advantages. Probes are now available for various hand-held devices, such as the Palm, through ImagiWorks; and the PASPORT System, through PASCO.

2.2 Tools that simulate phenomena that cannot be accessed in school science easily

Simulations combine video, pictures, computer graphics, text and interactivity to present to students phenomena that otherwise would be inaccessible, too hazardous, too time-consuming, or too expensive for students to observe. Using simulations, students explore what it might be like to manipulate variables that would otherwise be just too unethical, difficult, or impossible to do. For instance, Genscope (Horwitz & Christie, 2000) allows middle school students to breed various types of dragons to see the effect of selective breeding on observable characteristics, or phenotypes, in the offspring. Genscope allows students to ask “What if” questions and to do explorations that would otherwise not be feasible. Moreover, the linking between the visual characteristics of the offspring and the invisible world of chromosomes and DNA provides for unprecedented learning outcomes.

2.3 Tools that assist students in accessing second source data from online database and discussing with others around the country and the world

Spitulnik et al. (1998) proposed that “teachers need to provide environments which support students’ inquiry, collaborating, and communicating.” Such environments can help students to generate scientific understandings and can be built up through email, threaded discussions, and chat rooms.

In recent years, several projects have made substantive efforts to create a
collaborative environment for students to get access to second hand data and participate in the discussions with people in the U.S and from around the world. For example, the Global Learning and Observations to Benefits the Environment (GLOBE) Program (www.globe.gov), initiated by Vice President Al Gore on Earth Day, April 22, 1994, is a hands-on international environmental science education program that establishes a partnership between students, their teachers, and the scientific research community. GLOBE provides opportunities for children to communicate and collaborate with scientists and other GLOBE students around the world. Students can take part in threaded discussions with scientists on a variety of topics related to various investigations. GLOBE also supports students in the collection and analysis of data. After collecting the data, they report their data through the Internet. Students compare their data to archived data collected in previous years. This project has been joined by 3,800 schools in the U.S. and has drawn schools from 50 countries to participate (Rock et al., 1997).

Although these tools have shown potential to support science learning, they are rarely used or seen in the elementary science classroom. Thus, how to educate our next generation of teachers to integrate these tools into classroom is a major issue that science education programs in colleges and universities should strive to solve.

3. Preparing elementary prospective teachers to support students in science learning

3.1 Challenge of elementary preservice science education

Teaching plays an essential part in students’ learning process in that it organizes and presents the content knowledge of subject matter in ways that can assist students in grasping the ideas easily and effectively. Research has confirmed that good teaching does matter in the learning process. A meta-analysis of previous studies (Druva & Anderson,
1983) indicated a strong correlation between students’ achievement in K-12 science and mathematics, and the level of knowledge of K-12 teachers in science and mathematics. In 1989, McDiarmid et al. concluded that teachers’ content knowledge and pedagogical decisions influence their teaching quality. In short, teachers’ content knowledge and pedagogical skills impact students’ achievement in science (Chaney, 1995; Stoddard & Floden, 1995).

As a base for producing future teachers in grades K-12, preservice education has raised a concern about the inadequate preparation of elementary prospective teachers in having strong knowledge and pedagogy to educate children in science. The survey (Haselkorn & Harris, 1998) revealed that prospective teachers needed special training and skills, not simply a good general education. Numerous studies, the results from a variety of the Praxis, and other teacher licensing and certification examinations demonstrated that many teachers, especially those who will teach in grades K-8, do not have sufficient content knowledge or adequate background for teaching various subject areas. Thus, the Committee on Science and Mathematics Teacher Preparation (CSMTP) (National Research Council, 2001a) recognizes a pressing need to provide teachers with the appropriate content knowledge and pedagogy with the joint efforts of scientists, mathematicians, and engineers to improve the quality of teachers’ preparation in science education.

Based on the review of the literature, there are a number of reasons for anxiety and lack of confidence of elementary prospective teachers in science teaching, including their past experiences in science and preservice teacher education. Over the last two decades, the studies have shown that many elementary prospective teachers hold negative attitudes
toward science because of their past experience in science at the secondary level (Abell & Smith, 1994; Mulholland & Wallace, 1996; Palmer, 2002; Skamp, 1991). They typically have poor science knowledge and lack confidence in their ability to teach the subject.

College-level science courses are one of the reasons. Several studies assessed the status of elementary science education programs and found that most programs failed to meet the NSTA’s standards for content preparation (Barrow, 1991; Yager, 1991). Tolman and Campbell (1991) surveyed public and private institutions from which at least 75 elementary education majors graduated every year and found that less than one third of the institutions complied with the standard for 12 semester hours of science courses.

There are various sources of the problem of college-level science courses taken by elementary prospective teachers. Arons (1990) pointed out that college science courses focus on the major achievement in an area of science. In these courses, science is presented as a body of facts rather than a process of inquiry (Coble and Koballa, 1996). Arons (1990) also contended that much information is presented in too brief a time for students to understand science concepts, principles, and theories. Most of the courses are based on lecture and provide no opportunity to apply the knowledge (American Association for the Advancement of Science, 1990; National Research Council, 1989, 1995, 1999). Carter et al. (1990) affirmed that college science courses teach isolated concepts and rote problem solving, and neglect critical thinking, collaboration, and open-ended laboratory investigation.

In addition, science methods courses do not coordinate well with other aspects of education programs such as field experience, the time that elementary prospective teachers spend in schools and classrooms working with mentor teachers, and a faculty
member from the student teachers’ college or university who supervises their teaching. The lack of professional knowledge of the faculty in science education programs might be another source of the problem. The faculty at the nation’s colleges and universities may not be sufficiently aware of the changing expectations to provide the appropriate type and level of instruction and may not possess adequate knowledge and skills to teach prospective teachers how to teach science with children (Raizen & Michelsohn, 1994). Barrow (1987) characterized the elementary science faculty he surveyed as “generalists rather than science education specialists.” According to the results, nearly 39 percent of his respondents had eighteen or fewer hours of science courses beyond the bachelor’s degree while 35 percent had nine or fewer hours.

In light of these findings, elementary preservice science education programs should strive for providing opportunities for prospective teachers to practice and apply what they have learned in supportive environments that offer continual feedback, modeling of high quality teaching, and individual coaching from faculty, mentors, and peers. The Committee on Science and Mathematics Teacher Preparation (CSMTP) (National Research Council, 2001a) also advocates that two and four-year colleges and universities should assume greater responsibilities for improving teacher education.

As was noted from these reform documents and the research reports, inquiry-based science has become a major approach in science education that needs elaborations here. It is believed that understandings of scientific concepts are constructed by learners rather than given by teachers. While teachers serve as facilitators, students question their own comprehension, examine their misconceptions, are challenged to apply the knowledge in different contexts, and reason through scientific investigation (Lawson & Lawson, 1980).
Such an approach was shown to improve students’ attitudes toward science (Abraham & Renner, 1986).

To meet the demands over the past twenty years, the University of Michigan has developed a science education program that prepares new teachers who understand physical science and are able to create meaningful learning experiences (Krajcik et al., 1993) and the Science Education Group at Penn State (Dana & Zembal-Saul, 2001, Zembal-Saul et al., 2002). These programs connect science plus pedagogical courses, and provide an early teaching apprenticeship where students can develop lessons, discuss issues, and exchange ideas about using technology tools to enhance teaching with their peers.

3.2 Challenge of prospective teachers teaching science with technology

Most elementary prospective teachers know very little about effective use of technology and do not have confidence in using technology when they teach (US Congress, 1995). Handler and Pigott (1994) surveyed teacher education students in the Midwest one year after graduation and found that only 16% felt adequately prepared to use computers as instructional tools.

Davis and Coles (1992) surveyed the information technology experiences of incoming teacher education students in the United Kingdom. They reported that incoming students had a wide range of experiences and skills. 63% of them had used a computer, and 86% wanted to use technology in their classrooms when they graduated. But 25% doubted that they could learn to use technology effectively in college.

In addition, Novak (1991) pointed out that teachers did not know about many instructional strategies for using a computer for whole-group instruction and neither did
they know about the software packages that supported those strategies. Whetstone and Carr-Chellman (2001) also concluded from their survey results that elementary prospective teachers did not appear to see the importance of their roles in implementing technology in classrooms.

In other words, although elementary prospective teachers may have some prior experiences in technology, they feel unprepared for teaching subject matters with technology because they cannot identify useful instructional strategies and select appropriate software. They do not even realize their roles in implementing lessons with technology. Apparently, teacher education programs do not do enough work and need to make substantive efforts to prepare prospective teachers for teaching with technology.

Bork (1991) claimed that few colleges and universities are aware of their positions to deal with the lack of ability of elementary prospective teachers teaching with technology. For instance, junior and senior elementary education majors at New York University reported that computers were not any part of their courses (Beaver, 1990). Similar results were found by the surveys conducted at a large California college (Main & Roberts, 1990), a regional university in Pennsylvania (Sheffield, 1994), and several universities in the South (Huang, 1994).

Furthermore, teacher education is not able to consider all aspects of preparation programs and provide adequate opportunities for prospective teachers to apply what they have learned. Willis, Austin, and Willis (1994) contended that technology was not a major focus in student teaching placement, and less than one in four prospective students were required to teach one lesson that incorporated technology. Moursund and Bielefeldt (1999) also indicated that most institutions had information technology available in K-12
classrooms for student teaching, but information technology was not used routinely during field experiences.

In 1990, the Michigan State Board of Education identified three major barriers to integrate technology into preservice education: inadequate funding, lack of training of the faculty, and insufficient software and hardware.

Despite these problems, a number of colleges and universities have initiated work on integrating technology into different subject matters in preservice education recently. For example, Schmidt et al. (1994) described how the technology faculty and math faculty worked together to integrate technology into a reading and language arts course at Iowa State University. Ford et al. (1992) developed a model lesson that incorporated technology such as videodiscs and hypermedia software that were presented to teacher education students as demonstrations to stimulate discussions in social studies and science methods courses. Woodrow (1994) utilized a variety of technology tools in the science methods course at the University of British Columbia for several purposes, that is, to support lectures, to complement instruction in a physics classroom (e.g., CAI software), and to serve as a professional tool (e.g., word processor).

3.3 Tool to assist with teacher development – web-based portfolio

Web-based portfolio is one type of hypermedia portfolio. It is defined as “a user’s hypertextually linked set of electronic texts that have been created for and placed on the World Wide Web” (Watkins, 1996, p. 219). Research has suggested that web-based portfolios have more advantages than traditional paper-based and other types of hypermedia portfolios, including easy management, wide and global access to a variety of audiences (Pierson & Kumari, 2000), and unlimited storage capacity (Morris &
The notion of portfolio was proposed by the work of Lee Shulman (1988) and the creation of the National Board for Professional Teaching Standards in 1989. In teacher preparation programs, portfolio development has been demonstrated as useful in a number of areas for prospective teachers. First, portfolio development is a powerful tool to engage them in reflecting on their experiences, interrogating their practices, understanding their effects on students, and shaping their practices (Lyon, 1998; Schon, 1983).

Second, portfolio development facilitates prospective teachers connecting theories and practices (Morris & Buckland, 2000). Third, portfolio development enables them to construct scientific knowledge and concepts (Dana & Tippins, 1998).

The portfolio has been represented in different media over time. Because of the photocopying costs and storage problems (Aschermann, 1999), hypermedia portfolios gradually replaced paper-based portfolios. Jonassen (1996) defined hypermedia as a way of representing and organizing information using electronically connected networks of nodes, which are the basic units of storage in hypermedia. A number of studies have shown that hypermedia portfolios can promote students’ deep understandings of ideas in the development process (McKinney, 1998; Morris & Buckland, 2000). A similar finding was drawn by Glasson and McKenzie (1999) in examining the development of multimedia portfolios for enhancing learning and assessment in a science methods course. They concluded that “developing a hypermedia presentation enabled prospective teachers to construct and develop their ideas about teaching and learning. The portfolio documented the progress of prospective teachers as they developed curriculum and taught
Moreover, Zembal-Saul and Dana (2001) conducted a study about how 32 prospective elementary teachers had made progress in developing web-based portfolios that included evidence and evidence-based justification within one semester. The findings indicated that web-based portfolio development could engage them in meaningful reflection because they appeared to select more convincing evidence and provided stronger justification as the semester moved on. In other words, web-based portfolio development can support prospective teachers’ metacognitive activities because technology makes connections between evidence and justification explicit, and allows them to express themselves creatively and save changes over time (Avraamidou, & Zembal-Saul, 2001; Zembal-Saul, Haefner, Avraamidou, Severs, & Dana, 2002).

4. Technology integration in SCIED 458

In this study, the science education program in the Department of Curriculum and Instruction at Penn State served as one of the programs that strived for responding to the standards for science education. Particularly, SCIED 458 was an elementary science methods course that took different approaches to integrate content and pedagogy and introduced prospective teachers to experience inquiry-based science. This course scaffolded them to teach science to varying populations, from a small group of children on a university campus to a large group of children in the field experience classrooms. It provided opportunities for them to reflect on their teaching and the feedback given by methods course instructors, peers, and field experience supervisors. Most importantly, the prospective teachers were guided to integrate science specific tools that were very similar to the aforementioned tools to enhance students’ understandings of scientific concepts.
Throughout the course, the web-based portfolio was the tool that assisted elementary prospective teachers in teacher development.

In sum, the focus of this study was to explore the change process of technology integration in SCIED 458 at Penn State during the past six years. Change does not happen overnight. The change literature helps inform different stages in the process and factors that are involved.

5. Systemic change

5.1 Systems inquiry

Banathy (1996) noted that systems inquiry consists of systems theory (Bertalanffy, 1956; Boulding, 1956), systems philosophy (Blauberg, 1977; Bateson, 1972; Laszlo, 1972), and systems methodology. Systems theory explicates a set of interrelated concepts and principles that can apply to learn all systems. Systems philosophy provides a way of thinking that forms the basis of systems theory. Systems methodology suggests “a set of models, strategies, methods, and tools that instrumentalize systems theory and philosophy in analysis, design, development, and management of complex systems” (p. 75). In fact, the three domains interrelate to each other very closely.

In particular, general systems theory was developed in the 1920s to cope with the complexities that cannot be dealt with by traditional reductionist methods of science (Bertalanffy, 1968). A number of principles of general systems theory are identified from the literature (Brethower, 1999):

1. All systems are open systems, which means they must import energy to survive;
2. All systems have certain mechanisms for processing information and supporting
3. The energies of systems can be redirected to achieve specific goals;
4. They can change their goals and redirect their energies from the old goals to the new goals;
5. They have mechanisms for channeling energy to determine the priorities;
6. They can respond to the change immediately; and
7. They operate within the constraints imposed by the external environment and, therefore, by the available resources (p. 69-70).

Although systems inquiry is applied in a variety of fields such as business, health services and engineering (Banathy, 1996), there is little or no application in education. He strongly suggested that education researchers should embrace systems inquiry to ensure the successful school reform that the US has called for in recent years. He (1988) also described a comprehensive system of educational system that is composed of (1) the analysis and description of educational systems, (2) the design and redesign of systems, (3) systems development, implementation, and institutionalization, and (4) systems management and the management of change.

Banathy (1992) constructed three models to look at educational systems and to understand, describe, and analyze them as open, dynamic, and complex social systems. For example, the systems-environment model guides us to examine the relationships, interactions, and interdependencies between educational systems and social systems. A number of models (Ackoff, 1981; Checkland, 1992; Nadler, 1981) were generated to inform the design of social systems. For instance, Nadler (1981) developed a comprehensive model for the design of sociotechnical systems. In the first phase,
designers formulate the purposes of the mission. In phase two, designers are introduced to a variety of methods to figure out solutions to the problems. In phase three, designers are encouraged to come up with alternative solutions. In phase four, designers need to detail their solutions. In phase five, they need to illustrate how to implement the solutions. Because few research studies were concerned about the third and fourth areas, this study intended to make contributions to them.

In education, the systemic change paradigm, pioneered by Bathany and popularized by Reigeluth, should deserve more attention in that this paradigm is concerned about numerous issues surrounding school reform. Reigeluth and Garfinkle (1994) pointed out some commonalities among the issues, including ensuring stakeholder involvement, revisiting old practices, and examining interrelationships.

Specifically, Banathy (1987) defined a system as an integrated set of elements that interact with each other. He also characterized a system as interdependent, synergistic, dynamic, and cybernetic (Gustafson & Branch, 2001). Interdependent means that all the elements depend on each other to accomplish the system’s goal. Synergistic means that all the elements can achieve more than the individual elements alone. Dynamic means that the system can adjust to changing conditions. Cybernetic means that the elements efficiently communicate among themselves.

While a number of studies have focused on large-scale school reform such as a school or a school district (Danzberger et al., 1992; Darling-Hammond, 1997; Kemp, 1996), this study intended to learn about the change process of technology integration in SCI ED 458 in the science education program. This study was not only interested in this course because, in order to understand the change process of the course, it is impossible
to neglect the context where the change has occurred, that is, the science education program. Thus, this case can be regarded as small-scale school reform driven by technology; a systemic change perspective was applied to learn about this case.

6. Overview of the change process

Although a large body of the literature has discussed the change process, few research studies and theoretical frameworks can define the components of the change process. Thus, this study adopted the definition of Surry and Ely (2001). That is, the change process of educational technology consists of the stages of adoption and diffusion, implementation, and institutionalization.

The stages of adoption and diffusion involve how people form the initial decisions to use technology innovations. Fullan suggested (2001) that “initiation is the process leading up to and including the decision to proceed with implementation” (p. 53). There has been a long history of research related to the adoption and diffusion of innovations. The most important studies are those conducted by the earlier researchers in the field of rural sociology (Rogers, 1995). So far, Rogers’ book, *Diffusion of Innovations (4th ed.)*, has provided the most comprehensive overview of adoption and diffusion theory.

In the adoption and diffusion theory, Rogers highlighted four essential ideas. First, he suggested that the adoption of an innovation is a process rather than a single act. Potential adopters need to go through five phases to reach the final decisions to continue or terminate the utilization of an innovation. In the first phase (knowledge), they gain a basic understanding of what it is and how it works. In the second phase (persuasion), they can take a positive or negative attitude toward it. In the third phase (decision), they take
actions to accept it or reject it. In the fourth phase (implementation), they actually use it. In the fifth phase (confirmation), they examine how it has been used and make further decisions to use it or reject it based on the perceived benefits.

The second important idea is the concept of adopter categories. This concept illustrates that a certain percentage of the population, such as innovators, early adopters, and early majority, will readily adopt the innovation, while others, such as late majority and laggards, will show resistance to an innovation in the process.

The third idea is perceived attributes. That is, people form the opinions of an innovation based on if it provides a better way to do their jobs (relative advantage), how it is compatible with their values and beliefs (compatibility), how difficult to learn it (complexity), if it can be tried out before using it (trialability), and what benefits it can bring (observability).

The fourth idea is the S-shape adoption curve, which means that the adoption process begins with a period of slow adoption followed by a sudden period of rapid adoption and, then, a gradual leveling off. A number of researchers have applied adoption and diffusion theory to study the adoption and diffusion of technology innovations (Burkman, 1987; Farquhar & Surry, 1994; Fleet & Durrance, 1993; Holloway, 1996; Kearns, 1992; Stockdill & Morehouse, 1992). They contended that the utilization of technology innovations is increased within the organizations with the considerations of four essential ideas proposed by Rogers.

Fullan (1996) defined implementation as “the actual use of an innovation in practice.” Furthermore, he called the implementation perspective “both the content and process of dealing with ideas, programs, activities, structures, and policies that are new to
the people involved” (Fullan, 1996, p. 273). There have been a number of models generated to guide the implementation phase, such as Hall’s Concerns Based Adoption Model (CBAM) (Hall & Hord, 1987) and a model refined by Moersch (1995). For instance, Havelock & Zlotolow (1995) and Ellsworth (2000) provided guidelines for the change agent to the change process; that is, a circle of seven stages includes Care, Relate, Examination, Acquiry, Try, Extend and Renew. Yet little is known about what happens in the implementation phase.

Implementation leads to institutionalization, a stage when an innovation is assimilated into the structure of an organization and changes that organization in a stable way (Miles, Eckholm, & Vandenburghe, 1987). Eiseman, Fleming, and Roody (1990) proposed six indicators of institutionalization: acceptance by relevant participants, the innovation being stable and routinized, widespread use of the innovation throughout the institution or organization, firm expectation that use of the practice and/or product will continue within the organization, continuation depending not on the actions of specific individuals but on the organization, structure and procedures, and routine allocations of time and money.

Based on the literature review, basic definitions of the stages of adoption and diffusion, implementation, and institutionalization are gained. The literature also points out the gap of research studies about the stages of implementation and institutionalization and, furthermore, the complete change process. This study sought to understand the change process of technology integration into an elementary science methods course, SCIED 458. That is, this study attempted to explore how the process had evolved from adoption and diffusion, to implementation, and to institutionalization over the past six
years, and, most importantly, to examine what factors, such as people, tools, and processes, were involved. In short, this study intended to contribute to a deeper understanding of various factors of technology integration and gained an insight into the change process in an educational context.

7. Common factors that influence the change process

A number of factors that have consistently appeared in change research studies and theoretical frameworks are summarized in the following paragraphs and guide this study.

7.1 Definition of innovation

An innovation has been interpreted in various ways. Some organization models define an innovation as a new product or service that an organization, developer or inventor has created for the market (Amabile, 1988; Kanter, 1988; Tornatzky & Fleischer, 1990). In contrast, some models regard an innovation as a technology or a practice “being used for the first time by members of an organization, whether or not other organizations have used it previously” (Nord & Tucker, 1987, p. 6). In particular, diffusion theories treat an innovation as an idea or an object that is foreign to the individuals in the system (Rogers, 1995). Rogers classified one kind of innovation as technology, “A design for instrumental action that reduces the uncertainty of cause-effect relationships involved in achieving a desired outcome” (p. 12). Uncertainty suggests that no one can predict what the impact of a new idea, a practice, or an object will be on the system. A number of studies showed that several coordinated and mutually reinforcing innovations, such as infrastructure, curriculum, pedagogy, and technology are usually necessary to support effective, lasting change (Ellsworth, 2000; Hinnant & Oliva, 1997; Hirumi, 1995).
An individual makes the decision to adopt a technological innovation or to reject it based on expressing several major concerns. The first question is how a technology operates in order to help reduce uncertainty about the cause-effect relationships involved in achieving a desired outcome. The second question is how the consequences influence his/her situation. Thus, Hall and Rutherford (1983) provided six stages of concerns of potential adopters: awareness, informational, personal, management, consequence, collaboration, and refocusing and levels of use of the innovation by the users ranging from non-use, orientation, preparation, mechanical, routine, refinement, integration, and renewal.

7.2 Leadership

Because people are typically resistant to change, there must be stimuli that activate the change process. Ely (1999) identified eight conditions that facilitate the implementation of educational technology, including dissatisfaction with the status quo, the existence of knowledge and skills, the availability of resources and time, rewards or incentives, participation, commitment, and leadership. Other conditions driving the change process include shared vision, clearly-defined goals, and support for community (Baker, 1994; Cognitive and Technology Group at Vanderbilt, 1997, David & Goren, 1993; Riley, 1997). Among the conditions found in the literature, leadership is the most commonly identified factor involved in empowering the change (Senge, 1990).

Leadership is defined as the capacity or ability to lead, guide, command, take charge, or influence individuals or an organization. Vision is an essential element possessed by leadership in the change process because it mobilizes people to accomplish the goal (Belasco, 1991; Evans, 1996; Fullan, 1993, Gardner, 1981). With the trend of
globalization, change management skills become a critical trait of leaders and are established in the context and interwoven with complex and dynamic relationships in systems (Wheatly, 1992). In addition, leadership is involved in exercising strategic plans, which enable people within organizations to sustain their efforts in the change process. Fullan and Stiegelbauer (1991) suggested several ways for the change agent, such as thinking big but starting small, focusing on something tangible and essential, empowering your faculty and staff and so on. Based on the extent to which leaders share their vision with people and manage the change, as well as the kind of followers to whom they appeal, four leadership theories emerge.

First, perceiving the change as a new opportunity, transformational leadership shares values and beliefs on a deeper level with followers, independent persons and self-critical persons (Bennis & Nanus, 1997; Senge, 1990). Second, participative leadership attempts to consult the followers regarding the vision and does not always see the change as a turning point (Sergiovanni, 2001). Third, transactional leadership focuses on rigid plans, bargains with followers and avoids sharing values and beliefs (Bennis & Nanus, 1997). Finally, autocratic leadership serves the function of a monitor who doesn’t trust followers and creates bureaucratic structures (Owens, 2001). Recent studies have examined how different leadership styles influence employees’ behavior in e-business settings (Mackenzie, Podsakoff, & Rich, 2001; Jung, & Avolio, 2000; Thrite, 2000). However, there are no consistent answers regarding which leadership theory is the best. More specifically, the context of the organizations and the members within organizations determine which leadership theory is most effective (Holt, 1999; Mittler, 1999; Liedtka, 1999; Antrim, 1999; Sorenson, 2000; Cheung, Ng, Lam, & Yue, 2001).
7.3 Resources

Resources are referred to as money, tools and people that facilitate the change. Ely (1990) defined resources as “the things that are required to make implementation work” (p. 3). Some studies point out that many change projects fail due to shortage of resources or lack of preparation regarding the allocation of resources (Wilbur, 1999; Jayasuriya, 1999; Eshelman, Juras, & Taylor, 2001; Pipho, 1994).

In addition to money and tools, people play a crucial role in the change process because participation is required to facilitate change. There are several elements that encourage people to participate, including “advantage, compatibility, complexity, trainability, and observability” (Rogers, 1995, p. 15). In short, people are more likely to adopt an innovation if the innovation offers them a better way to do something, is compatible with their values and needs, is not too complex, can be tried out before adoption, and has observable benefits. Another factor that can support the change process is the communication channel, which is formed to spread new ideas from one individual to another in the system. The interpersonal channel is a face-to-face way of exchanging new ideas among individuals. The rate of adoption is increased when peers who are homogeneous in education background or social-economic status attempt to imitate the previous adopters. However, in most cases, the individuals within organizations are heterogeneous with respect to education background or social-economic status.

Although many organizations tend to avoid dealing with people when the change is undertaken, professional development (Benne & Chin, 1976; Orrill, 2001) can ensure people engage in an innovation successfully and retain interest in implementing it (Belasco, 1991; Senge, 1990). Professional development was shown to be a powerful tool
to combat resistance when the change is necessary within organizations (Suna, Hodges, & Sunal, 2001; Anderson, 2001, Barnes, Miller, & Dennis, 2001).

7.4 Obstacle and consequence

Fullan (1993) argued that problems are friends in the change process. Actually, problems mainly come from two sources. First, lack of resources might be one source of an obstacle. Another source of an obstacle is failure to take individual factors into consideration. Gardner (1981) described people’s habits, attitudes and beliefs as “mind-forged manacles” (p. 44) that can be extremely difficult to tackle. Although obstacles associated with lack of time or tools are prevalent in the literature, the biggest obstacle is resistance from people within organizations (Grow, 2001; Lakos & Gray, 2000; Bucci, 2000). Zaltman and Duncan (1997) identified eighteen resistance factors, comprising four major categories of barrier focused on increasingly smaller social units: cultural, social, organizational, and psychological (p. 61).

It is very important to examine consequences after an innovation is adopted or rejected. The impact of an innovation ranges from individuals within organizations to the societies outside organizations. Some impacts are positive, while some are negative. Impact is further categorized as desirable consequences versus undesirable consequences, direct consequences versus indirect consequences, and anticipated consequences versus unanticipated consequences (Rogers, 1995, p. 31). In terms of negative effects, Tenner (1996) proposed that “revenge effects” are the results of unintended consequences upon the socio-technical system at the end of implementation of innovation. Surry and Gustafson (1999) illustrated different effects to elaborate on societal revenge due to implementation of technology innovations such as assimilating effect, disintegrating
effect, repurposing effect, compressing effect, expanding effect, and obsolescence effect. Specifically, assimilating effect refers to lost power of technology within larger systems. Disintegrating effect means that a technological system is broken down into component parts. Repurposing effect refers to other purposes rather than the one that technology intends to achieve. Compressing effect means that technology is used in shorter segments then desired. Expanding effect causes technology to do more than intended without additional resources. Obsolescence effect brings a technological system to be kept in place that is outdated. Some studies have discussed benign consequences, unintended consequences, and societal consequences as a result of the implementation of educational technology (Hermann, Fox, & Boyd, 1999; Link, 1999; Monke, 1999; Bauer, Petkova, & Boyadjieva, 2000).

8. Summary

This chapter provided the background of reform in science education in the United States in the last two decades. This chapter also addressed several types of technology tools that are responsive to reform efforts. In addition, this chapter pointed out the challenges of elementary preservice teacher education and justified why the technology integration change process of SCIED 458 at Penn State is worthy of further examination. Change takes time and efforts; not all change can be sustained. Thus, the literature from the system and change theories was addressed.
Chapter 3 Methods of Inquiry

This study undertook qualitative research that employs case study research design. According to Bogdan and Taylor (1975), research design refers to the entire process of research from conceptualizing a problem to writing the narrative, not simply the methods of data collection, analysis, and report writing. The first part of the chapter contributes to building the rationale for qualitative research, followed by the justification of the selection of case study for this research. Data collection and data analysis methods are described. The researcher’s role is specified and strategies of trustworthiness are addressed.

1. Rationale for research design

Qualitative research was considered appropriate in this study for a number of reasons. First, the purpose of this study was to gain an in-depth understanding of the change process of technology integration into an elementary science methods course over the past six years. This study intended to explore what had happened in the process and how and why the process had evolved over time rather than explain relationships among variables. Denzin and Lincoln defined (1994) qualitative research as a “multi-method, involving an interpretive, naturalistic approach to its subject matter” (p. 2). The nature of an interpretive and naturalistic approach to the subject of interest leads researchers to understand it and, furthermore, to explore it (Bogdan & Biklen, 1982; Creswell, 1998; Marshall & Rossman, 1999; Merriam, 1998; Stake, 1995).

Second, the change process of technology integration into an elementary science methods course took place at an academic program within a college. To understand the complex change process requires consideration of contextual factors, such as the culture
of this science education program, types of technology tools used, relationships between technology use and science teaching and learning, and so on. In particular, in order to understand the change process, this study aimed at including perspectives of persons who were experiencing or had experienced the change process rather than having these persons receive treatments in a contrived circumstance that takes place at a specific time and a designated location. In short, qualitative researchers “study things in the natural setting, attempting to make sense of or interpret phenomena in terms of the meanings people bring to them” (Denzin & Lincoln, 1994, p. 2).

Third, as a researcher, I was the primary instrument of data collection and data analysis. Data collection and data analysis are not a linear process in qualitative research. I conducted the interviews and reviewed the relevant documents. By analyzing the transcripts, I was able to revise the interview questions, generate new interview questions, and raise further questions to the interviewees. By analyzing the documents, I was able to check what additional documents I should obtain. As the study evolved, I could clarify and summarize the findings. Finally, I presented the story about the change process from my interpretation and analysis of this case.

Qualitative and quantitative research draws on different philosophical orientations (Carr & Kemmis, 1986). Quantitative research is based on a different view about the nature of reality, the purpose of doing research, and the type of knowledge to be produced. In this study, the nature of the research questions attempted to explore a how or a what rather than a causal relationship that is sought in quantitative research. Specifically, qualitative research seeks to understand something that cannot be done experimentally. It works with a few cases and many variables that have yet to be identified. In contrast,
quantitative research seeks to explain something. It works with many cases and a few
variables that have been operationally defined (Ragin, 1987). Indeed, there is a fine line
between understanding and explanation. Finnish philosopher George Henrik von Wright
(1971) proposed an argument to distinguish these perspectives:

Practically every explanation, be it causal or teleological or of some other kind, can
be said to further our understanding of things. But “understanding” also has a
psychological ring which “explanation” has not. This psychological feature was
emphasized by several of the nineteenth-century antipositivist methodologists,
perhaps most forcefully by Simmel who thought that understanding as a method
characteristic of the humanities is a form of empathy or re-creation in the mind of
the scholar of the mental atmosphere, the thoughts and feelings and motivations, of
the objects of his study. (…) Understanding is also connected with intentionality in a
way that explanation is not. One understands the aims and purposes of an agent, the
meaning of a sign or symbol, and the significance of a social institution or religious
rite. This intentionalistic… dimension of understanding has come to play a
prominent role in more recent methodological discussion (p. 6).

Although there are numerous differences between qualitative and quantitative research,
I believe that both of them should complement each other rather than diminish each other.
In this study, qualitative research was selected because it strives for “illuminating the
inner dynamics of situations” and acknowledges the “legitimation of tacit knowledge
(e.g., intuitive, felt) and propositional knowledge (e.g., knowledge expressible in
language form)” (Lincoln & Guba, 1985, p. 11).

2. Case study

The term “case study” is prevalent in the literature, but no definite and precise
definition can be agreed upon among researchers. It also can be argued that every study is
a case study, further turning “case study” into a general terminology used widely in
research (Merriam, 1998; Stake, 1995; Yin, 1994). Although Creswell (1998) described
case studies as a tradition, I take the position suggested by Stake:
A case study is not a methodological choice, but a choice of object to be studied. We choose to study the case. We could study it in many ways (...). As a form of research, a case study is defined by interest in individual cases, not by the methods of inquiry used (p. 86).

Yin (1994) further explicated the definitions of a case study. First, a case study is “an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident” (p. 13). This study attempted to explore the change process of technology integration over the past six years. In other words, this study’s focus was on learning about phenomena that had happened in the past and continued to happen in the present. It was necessary to take various contextual factors, such as the culture of the science education program, into consideration because the change process cannot be separated from the context in which it has occurred.

Second, the case study inquiry “copes with the technically distinctive situation in which there will be many more variables of interest than data points, and as one result relies on multiple sources of evidence, with data needing to converge in a triangulating fashion, and as another result benefits from the prior development of theoretical propositions to guide data collection and analysis” (Yin, 1994, p. 13). This study drew on a number of data sources such as interviews and relevant documents. The preliminary data analysis from the transcripts and the documents guided me to conduct further interviews with new questions and obtain additional documents.

Based on the nature of the problem in research, the case can be used for two purposes: intrinsic or instrumental case study (Stake, 1995). Intrinsic case study focuses on the uniqueness of the case. The reason to study the case is because of the need to learn about
this particular case, not because of the intent to learn about other cases or about some
general problems. In the instrumental case study, the case is utilized instrumentally to
illustrate or gain insight into issues, concerns, or questions. The case in this study was
used instrumentally to understand and illuminate the factors or issues that were involved
in the change process of technology integration in educational settings.

In sum, this study was a descriptive, interpretive and analytical case study because the
overall intent of this study was to gather a thick and detailed description of the change
process of technology integration as well as “to develop conceptual categories or to
illustrate, support, or challenge theoretical assumptions held prior to the data gathering”
(Merriam, 1998, p. 38), that is, to identify essential factors or issues involved in the
change process and examine how these factors influenced each other.

3. Case selection

What can be considered as a case? A number of researchers (Miles & Huberman, 1984;
Smith, 1994; Stake, 1995) contend that the case is a “bounded system.” Miles and
Huberman (1984) think of the case as “a phenomenon of some sort occurring in a
bounded context” (p. 25). Be it a thing, a single entity, or a unit, it should be bounded by
time and place. In other words, the case is situated in a certain unique context or setting.
Specifically, this study could be defined as a case of technology integration in the context
of an elementary science methods course from 1997 to 2003.

Stake (1995) proposed that case study is the study of the particularity and complexity
of a single case, namely, coming to understand its activity within important circumstances.
Thus, the case study should be able to enhance, maximize, and optimize the
understanding of the case. In case study research, first, the case must be determined.
Second, sampling is done within the case. Specifically, the bounded system should be identified in advance. This case was selected based on two reasons. First, Fullan (2001) suggested that “moderately complex changes of innovation integration can take from 3 to 5 years, while larger scale efforts can take 5 to 10 years” (p. 52). The elementary science methods course, SCIED 458, had been ongoing over the past six years, 1997 to 2003. The six-year time period, suggested by Fullan, is a significant milestone to examine how the case had evolved.

In addition, a growing number of studies have discussed how to integrate technology into the reading, language arts, and math methods courses. For example, Schmidt, Merkley, Strong, and Thompson (1994) described how technology faculty and math faculty worked together to integrate technology into a reading and language arts course at Iowa State University.

Research studies regarding technology integration into elementary science methods courses are limited (Woodrow, 1994) and more attention should be addressed to this area in order to respond to the National Science Education Standards (National Research Council, 1996, 2000, 2001a, 200b) of recent years. Thus, the elementary science methods course, SCIED 458, at Penn State makes an appropriate case in this study.

4. Sampling

Because of the uniqueness of a single case, a purposeful (Miles & Huberman, 1994) sampling strategy was employed within the case. This study used the “criterion” sampling strategy suggested by Miles and Huberman (1994) to select the people to interview. The purpose of the criterion sampling strategy was to select persons who had experienced or were currently experiencing the change process. They included three
faculty members in the science education program, a former graduate student who participated in writing a science education reform grant proposal: Link-to-Learn grant, a former graduate student who taught SCIED 458, and two graduate students who were teaching SCIED 458. Dr. Donahue (pseudonym) had been in the science education program early before 1997 and had initiated a number of projects to reform SCIED 458. Dr. Zimmerman (pseudonym) had been in the program since 1997 and had demonstrated leadership on a number of innovative projects. Dr. Stoker (pseudonym) had been in the program since 1999 and had played an essential role in integrating technology into SCIED 458. As a former graduate student, Ms. Friedman (pseudonym) worked on a major Link-to-Learn grant proposal awarded by the Pennsylvania Department of Education in 1999, particularly focusing on the area of technology integration. As a former graduate student, Ms. Hess (pseudonym) was a SCIED 458 course instructor from 1998 to 2002. Ms. Aberdeen (pseudonym) had been a SCIED 458 course instructor from 2001 to 2003 and had studied how web-based portfolios enhanced science teaching for elementary prospective teachers. Mr. Bell (pseudonym) had been a SCIED 458 course instructor from 2001 to 2003 and had developed a project complemented by ANGEL™, a course management system at Penn State.

5. Data collection

5.1 In-depth interviewing

In-depth interviewing was one of the major data collection methods in this study. The primary purpose of conducting interviews is to obtain a special kind of information “in and on someone else’s mind” (Patton, 1990, p. 278). Because the change process in this study had been ongoing for six years, it is impossible to replicate the process;
therefore, interviewing people who had experienced or were experiencing the change process became an effective way to obtain information regarding past experiences. Semi-structured interviews were conducted and guided by a number of particular issues of interest. Interview questions consisted of specific, open-ended, and follow-up questions or comments to probe for elaboration (Merriam, 1998). The interviews were recorded by a digital voice recorder and transcribed verbatim by me. The data were triangulated with the data gathered from other sources, such as document reviews, to ensure the quality of the findings.

I employed a series of steps recommended by Creswell (1998) to design the procedure for the interviews. First, interviewees had been identified based on a purposeful sampling strategy: the criterion sampling (Miles & Huberman, 1994). The interviews were conducted one-on-one and were recorded by a digital voice recorder. The interview protocol was designed in advance to indicate interview questions and closing comments (see Appendix A).

Second, I contacted the interviewees via email and scheduled a time and a location in advance. For the interview timeline, I conducted the first round of the interviews in the order of Ms. Aberdeen, Dr. Stoker, Ms. Bell, Ms. Friedman, Ms. Hess, Dr. Donahue, and Dr. Zimmerman, depending on their availability. Except Ms. Friedman and Ms. Hess, I was able to interview the interviewees on site and present them a copy of the informed consent form (see Appendix B) to sign. Because Ms. Friedman and Ms. Hess moved to other states, I needed to call them in order to conduct the interview. I mailed them the consent form and a stamped envelope and asked them to return it to me before the interview took place. At the beginning of each interview, I briefly introduced the purpose
of this study and explained to them why they were important in this study. I informed
them that I would request a follow-up interview if I needed them to elaborate on or
clarify some points in the interview. I also allowed some time for them to ask questions.
The interviews took about 90 minutes each. I ended the interviews with the closing
comments that thanked the individual participant for his/her time.

Third, because the interviewees participated in the change process at different
periods of time, not all interview questions applied to each of them. I adapted the
interview questions in response to their experiences. For example, when interviewing Ms.
Friedman, I asked additional questions such as: ”What was the rationale for integrating
technology in the Link-to-Learn grant proposal?”

I conducted a second round of interviews with Dr. Donahue and Dr. Stoker. Other
interviewees often directed me back to Dr. Donahue for additional information when I
asked certain questions such as the extent to which SCIED 458 was integrated with
technology before 1997. Thus, I created an interview protocol that was tailored to his
experience (see Appendix C). The same situation was applied to Dr. Stoker. Other
interviewees referred back to her regarding her efforts in technology integration. Thus, I
decided to interview her again to learn more about her role in the change process (see
Appendix D). Conducting the interviews took about four months. The time interval
between first round and second round interviews was about two months. Table 1 details
the number of interviews, length of each interview, and pages of transcript.
Fourth, throughout the interviews, I used a variety of probing strategies to learn and clarify information. For example, when I asked Ms. Aberdeen to describe current technology integration projects, she seemed puzzled at first. Then I realized, based on my studies of documents, that I needed to provide the interviewees more examples such as the web-based portfolio, the probeware, and so on, based on my studies of the documents. In asking about the history of each project, I told the interviewees that they could think of when it started, why it was initiated, and how it had changed in terms of each technology project. That is what Rubin and Rubin (1995) called steering probes. I also summarized the interviewees’ answer for each question because I wanted to make sure that I did not misinterpret their statements. I found sometimes that could elicit more responses from the interviewees because the time I used to summarize the statements provided them opportunities to reflect on what they had said to me. That was another good strategy for
probing, called clarification probes (Rubin & Rubin, 1995). For example, I asked about when the web-based portfolio was started. Ms. Hess told me it was in the summer but did not tell me which summer. So I probed and asked additional questions to clarify the exact year. When I asked about the perceptions of the students of technology, she told me that she felt that the students were getting more comfortable. I probed and asked for more elaboration on this statement. She responded by giving me an example of the prospective teachers’ improved technological skills in creating the web-based portfolio throughout the semester. She also clarified that she was not certain if the prospective teachers’ conceptual understanding of teaching science and science learning improved so much as the technological skills. In addition, I followed up on Ms. Aberdeen’s answers about her role and duties by further inquiring about changes in the syllabi and the contribution of her research in the area of the web-based portfolio. At the end of each interview, I asked the interviewees to see if I missed anything that they thought was important or that would elicit other essential information.

5.2 Review of documents

Documents were the second source of data collection in this study. Merriam defined documents as “an umbrella term to refer to a wide range of written, visual, and physical material relevant to the study at hand” (1998, p. 112). Reviewing the relevant documents enabled me to get a big picture of the history of the change process in this study. I collected the documents produced during 1997 and 2003, including publications, presentations, the Link-to-Learn grant proposal, SCIED 458 syllabi, theses, dissertations, and the internet resources for the course (see Appendix E). Each type of document had different functions. The publications and presentations provided me information about
each participant’s research interest, how these participants collaborated on research studies, theoretical framework of technology integration in elementary science education and feedback of the prospective elementary teachers’ attitudes toward technology integration in SCIED 458. The Link-to-Learn grant proposal entailed detail on the differences of the design of SCIED 458 before and after the grant was awarded. The syllabi provided information regarding the assignments and activities related to technology integration in class. The theses helped me gain insight into the issues of technology integration in SCIED 458. In addition, the internet resources offered the names of the school districts where the science education program established the partnerships. These documents had a combined total of 987 pages that were used for initial and detailed document analysis.

6. Data analysis

Merriam (1998) suggested that researchers spend time managing the data during the early stages of the research. At the initial stage of data collection, I organized files by data sources (i.e., interview transcripts, document reviews). The interview transcripts were categorized by interview positions (i.e., faculty member, grant writer, former instructor, current instructor) in the order of interview time. The reviews of the documents were filed by sources (i.e., publications, presentations, syllabi, theses, dissertations) in the order of the time presented or published. In the course of data collection, I created other files by categories such as portfolios, science specific tools, and the role of each participant from initial analysis. This study adopted the procedures provided by Strauss and Corbin (1990) and Rubin and Rubin (1995) to analyze the data. The purpose of data analysis is to “organize the interviews to present a narrative that explains what happened
or provide a description of the norms and values that underlie cultural behavior” (Rubin and Rubin, 1995, p. 229).

NVivo™ is the qualitative computer software that I used in conducting the analysis in that it: (1) has the capability of incorporating the data in the form of texts, photos, sound, and diagrams, (2) enables me to retrieve or compare the codes across a number of sources, (3) allows me to create a theoretical model in an efficient manner based on the codes generated in the program (Richards and Richards, 1994). I take the same position about computer use in qualitative data analysis as Rubin and Rubin do. They indicated that:

The computer helps in grouping the coded data; it is fast and efficient and saves many, many hours of tedious work. But the computer cannot do the creative part of coding, such as setting up and modifying the categories and figuring out in what categories each segment of an interview belongs. Nor can the computer label ideas as concepts or recognize theme, compare the separate concepts, find subtleties in meaning, or follow up on comparisons or nuances (p. 241).

Figure 1 indicates the flow chart of data analysis. Initially, I read and reread the transcript word by word, sentence by sentence, and paragraph by paragraph. In the first step, using NVivo, I coded for time and project, along with time and roles of people in each transcript because those were two concepts that frequently showed up when I read the transcripts and documents. Table 2 is a list of start codes. The way I coded allowed me to describe the states of technology integration projects and roles of people at different periods of time from 1997 to 2003. It is essential to understand the chronological history of technology integration and roles of people when I looked for patterns and trends. Then I exported the file to Microsoft Word so that I could arrange the coded passages in time order.
Step 1:
Code for different periods of time and project categories and roles of people

Step 2:
Identify themes and trends and code for patterns, such as themes, cause/relationships or emerging constructs (e.g., initiating and influencing factors)

Step 3:
Reduce the data for analysis of trends and synthesize and summarize the data

Step 4:
Integrate the data into one analytical framework

Figure 1. Flow Chart of Data Analysis
Table 2. A Start List of Codes

<table>
<thead>
<tr>
<th>Code</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Time</strong></td>
<td></td>
</tr>
<tr>
<td>B97</td>
<td>Before 1997</td>
</tr>
<tr>
<td>SU97</td>
<td>Summer semester of 1997</td>
</tr>
<tr>
<td>FA97</td>
<td>Fall semester of 1997</td>
</tr>
<tr>
<td>SP98</td>
<td>Spring semester of 1998</td>
</tr>
<tr>
<td>FA98</td>
<td>Fall semester of 1998</td>
</tr>
<tr>
<td>SP99</td>
<td>Spring semester of 1999</td>
</tr>
<tr>
<td>FA99</td>
<td>Fall semester of 1999</td>
</tr>
<tr>
<td>SP00</td>
<td>Spring semester of 2000</td>
</tr>
<tr>
<td>FA00</td>
<td>Fall semester of 2000</td>
</tr>
<tr>
<td>SP01</td>
<td>Spring semester of 2001</td>
</tr>
<tr>
<td>FA01</td>
<td>Fall semester of 2001</td>
</tr>
<tr>
<td>SP02</td>
<td>Spring semester of 2002</td>
</tr>
<tr>
<td>FA02</td>
<td>Fall semester of 2002</td>
</tr>
<tr>
<td>SP03</td>
<td>Spring semester of 2003</td>
</tr>
<tr>
<td><strong>Project</strong></td>
<td></td>
</tr>
<tr>
<td>WP</td>
<td>Extent of the use of web-based portfolio in class</td>
</tr>
<tr>
<td>SM</td>
<td>Simulations and modeling tools</td>
</tr>
<tr>
<td>OC</td>
<td>Online collaborative tools</td>
</tr>
<tr>
<td>OD</td>
<td>Online discussion boards</td>
</tr>
<tr>
<td>DC</td>
<td>Data collection tools</td>
</tr>
<tr>
<td><strong>Role</strong></td>
<td></td>
</tr>
<tr>
<td>CI</td>
<td>SCIED 458’s course instructor</td>
</tr>
<tr>
<td>CC</td>
<td>SCIED 458’s course coordinator</td>
</tr>
<tr>
<td>LI</td>
<td>Liaison between the science education program and the school districts</td>
</tr>
<tr>
<td>LR</td>
<td>Lead researcher of SCIED 458</td>
</tr>
</tbody>
</table>
For example, when I worked on Dr. Zimmerman’s transcript, I identified and labeled time and the project category of the web-based portfolio (see Appendix F). I proceeded to code other transcripts, research articles, conference papers, syllabi and the internet resources in the same manner. Then I retrieved all the passages with a combination of time period and the web-based portfolio project and exported the file to Microsoft Word. I rearranged the exported passages in time order (see Appendix G). I was able to learn the state of the web-based portfolio in different periods of time, drawing on multiple sources of data. Then I went through the same procedure with different project categories, including simulation and modeling tools, online collaborative tools, online discussion boards, and data collection tools. At this point, I was able to describe the evolution of technology integration from 1997 to 2003 (see Appendix H). Creating a time series analysis strategy was also supported by Yin (2003) as specific data analysis strategies in a case study. In the same procedure, a matrix that details the roles of each interviewee during different periods of time in the change process is presented in Table 5 in Chapter 4. This step is referred to as open coding (Strauss and Corbin, 1990). Rubin and Rubin (1995) defined coding as:

The process of grouping interviewees’ responses into categories that bring together the similar ideas, concepts, or themes you have discovered, or steps of stages in a process. You can code for names, evidence, or time sequences. You can also code for hesitation, blocking, signs of emotion, and indications of fear or amusement. In fact, you can code on anything you think may later help you analyze the data. You can use several schemes in combination if you wish. And you can recode the data as often as you please (p. 238).

Although NVivo assisted me in coding transcripts and documents, it was not able to
generate the coded passages in the order of time, which was a great challenge for me. NVivo was helpful in coding the data in the initial stage. Yet from this study I found it was weak in organizing the data in time order.

In the second step, I examined the matrix (see Appendix H) and looked for trends and patterns of technology integration. There are a number of trends in this matrix. Before 1997, it seemed that a number of technology tools were tried in class and then were not able to continue. The portfolio had evolved from the paper portfolio, to the electronic portfolio, and then to the web-based portfolio with a different organization. The data collection tools, such as Vernier probes, came into the course during 1997 and 1998 and then were integrated into the course again in 1999 along with simulations, modeling tools and online collaboration tools. In addition, online collaboration tools were tried during 1997 and 1998 and were integrated into the course again in 2001. Online discussion boards stayed in the course for a while and then were dropped out of the course. In recent years, a number of emerging interactive web sites were used in class. In addition, the roles of the people during different periods of time seemed to have influence on the evolution of technology integration in the change process. Following these trends, I reflected on the research questions in this study and proceeded to examine the factors that initiated, facilitated, and sustained the changes by coding for themes, causes / explanations, relationships among people, or emerging constructs (Miles & Huberman, 1994). Thus, I generated another list of pattern codes to code the data. Appendix I shows an example of coding for the formation of research community using code FIRES.
Table 3. A List of Pattern Codes

<table>
<thead>
<tr>
<th>Code</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>IF</td>
<td>The factors that initiated the technology integration projects at different periods of time from 1997 to 2003</td>
</tr>
<tr>
<td>IFPL</td>
<td>People factors, such as faculty interest</td>
</tr>
<tr>
<td>IFG</td>
<td>Grant factor</td>
</tr>
<tr>
<td>IFOTH</td>
<td>Other initiating factors</td>
</tr>
<tr>
<td>FI</td>
<td>The factors that facilitated or inhibited the technology integration change process</td>
</tr>
<tr>
<td>FISOPH</td>
<td>Emerging sophisticated technologies</td>
</tr>
<tr>
<td>FIRES</td>
<td>Availability of resources</td>
</tr>
<tr>
<td>FITRAIN</td>
<td>Technology training job</td>
</tr>
<tr>
<td>FITEAM</td>
<td>Team work</td>
</tr>
<tr>
<td>FIRES</td>
<td>Research within the context of SCIED 458</td>
</tr>
<tr>
<td>FIASSIGN (FITWI &amp; FISTEPS)</td>
<td>Assignments that supported technology integration, such as Teaching with Technology in Field Experience, and STEPS Days</td>
</tr>
<tr>
<td>FIEXDIST</td>
<td>External environment that influenced the technology integration change process, such as school districts</td>
</tr>
<tr>
<td>FIEXEDU</td>
<td>External environment that influenced the technology integration change process, such as state’s department of education</td>
</tr>
<tr>
<td>FIEXACCR</td>
<td>External environment that influenced the technology integration change process, such as accreditation agencies</td>
</tr>
<tr>
<td>FIEXSOFT</td>
<td>External environment that influenced the technology integration change process, such as software companies</td>
</tr>
<tr>
<td>PT</td>
<td>Elementary prospective teachers’ attitudes toward technology</td>
</tr>
</tbody>
</table>

In the third step, I reduced, summarized, and synthesized the data. The first step assisted me in describing the extent of technology integration during different periods of time from 1997 to 2003. The second step assisted me in aggregating the data and understanding what initiated and influenced the change process. If there were any
contradictory concepts, I reconciled by giving more weight to the persons that had stayed in the science education program longer and participated in the change process directly. This step is referred to as axial coding (Strauss & Corbin, 1990). In this step, I formed overarching themes by linking technology integration initiatives and different types of factors that emerged from the data analysis (see Appendix J). For example, Appendix H shows that since 1997, a number of technology initiatives had been tried in class. By looking at possible factors that influenced the change process, the data analysis indicated that faculty interest played a positive role in initiating it. That is how the claims are derived from the data analysis process that is presented in Chapter 5.

In the fourth step, I integrated the data into exploratory framework. I reflected on the theoretical framework in this study and categorized the change process into different stages by matching different characteristics of each stage (see Appendix J). I also analyzed the factors (see Appendix K) and interrelationships between the factors (see Appendix L). I combined what had occurred in different stages of the change process and the factors that were involved in it and developed the theoretical propositions to construct a conceptual framework of technology integration. Throughout the analysis process, I revisited the data frequently to confirm the concepts and themes grounded in the data. I routinely checked the data to ensure that no further ideas needed to be brought up. Table 4 indicates types of the data that answered each research question in this study.
Table 4. Data and Research Questions

<table>
<thead>
<tr>
<th>Research Question</th>
<th>Transcripts</th>
<th>Documents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td>Transcripts of Dr. Zimmerman, Dr. Donahue, Dr. Stoker, Ms. Aberdeen, and Mr. Bell</td>
<td>Publications, presentation, and syllabi</td>
</tr>
<tr>
<td>Q2 Q2a</td>
<td>Transcripts of Dr. Zimmerman, Dr. Donahue, Dr. Stoker, Ms. Friedman, Ms. Hess</td>
<td>Link-to-Learn grant proposal, publications, presentations</td>
</tr>
<tr>
<td>Q2b</td>
<td>Transcripts of Dr. Zimmerman, Dr. Donahue, Dr. Stoker, Ms. Friedman, Ms. Hess, Ms. Aberdeen, and Mr. Bell</td>
<td>Publications</td>
</tr>
<tr>
<td>Q2c and Q2d</td>
<td>Transcripts of Dr. Zimmerman, Dr. Donahue, Dr. Stoker, Ms. Friedman, Ms. Hess, Ms. Aberdeen, and Mr. Bell</td>
<td>Publications, presentations, thesis, syllabi, internet resources, and Link-to-Learn grant proposal</td>
</tr>
</tbody>
</table>

I also tried to present the findings in a broader context of the literature and theory in my field and to think about the implications of the data. Finally, I wrote up a research report that discusses how the findings contributed to modifications, extensions, or revisions of systems and change theories.

7. The researcher’s role

This part entails the researcher’s role in terms of technical considerations (Marshall & Rossman, 1999), ethics, and personal biography. For technical considerations, I was able to identify the potential participants to interview through the professor in charge of the science education program. When conducting the interviews, I revealed the purpose of this study to the participants in advance.

Taking ethics into consideration, I provided a copy of the informed consent form to
each participant to ensure the anonymity and the rights as a volunteer participant before I conducted the interviews. Kimmel (1988) suggested that researchers should consider possible consequences of the research before taking it, present results with as little distortion as possible by providing quotes and using triangulation, and take special care in disseminating results in order to cover the issues related to ethics. Thus, I used pseudonyms to describe the participants in writing up the findings.

Next is a discussion about my educational experiences that contributed to shaping the theoretical orientation I took in this study. I had been a supervisor of elementary education field experience in the Department of Curriculum and Instruction from 1999 until present. I was aware that the science education program within this department had reconstructed the science methods course, SCIEd 458, and integrated technology into it because my students were required to implement several science lessons into their classrooms in the field experience. Although I was not engaged in the development of the course, I had a sense that the course structure had continued because the students were required to meet similar requirements for SCIEd 458 every semester, including teaching science lessons integrated with technology, and creating web-based portfolios. I believed that studying the sustainability of the change process was a topic worthy of pursuing for two reasons. First, studying this case enhanced understanding of the change process of implementing technology into a course in educational settings. Since the case has sustained for six years, this period of time is of significance for me to examine (Fullan, 2001). Second, this case contributed to gaining insight into technology integration in a science methods course. There had been a growing number of studies discussing how to integrate technology into the reading, language arts, and math methods courses (Schmidt,
Merkley, Strong, and Thompson, 1994; Woodrow, 1994). But researchers need to pay more attention to science education due to the reforms in recent years.

My major is Instructional Systems, and I took several courses that addressed systems theory. From a systemic view, the instructional system is not limited to planning and development processes of instructional design alone. The instructional system is an open system that interacts with the educational system and is an interdisciplinary subject matter that integrates psychology, communication, education, and computer science. Recently, systemic adoption of instructional innovations and systemic changes due to innovations had become a major issue of discussion. Systems theory provides a comprehensive perspective for educators to foresee the resistance to change and enables them to understand the complexity of the educational system. There were a number of theoretical frameworks that explored the roles of people, leadership, resources, technology, and obstacles in the change process (Belasco, 1991; Ely, 1990; Evans, 1996; Rogers, 1995). Few empirical studies were conducted from the perspective of systems theory. Based on the prior experience with systems theory, I intended to examine how these elements interacted within the context of this study.

Based on my personal experiences, there were potential biases that might influence the findings. I might assume that SCIED 458 is already a successful case, and there is a mechanism to sustain the change process because I had worked in the department and observed prospective students teaching science lessons enhanced by technology for four years. It probably hindered me investigating what SCIED 458 had been undergoing over time, particularly the negative aspects. I was aware of the biases and tried to work on them when I analyzed the data.
Miles and Huberman (1994) discussed two types of biases: (1) the effects of the researcher on the case and (2) the effects of the case on the researcher. Most researchers experience type 2 biases more frequently than type 1. They listed a number of ways of avoiding biases that I used in the data collection and data analysis. First, avoid the elite bias by spreading out the informants (Miles & Huberman, p. 266). I sampled the participants who participated during different periods of time in the course of the change process. These participants’ roles varied; they included faculty members and course instructors. Second, consider finding an informant who agrees to provide background and historical information and collect information when the researcher is off-site. In this study, a number of participants volunteered to provide the background and collected documents for me. Third, triangulate with several data collection methods. I did not overly depend on one source of data. I interviewed the participants and collected relevant documents, which are the two major sources for the data collection and data analysis. Fourth, do not casually show off how much you do know. I asked open-ended questions in interviews to avoid misleading the interviewees. I adopted a number of strategies to probe their answers. Fifth, show the field notes to a colleague. I met with my advisors on a regular basis to discuss the ways that I collected and analyzed the data. Working with two other colleagues helped reduce biases because they asked questions to assist me clarifying why I collected and analyzed the data in a certain way.

8. Issues of trustworthiness

Trustworthiness is concerned with valid and reliable knowledge from conducting qualitative research. As Stake (1995) asked, “Did we get it right?” Validity and reliability are common terms in quantitative studies when the quality of the studies is discussed. In
qualitative research, credibility, transferability, dependability, and confirmability are the criteria used to evaluate the quality of qualitative studies (Lincoln & Guba, 1985). A number of strategies are suggested to assist researchers in achieving these criteria. The following paragraphs explicate how strategies were used to meet these four criteria in this study.

Credibility intends to examine if researchers capture valid, accurate and complete data in regards to what they see and hear; that is, they need to understand the perspective of the people studied and the meaning the participants attach to their words and actions. Among the strategies suggested by Lincoln and Guba (1985), this study adopted triangulation, member check, and peer debriefing to ensure this criterion had been met. The purpose of triangulation is directed at judging the accuracy of data. Multiple data sources, such as interview transcripts and document reviews including research articles, conference papers, grant proposal, syllabi, and internet resources, were compared to confirm the emerging findings (triangulation). In addition, interview transcripts and document reviews were brought back to the persons who participated or generated them to see if the interpretation was correct and the results were plausible (member check). I emailed the interpretation and the results back to the participants for checking. Member checking intends to judge overall credibility. In peer debriefing, I consistently shared the emerging findings with dissertation advisors and explained to them my thinking process. In other words, I made explicit the decision process regarding how I interpreted the data and generated the findings; therefore, they had opportunities to examine if there were any flaws in the process, such as imposition of my meaning on the findings.

Transferability is concerned about the extent to which the findings of one study can
be applied to other situations. Patton (1990) purported that:

Qualitative research should “provide perspective rather than truth, empirical assessment of local decision makers’ theories of action rather than generation and verification of universal theories, and context-bound extrapolations rather than generalizations” (p. 489).

Therefore, thick description provides necessary information to reach a conclusion about whether transfer could be considered as a possibility. The decision of transfer is decided by the reader, not the researcher. My role was to provide very detailed descriptive data to support readers’ decision making. Thus, other researchers would look into the findings in this study and examine how these findings informed their plans to integrate technology in a different context.

Dependability and confirmability refer to the extent to which the research process can be replicated. I kept a reflexive journal on a daily basis at the stages of data collection and data analysis. The journal consisted of: (1) the daily schedule and logistics of the study, (2) a personal diary that provides opportunities for reflection on what is happening in terms of my own values, interests, and biases, and (3) a methodological log with methodological decisions and rationale (see Appendix M).

I used the “critique checklist” suggested by Stake (1995, p. 131) to assess the quality of the report of this case study:

1. Is the report easy to read?
2. Does it fit together, each sentence contributing to the whole?
3. Does the report have a conceptual structure (i.e., themes or issues)?
4. Are its issues developed in a serious and scholarly way?
5. Is the case adequately defined?
6. Is there a sense of story to the presentation?
7. Is the reader provided some vicarious experience?

8. Have quotations been used effectively?

9. Are headings, figures, artifacts, appendixes, and indexes used effectively?

10. Was it edited well, then again with a last-minute polish?

11. Has the writer made sound assertions, neither over-nor under-interpreting?

12. Has adequate attention been paid to various contexts?

13. Were sufficient raw data presented?

14. Were data sources well chosen and in sufficient number?

15. Do observations and interpretations appear to have been triangulated?

16. Is the role and point of view of the researcher nicely apparent?

17. Is the nature of the intended audience apparent?

18. Is empathy shown for all sides?

19. Are personal intentions examined?

20. Does it appear that individuals were put at risk? (Stake, 1995, p. 131)

Overall, the use of triangulation, member check, peer debriefing and thick description ensured validity of this study. Reliability was taken care of by the use of a log that recorded the logistics of this study, my reflections, methodological decisions and rationale.

9. Summary

In this chapter, I described how this study undertook qualitative research that employed case study research design. I used the criterion sampling strategy to select the people to interview. I collected the data by conducting in-depth interviews and reviewing the documents. I also provided a number of strategies that assisted me in data analysis and
different phases in the data analysis process. I identified my role in this study and addressed ways to avoid bias. I concluded this chapter by illustrating the strategies to ensure validity and reliability of this study.
Chapter 4 Context

This chapter provides descriptions of SCIED 458, the key members, and different types of technology tools to put the reader in context to make better sense of what had occurred in this case from 1997 to 2003. Because SCIED 458 had been transformed in a number of ways in the past six years, I briefly introduce the course and its fit into the elementary education curriculum in this chapter. Then I provide descriptions of different types of technology, the software, what it allows people to do, and how these technology tools were used in context.

1. SCIED 458

SCIED 458, Teaching Science in the Elementary School, is a required course before student teaching for Elementary and Kindergarten Education majors in the Department of Curriculum and Instruction at the Pennsylvania State University. The course is taken concurrently with MTHED 420 (mathematics methods course), SS ED 430W (social studies methods course), CI 495B (Elementary Education Field Experience) as a part of a block of courses called the Disciplined Inquiry Block (DI Block) that takes twelve hours per week. On average, there are six to seven sections offered each semester. Some sections are in the morning and some are in the afternoon. About thirty elementary prospective teachers are enrolled in each section. Each instructor from the science education program is responsible for teaching one to two sections.

2. The roles of key members

In this study, there were seven key members. Although I explained the criteria for selecting the participants in chapter three, it is necessary to point out when the key members entered the change process and how they shifted their roles in the change
process. Table 5 indicates the key players, when they entered the change process, and what their roles were at different times.
Table 5. The Roles of Key Members

<table>
<thead>
<tr>
<th>Year</th>
<th>Dr. Zimmerman</th>
<th>Dr. Donahue</th>
<th>Dr. Stoker</th>
<th>Ms. Hess</th>
<th>Ms. Friedman</th>
<th>Ms. Aberdeen</th>
<th>Mr. Bell</th>
</tr>
</thead>
</table>
| 97-98 | • course instructor  
|       | • course coordinator  
|       | • lead researcher     | • course instructor  
|       | • course instructor (on-campus and PDS)  
|       | • course coordinator  
| 98-99 | • lead researcher     | • course instructor  
|       | • course instructor  
|       | • course coordinator  
| 99-00 | • lead researcher     | • course instructor  
|       | • course instructor (PDS)  
|       | • course coordinator  
| 00-01 | • lead researcher     | • course instructor  
|       | • course coordinator  
| 01-02 | • lead researcher     | • student teaching supervisor  
|       | • course instructor  
| 02-03 | • lead researcher     | • course coordinator  
|       | • course instructor  
|       | • student teaching supervisor  

- Dr. Zimmerman: • course instructor  
- Dr. Donahue: • course instructor  
- Dr. Stoker: • course instructor  
- Ms. Hess: • course instructor  
- Ms. Aberdeen: • course instructor  
- Ms. Friedman: • course instructor  
- Mr. Bell: • course instructor  
- Ms. Aberdeen: Graduated  
- Ms. Friedman: Graduated  
- Ms. Hess: Graduated
2.1 Dr. Zimmerman

Dr. Zimmerman (pseudonym) joined the science education program as an assistant professor in May of 1997, the first year in the change process. She graduated from a specialized science education program that used technology extensively. In her previous program, the elementary prospective teachers were expected to teach science with technology; thus, her expertise lay in that area. She described how past experiences shaped her research interest and teaching:

(...) It [teaching science with technology] is just very much a part of who I am. So I cannot imagine it[teaching science with technology] would not be a fundamental influence on the work that I do.

Dr. Zimmerman had played a variety of roles from 1997 to 2003 as shown in Table 5. During 1997 and 1998, she taught SCIED 458. She co-taught SCIED 458 with Dr. Donahue in summer 1997, which was her first semester at Penn State, and with Ms. Hess in summer 1998, the last time the course was offered in summer. During 1998 and 1999, the professional development school (PDS) partnerships started. She taught SCIED 458 in the PDS program and on campus at the same time. She described that it was a difficult time for her because the PDS program was very intensive and had different needs from the regular on-campus program. Since 1999 she had been teaching in the PDS program.

During 1997 and 2001, Dr. Zimmerman was in charge of coordinating SCIED 458. She held regular meetings with the graduate students who taught a particular section. After the fall semester of 2001, she was not in charge of coordinating the class but served as a consultant.

Dr. Zimmerman had been a lead researcher in the context of SCIED 458, working with the graduate students to study their own practices in that course. For instance,
she taught a graduate course on technology tools for sciencing. As indicated in Figure 2, the technology integration model synthesized from the graduate-level course in 1998 guided the integration of technology in the next few years. “The technology integration model provided a valuable framework for planning teacher education curriculum and experiences,” she said as she reflected her technology interest in her own classroom teaching experience and research agenda.

Figure 2. Technology Integration Model

Dr. Zimmerman had brought numerous major changes not only in technology integration but also in the overall design of the course. She believed that science teaching and learning was an iterative process. She was very instrumental in introducing that into SCIED 458:

There was a great deal of preparation involved to better assess children’s prior knowledge such as through interviewing. In order to explore one set of ideas in depth, the prospective teachers were instructed to develop the mini units taught over multiple days. Then, they needed to consider how to integrate technology wherever appropriate to enhance their science lessons. The last came with
reflective analysis piece.

2.2 Dr. Donahue

Dr. Donahue (pseudonym) had been in the science education program for a number of years before 1997. He was promoted to associate professor in 1998. He had worked in the science education program as a course instructor and had been the coordinator of the teacher education program in the Department of Curriculum and Instruction.

During 1997 and 1998, Dr. Donahue and Dr. Zimmerman were the key persons who began to work on restructuring SCIED 458. During 1998 and 1999, he co-authored the Link-to-Learn grant proposal with Dr. Zimmerman and a graduate student, Ms. Friedman. When the grant was awarded by the Pennsylvania’s Department of Education in 1999, he was the co-director of the technology integration project. During 2001 and 2003, he was not directly involved in SCIED 458 as much as before because of other duties in the department such as helping other faculty members in other subject areas to integrate technology and persuading the College of Education to make better use of technology resources in place. But he was connected to SCIED 458, kept an eye on what happened in that course, and helped out when he could.

His philosophy of restructuring SCIED 458 was to provide more opportunities for the prospective teachers to see what types of science specific technology tools were available to them and how to integrate technology in a meaningful way in science teaching and learning. He was proud that SCIED 458 had strived to achieve the goal with efforts of the key members over the years. He said, “I think that SCIED 458 gives our candidates much more of the advantages over other candidates from other schools….We had some good evidence that we helped the prospective teachers
2.3. Dr. Stoker

Dr. Stoker (pseudonym) was a doctoral student in the science education program and graduated in 1998. Then she returned to the elementary school where she had been employed. She joined the science education program on the Link-to-Learn grant in 1999, the third year in the change process, as liaison between the program and the local elementary school districts as shown in Table 5. In 1999, she worked with a number of elementary schools where the elementary prospective teachers were placed in their field experience. When the prospective teachers wanted to use technology tools, such as the probes, Science Court, or computers, and could not locate them in their school, she delivered those tools for them to teach technology-enhanced science lessons in the field experience classrooms. The next year, 2000, she did less of that because a partnership between the science education program and a local school district was established.

During 2001 and 2003, Dr. Stoker partnered with this school district and became the field experience and student teaching supervisor. She was also the course coordinator for SCIED 458, holding weekly seminars with the instructors and serving as mentor for new instructors. She had been a course instructor since 1999.

Dr. Stoker pointed out that it was a great advantage to have consistency in a position over time. She had been in the program for a few of years as an instructor, thus providing her time to look at the course more critically. Her explanation was that people were caught up in the organization and the administrative details as a novice instructor. By the time she was in the third or fourth year, she could start to examine more closely what helped the elementary prospective teachers learn and then focus on teaching, which was the biggest thing she noticed. She added:
This is my class. I am really trying to improve it. … This is my most important thing to do today. I am going to do it well. It is taking more pride, or more ownership, or more concern for what is really happening in the course.

2.4 Ms. Hess

Ms. Hess (pseudonym) pursued her master degree in agriculture before she joined the science education program in the summer semester of 1998 as a doctoral student. She graduated in the fall semester of 2001. She had been a course instructor during this period of time. In 1998, her major responsibility was to co-teach SCIED 458 with Dr. Zimmerman. Furthermore, she conceptualized the web-based portfolio with Dr. Zimmerman, planned how to integrate the portfolio into the design of the course, and trained the prospective teachers to learn Claris HomePage to create the web-based portfolio. “SCIED 458 is a highly-reflective course….We are constantly trying to implement changes that make this experience better and more powerful for the prospective teachers,” she said as she reflected on teaching SCIED 458.

2.5 Ms. Friedman

Ms. Friedman (pseudonym) joined the science education program in 1998 as a doctoral student. Her major role in the change process was to co-author the Link-to-Learn grant proposal for technology integration in 1998 with Dr. Zimmerman and Dr. Donahue. That was the first grant proposal she had ever participated in. Although she was not involved in any activities related to SCIED 458 after the grant was awarded by the the Pennsylvania’s Department of Education, she was active in a multitude of research projects in the science education program and implemented grant activities at the secondary level (grades 7 to 12). She believed that the technology integration model (Figure 2) guided the organization of technology integration into the design of SCIED 458.
2. 6 Ms. Aberdeen

Before 1999, Ms. Aberdeen (pseudonym) had been an elementary science teacher in another country. She came to Penn State in 1999 to pursue her master degree and then Ph.D. degree in science education. Between 1999 and 2001, she had been very active in the science education program, such as managing hardware and software in the science education program’s computer laboratory. She had been a course instructor since 2001. She developed her research agenda within the context of SCIED 458 and worked closely with Dr. Zimmerman. Ms. Aberdeen was interested in the efficacy of the web-based portfolio in helping the prospective teachers reflect on their teaching. Her master and doctoral theses were based on this area. While reflecting on the purpose of SCIED 458, she said:

As far as the use of probeware and science specific software used in instruction, the prospective teachers usually respond positively to those and are enthusiastic about their use as a different way of representing knowledge but also as a way of making learning fun and interesting especially to young learners.

2.7 Mr. Bell

Mr. Bell (pseudonym) was a science educator in a local school district before he joined the science education program in 2001 at Penn State. He had been a course instructor since then. “If the elementary prospective teachers do not use technology in their prestudent teaching and maybe student teaching, they are not going to take it with them and see it as a valuable resource,” he said as he described that SCIED 458 provided them an opportunity to teach science with technology.

Mr. Bell was interested in how an online collaborative learning environment changed the prospective teachers’ beliefs in science learning and teaching. He took Dr. Donahue’s suggestion and built an online collaborative environment in ANGEL, a
classroom management system at Penn State, to engage the prospective teachers in a long-term inquiry-based investigation project. His dissertation will pursue this line of research.

I identified seven key members in the change process and described their beliefs in integrating technology in science teaching and learning. They included Dr. Zimmerman, Dr. Donahue, Dr. Stoker, Ms. Hess, Ms. Aberdeen, and Mr. Bell, and Ms. Friedman.

3. Overview of technology tools

In this part, I provide an overview of the definitions of types of technology tools, such as science specific tools, the web-based portfolio, online discussion boards, and processes. Specifically, I provide a description of the software and what it allows people to do. In addition, I describe how they were used in SCIED 458.

3.1 Definitions of science specific tools and processes

3.1.1 Definitions

In this section, I describe why science specific tools are different from general productivity tools. Then I provide descriptions of each type of technology and their processes.

Dr. Zimmerman and Dr. Donahue gave careful attention to why they categorized technology tools as science specific tools and general productivity tools. Science specific tools were designed to enhance science learning. Dr. Zimmerman distinguished two types of technology tools:

So we have these two categories of tools - general productivity tools and science specific tools. In SCIED 458, our aim has been to introduce science specific tools to prospective teachers and ultimately use them to support students’ science learning. We do not spend time teaching people how to use Microsoft Word, spreadsheets or PowerPoint.
Dr. Donahue illustrated a non-example of using the general productivity tool in science learning:

At another university in Pennsylvania, they had a Link-to-Learn project also. They also had PT3 project. I went to one of their sessions to see what they were doing. They were teaching people how to use Word. I sat there saying, “How is that going to help?”...I just kept thinking it is great you can change the font size, insert the graphic, and make a nice worksheet. That was not very helpful to use these tools to teach children to learn mathematics, help them learn science, help them learn reading and other literacy skills.

<table>
<thead>
<tr>
<th>Learning to Teach (Science)</th>
<th>Three levels that prospective teachers went through</th>
<th>Science Specific Learning Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>Online discussion tools(CourseInfo)</td>
<td>1. Learning science with technology as a learner</td>
<td>Data collection tools (the PASCO probes)</td>
</tr>
<tr>
<td>Web-based portfolio</td>
<td>2. Planning and teaching science with technology in STEPS Days</td>
<td>Simulation and modeling tools (Tom Snyder Science Court)</td>
</tr>
<tr>
<td></td>
<td>3. Independent teaching in field experience classrooms</td>
<td>Online collaborative tools</td>
</tr>
</tbody>
</table>

Figure 3. Integration of Technology in SCIED 458

As indicated in Figure 3, there are three strands of science specific learning tools: data collection tools, simulations and modeling tools, and online collaborative tools.

Data collection tools facilitate data collection process as the Link-to-Learn grant proposal described:

The prospective teachers are able to efficiently and accurately collect data points in real time. The robustness of spreadsheet functions allows them to perform multiple analyses of the data set in a relatively brief period of time.

PASCO is one of the probeware manufacturers. SCIED 458 adopted PASCO Science Workshop probeware and PASPORT. Thirteen different types of probes, including temperature, voltage, sound, and motion sensors, were available for class.
Simulations and modeling tools enable people to focus on exploration and representation of scientific processes and conceptions. The grant proposal described:

Students in a laboratory might use a simulations or modeling program to formulate hypotheses, create simulations, and run experiments that may normally require equipment and resources not readily available.

The science education program purchased a suite of programs, Science Court, from Tom Snyder. Available resources for the course included eight different Science Court programs (electric current, friction, living things, magnets, pendulums, seasons, water cycle, work and simple machines). Science Court was a loose example of simulations and modeling tools.

Online collaborative tools were intended to create a learning community that people can share resources and explore scientific phenomena with communities beyond the confine of their own classrooms as the grant proposal described, “Online collaborative tools allow students to collaborate beyond classroom walls to collect, share, and interpret data with children and scientists around the world.” GLOBE and ANGEL were two examples. The Global Learning and Observations to Benefit the Environment (GLOBE) Program (www.globe.gov), initiated by Vice President Al Gore in 1994, is a hands-on international environmental science education program that establishes a partnership between students, their teachers, and the scientific research community. ANGEL is a classroom management system developed by Penn State in recent years.

3.1.2 Processes

Figure 3 specifies how these three strands were used in three levels in SCIED 458. Each strand had three scaffolded levels: 1. Prospective teachers experienced technology-rich science as learners. 2. Prospective teachers taught children using
exemplary science curriculum infused with appropriate technology under the
guidance of the methods instructor in STEPS Days. 3. In their field experience,
prospective teachers taught technology-enhanced science lessons using technology
resources from either the TEST lab and Resource Center or from their field
experience site.

In level one, the prospective teachers had to become acquainted with the
technology at the beginning of the semester. At this point in the semester, the science
education instructors introduced them to the two types of software, Science Court and
PASCO Science Workshop probeware, by setting up various stations for the duration
of one their science methods classes. As the prospective teachers progressed through
the stations, they experienced direct inquiry lessons that were integrated in the
software.

In level two, after briefly experiencing these concepts as learners, the prospective
teachers chose one concept exhibited by the software, and as an instructional team of
three or four, prepared a lesson to be used with visiting elementary students. Along
with the technology, the prospective teachers were required to include a hands-on
activity to help elementary students learn a science concept.

During one four-hour class, the prospective teachers within an instructional team
designed a lesson. They also taught the lesson to their peers, plus then reflected and
revised their lessons. After clarifying other organizational details, they were ready to
host visiting elementary students and team-teach a technology enhanced science
lesson.

They taught during an event called STEPS (Science and Technology Experiences
at Penn State) Days. Five classes (20-35 students) of elementary students (grades 2, 3,
4, 5-6) and their teachers and chaperones from schools within a 35-mile radius of
Penn State, visited the five elementary science methods classes. Upon arrival, students were divided into small groups of two to four students. In those groups, the students traveled through three different technology-enhanced science stations. On the average, the student-to-teacher ratio was one-to-one with three to four teachers and two to four elementary students. Time at each station was between 25-35 minutes. Each prospective teacher experienced one of three roles as students rotated: teacher, observer, and manager. Technology used included the temperature, sound and motion probeware in addition to the Science Court water cycle, living things, and magnets. As mentioned before, the concepts were chosen by the visiting teachers.

In level three, the prospective teachers were required to design, teach and reflect on technology-enhanced science lessons during their field experiences near the end of the semester. The cooperating teachers and the prospective teachers spent their time exploring the software and discussing how the lesson would take shape within the classroom. The prospective were more knowledgeable about the technology, while the practicing teachers were more knowledgeable about classroom management techniques and strategies. The prospective teachers integrated his or her particular school’s existing technology into the school’s current curriculum. Resources from the university were available to them, including hardware and software.

3.2 Definitions of online discussion boards and the web-based portfolio and processes

3.2.1 Definitions

In addition to science specific tools, there were two types of tools for supporting the prospective teachers in developing as teachers of science: online discussion boards and the web-based portfolio. Online discussion boards were intended to engage the prospective teachers in logistical conversation outside class. CourseInfo, free software through blackboard.com, was an example. It also shifted to ANGEL when it became
available at Penn State. The web-based portfolio was intended to assist the prospective teachers in reflecting on their teaching throughout the semester and in authoring web design software included Claris HomePage and Microsoft FrontPage.

3.2.2 Processes

At the beginning of the semester, the prospective teachers were introduced to the classroom communication tool, CourseInfo. Weekly communications were begun immediately and included reflections on readings, classwork, field experiences, and other relevant prompts provided by the instructor. After requesting and receiving allotted web space from the university, the prospective teachers began construction of their web-based portfolios throughout the semester.

Here, I provided an overview of different types of technology tools. Science specific tools were intended to help the prospective teachers in science learning. These tools were incorporated into the class in three levels in order to help the prospective teachers learn how to teach science with technology progressively. The web-based portfolio was a useful tool to engage them in reflecting on their teaching during the semester. Throughout the later chapters, I will follow the same language to discuss each technology tool.

4. Summary

In this chapter, I described SCIED 458, seven key members, and the definition of technology tools in order to put the reader in context to understand what had occurred in this case from 1997 to 2003. The next chapter will unfold the change process of technology integration in SCIED 458 and the influences on the change process in terms of research, practice and theory.
Chapter 5 Research Findings

The purpose of this study was to provide a detailed description, interpretation, and analysis of the change process of technology integration into a science methods course, SCIED 458, as well as to identify essential factors or issues involved in the change process and examine how these factors influenced the change process.

This chapter consists of five sections: technology integration initiatives and major initiators from 1997 to 2003, current state of technology integration in SCIED 458 in 2002-2003, inhibiting factors that influenced technology initiatives negatively, factors that sustained technology initiatives, and the overarching factors that influenced the change process positively. Each section includes a number of claims. The claims are presented first in bold text in order to give the reader a summary of my interpretation and analysis of the data. In other word, the claims I presented in this chapter allowed me to assert my analysis and interpretation of what had occurred in the change process based on evidence. Stake (1985) stated that claims summarize what the writer understands about the case or “whether initial naturalistic generalizations or conclusions arrived at through personal experience or offered vicarious experiences for the reader have been changed conceptually or challenged” (p. 187). The claims are followed by evidence drawing on multiple sources in the data and discussions that were organized either chronologically or by specific themes. Erickson (1986) suggested three components in balancing description and analysis in writing qualitative reports. That is, the raw data are reported as particular description and patterns discovered in the data are reported as general description. Interpretive commentary provides a framework for understanding the particular and general description.

This section begins with a timeline (see Table 6) that provides a brief summary
of the major attempts to integrate technology into SCIED 458 from 1997 to 2003. The timeline was constructed in terms of technology integration initiatives, the initiators such as people, tools, and processes, the sustaining or positive factors, the inhibiting factors, and overarching positive factors. I will refer back to the information in Table 6 throughout the discussions. As shown in Table 7, thirteen claims are presented in this chapter and further explain the emerging themes that described technology integration initiatives and initiators, inhibiting factors that resulted in weak integration or termination, a combination of positive and inhibiting factors that drove evolution, and overarching sustaining factors.
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1. Technology integration initiatives and major initiators over the past six years

1.1 Prior to the 97-98 academic year

**Claim: Lack of appropriate technology tools for elementary science education and lack of a framework for integrating technology inhibited the initiation of the change process.**

As indicated in the second column of Table 6, paper portfolios, Vernier probes and various technology tools were tried at different points of time in class prior to 1998. The syllabus in the summer semester of 1997 included paper portfolios as part of class assignments and informed how this assignment assisted elementary prospective teachers in reflecting on learning throughout the semester. Dr. Donahue and Dr. Zimmerman began to conceptualize the portfolio during this period and described its purpose as follows in the syllabus in 1997:

> We [instructors] expect to be able to see your [elementary prospective teachers’] growth in your thinking about science and science teaching and learning in the portfolio. The philosophy of science education statement you prepared early in the course and revised throughout may be one piece of evidence you choose to show. We [instructors] will hold interviews with students [elementary prospective teachers] about their portfolios near the end of the course.

However, unlike portfolios, the Vernier probes and various technology tools were tried and were not used consistently in class. Dr. Donahue pointed that the Vernier probes and Community of Connecting Learners, an online collaborative tool, were used but discontinued because very few appropriate tools were available for elementary science education at that point of time. Dr. Donahue said:

> We [instructors] used varying types of software and hardware in SCIED 458 beforehand. It depended on the semester what we would be interested in doing….The probes were Vernier probes. Those probes were more geared toward high school and college students. We tried using it one semester in class. That was too complicated for the elementary ed majors. So that was one type of hardware and software that we occasionally used….It was probably in 1996 or
1997. I would think I started to work with that [Connecting Communities of Learners – online collaborative tool]. Then we decided to jump to CourseInfo.

In addition, the prospective teachers were not required to complete any assignments related to technology, which was a factor that caused the slow development of technology integration in SCIED 458. Although the prospective teachers’ exposure to technology tools served as a precursor of change, without any substantial rationale or major framework, it was hard to initiate change. As Dr. Donahue described:

Without any really reason other than exposed the students [prospective teachers] to the opportunities to see what exists. We [instructors] did not require them to teach with it nor was integrated it fully into our methods class.

Dr. Zimmerman also referred to the lack of the technology integration as a function of the lack of general technology related outcomes in the syllabus, “There were no assignments in which students had to develop technology-based projects, whether portfolios or teaching with technology.”

In short, no specific technology tool was fully integrated into SCIED 458 because there was no strong stimulus empowering the changes. The major problems included lack of availability of appropriate tools for elementary science education and lack of a framework or conceptual coherence to guide technology integration.

However, the portfolio was backed up by strong interest from the faculty and had a very good chance of continuing later.

1.2 Between 1997-2001

1.2.1 Faculty interest and commitment

Claim: Faculty interest was a major initiator of projects.

As indicated in the third column in Table 6, the electronic portfolios were developed in 1997 by Dr. Zimmerman. She had been using electronic HyperStudio
style portfolios with elementary education majors since she was a doctoral student at another university before 1997. Dr. Donahue described how he combined his prior efforts with Dr. Zimmerman and how both of their experiences shaped the development of the web-based portfolio. Dr. Donahue said:

I had been working on paper portfolios. Dr. Zimmerman had been working on e-portfolios. And then she came here in 1997. We both decided that we would combine our efforts and have our students develop electronic portfolios, which was not web-based at that time initially.

Dr. Zimmerman described her enthusiasm in technology integration in science education as a catalyst for the integration of technology in SCIED 458. She said:

I came from a program that was very technology intensive. Prospective teachers were expected to teach with technology. I suppose it was only natural to bring that perspective to my work here.

As indicated in the fourth column of Table 6, the electronic portfolios progressed to the web-based portfolios in 1998, the second year in the change process. It was the very first attempt to move the project to a web-based form. As a new graduate assistant at that time, Ms. Hess co-taught the class with Dr. Zimmerman. She assisted Dr. Zimmerman in conceptualizing the web-based portfolio and training the prospective teachers in using Claris HomePage- which she referred to as very user-friendly software- to create the web-based portfolio. The technology coordination seemed to be delegated more and more so that the lead faculty member, Dr. Zimmerman, had more time to plan the content and Ms. Hess was able to take care of the technical aspect. They piloted the web-based portfolio task with a group of 16 prospective teachers. Dr. Zimmerman described that Ms. Hess shared responsibility in taking over the technology training for her:

Ms. Hess co-taught that with me. And that was, I guess, summer 1998, and so I did not [learn Claris HomePage] at that time. She [Ms. Hess] is the one who learned Claris HomePage. And she ran the computer labs for students.

1.2.2 Emerging appropriate tools for teaching elementary science
Claim: Technology integration over time paralleled availability of appropriate tools for teaching elementary science.

During 2000 and 2001, the fourth year in the change process, the university gave more technological support by providing more space, approximately 50 megabytes (MB) each, for the prospective teachers to save their files and also providing more user-friendly software to upload their files. Such support became important because the elementary prospective teachers could select and use various pieces of evidence, such as lesson plans or pictures, without being limited by server space at Penn State and the time it took to upload the files. Before the university provided such support, the prospective teachers needed to request more server space, which discouraged them from using a variety of sources in the web-based portfolio. Dr. Zimmerman described:

PSU provided prospective teachers with 2 megabytes of web space at the time we switched HyperStudio to the web-based portfolio. We had to request additional space, upping the total to 7 megabytes….Now they get 50 megabytes from PSU, so there is more they can do.

In short, between 1997 and 2001, the web-based portfolio had been developed more fully in terms of conceptualization and technical aspect in class. The web-based portfolio became a consistent part of the course because of faculty interest and growing number of appropriate technology tools for elementary science education.

1.3 Between 1999 and 2000

Claim: A state funding and strong research community positively influenced the systemic integration of technology.

Dr. Zimmerman, Dr. Donahue and Ms. Friedman brainstormed and co-authored a Link-to-Learn grant proposal in 1998; the grant was awarded in February of 1999 by the Pennsylvania’s Department of Education to allow more integration of technology in the science education program for implementation in the subsequent school year, 1999-2000. The organization of the grant proposal was based on a technology
integration model generated by a graduate course that Dr. Zimmerman taught in 1998. There were a number of supportive elements of the grant that facilitated the changes. They included the revision of the course and the ability to buy appropriate technology and hire key personnel to support appropriate functions. Dr. Zimmerman described:

The grant was instrumental in many ways. I think students would still be getting a good technology experience. However, the grant provided resources that allowed us to make use of cutting edge technologies in a systematic way.

1.3.1 Revision of the course to integrate more science specific content and tools

Dr Zimmerman described that the grant allowed the faculty members and the instructors to put their ideas together about the course in terms of technology tools and assignments. She said:

The grant allowed key players the space to re-conceptualize the course and to step back and consider, “What are these key tools for sciencing that we want to integrate? How would particular assignments be modified?” The grants actually gave us time and space to get together, dialogue about issues associated with teaching science with technology, and put our ideas into play.

The syllabus was reinvented in 1999. The faculty members and the instructors had the ability to tie in appropriate technological integration into the changes. The syllabus specified a learning outcome related to technology integration. The course activities and assignments were organized into four modules and showed a tie between the technology tools and the assignments. Different technology tools were incorporated into each module. The syllabus indicated:

**Learning Outcome (related to technology)**

Prepare (select/adapt/design) and implement instruction that supports children’s scientific inquiry using appropriate technology tools (e.g., probeware and other data collection devices, simulations and modeling software, and online collaborative tools)

**Major Assignments:**

Module 1: Introduction to Scientific Inquiry and Tools for Sciencing (20/100)
One of major assignments: STEPS Day #1: Using probeware and other data collection devices to support children’s scientific inquiries

Module 2: Supporting Children’s Scientific Inquiries Using Simulations and
Modeling (20/100)
Two major assignments:
School Context and Technology Resources Project
STEPS Day #2: Using simulations and modeling to support children’s scientific inquiries

Module 3: Teaching for understanding (20/100)
Two major assignments:
Plan and Teach 2-3 Technology units
Teaching Science for Understanding Project – plan, teach, and reflect on 2-3 technology enhanced science lessons that emphasized scientific inquiry

Module 4: Online Collaborative Inquiry (ongoing investigation) 20/100
Major Assignments:
Online Collaborative Project- engage in a semester-long, web-based scientific inquiry project
Project review and presentation – review the online collaborative project, contribute evaluation to class data base, and present project to class

A number of the faculty members and instructors emphasized that STEPS Days and Teaching Science with Technology in Field Experience were two significant events that assisted the prospective teachers in integrating technology in science teaching developmentally. Dr. Zimmerman pointed out that these were the two critical projects that came with the re-conceptualization of the course in 1999. Ms. Hess experienced the course before and after STEPS Days were incorporated. She emphasized that STEPS Days provided opportunities for the elementary prospective teachers to teach science with technology in a supported environment where science education faculty and graduate students were there to help if needed. By practicing in STEPS Days, they could build their confidence and carry that confidence when teaching in the field experience classroom at a later time. Ms. Hess said:

When I first started, we did not have STEPS Days. STEP Days was the result of the Link-to-Learn grant. So part of it we wanted them to have opportunities to teach with technology and guided environment which would be on campus before they went out to the classroom and try to do it with the students. That is the idea.

1.3.2 Ability to buy appropriate technology

The grant leveraged resources to make technology integration happen. A variety
of hardware and software was made available in the science education program. The lab was in the science education program and the prospective teachers could get access to it and technology tools very easily. The hardware and software in the lab were also accommodated to support the prospective teachers in science learning and teaching. The grant’s web site described:

Located in the Science Education Center in Rooms 116-121 C Buildings, the TEST (Technology Enhanced Science Teaching) lab is a preview and demonstration site for the latest technology tools to support student scientific inquiry….A variety of hardware can be found in the TEST lab and Resource Center. We mainly use iMac computers that also run Window 98 through virtual PC software.

The grant played a critical role in making the course become technology-intensive. Ms. Hess stressed that the grant allowed the faculty members and the instructors to integrate technology systemically rather than piece by piece:

Most of them [hardware and software] started when we got the Link-to-Learn grant. I think that was really kind of stimulus for implementing the technology. We got the Link-to-Learn grant. We were able to buy a lot of technology and modify the course to be technology intensive….Once we got the computer lab, we started integrating the probeware and the software. That all came out at the same time [1999].

1.3.3 Ability to hire key personnel to support appropriate functions

The grant provided the funding to hire a key person, Dr. Stoker, as liaison between the program and local elementary schools. Dr. Stoker facilitated the prospective teachers to teach science lessons with technology in their concurrent field experience classrooms. She explained to the local schools the program’s expectation of the prospective teachers and indicated that she would consider the schools’ needs as well. Dr Zimmerman explained the importance of her role in assisting the prospective teachers in realizing this assignment in the field experience classrooms.

Dr. Zimmerman said:

One of the key pieces, there actually was a person, a liaison, which was Dr. Stoker at that time, who was hired specifically to sort of facilitate what we were
trying to get students to do in terms of teaching with technology and what was happening in the schools. And typically there was a big disconnect there. Our students are in many different school districts within an hour of State College. And we were changing the expectations. Having someone like Dr. Stoker as facilitator allowed us to do what was needed to make teaching with technology happen. For example, we packed up 4 iMacs and took them into schools along with a set of probes. Or we helped them locate the resources in their school district. Dr. Stoker was the contact person. People would call. There was an actual person on the other side. She was able to explain and sort of mediate this process of teaching in school. We never had that before. …There was no excuse for not teaching with technology. The grant really allowed us to do that.

Dr. Stoker was also the coordinator of STEPS Days. The grant funding provided the opportunities for her to travel to the schools to negotiate the logistics of STEPS Days and for the elementary children to travel to the university to attend STEPS Days in 1999. She detailed her tasks in coordinating STEPS Days and developing partnerships with the local school districts. Dr. Stoker said:

I put out this blanket invitation to please come to the university to our methods classes. We had people from Lewistown, Bald Eagle, Bellefonte, Philipsburg respond and bring elementary classes to us. I just had to coordinate the times so that their visits were when we had our science methods classes. When they came, we did technology-enhanced science lessons! On the day of their visit, we arranged to have a double block of science methods. That gave us about an hour and half of instruction time with them. The prospective teachers were all ready for them, and we, the instructors and the elementary prospective teachers, took them, the elementary students, through the lesson. That was the first year we had STEPS Days. The next year, I started working to build a partnership with my school district, Bellefonte. So since then, the elementary classes have always come from that district, which is closer.

Dr. Donahue reinforced Dr. Stoker’s importance in realizing the goal of SCIED 458. STEPS Days and Teaching Science with Technology in Field Experience were two important events that assisted the prospective teachers in integrating technology into science teaching developmentally. In Teaching Science with Technology in Field Experience, Dr. Stoker communicated to the school districts what the prospective teachers intended to do and also considered the situation of the school districts. She would suggest different ways for the school districts to meet the prospective teachers’ requirement. Dr. Donahue described:
Her job turned out to be to negotiate with all the teachers and, in many cases, the technology coordinator or others in the school district. Suddenly, hardware and software became available. So students could integrate technology into their teaching.

Dr. Stoker’s role was significant in a way that she could consider the course’s requirement, negotiate the availability of technology resources in school and assess the situation holistically. She would report on what technology resources the elementary schools had. She could identify a number of obstacles that the prospective teachers might encounter and helped the science education program in making a better connection between the course requirement and the feasibility of technology integration in elementary classrooms.

The grant was instrumental in bringing systemic changes in terms of technology integration in SCIED 458. The course structure and content were revised to incorporate three major strands of technology. The affordances of the grant were the ability to buy appropriate technology and to hire key personnel to support appropriate functions.

1.3.4 Formation of research community

The research community was critical in two ways as an initiator in 1999. First, Dr. Zimmerman had been a lead researcher in the context of SCIED 458, working with the course instructors and graduate students to study their own practices in that course. For instance, she taught a graduate course on technology tools for science. As indicated in Chapter 4, the technology integration model synthesized from the graduate-level course in 1998 guided the organization of the grant proposal in 1999 and the implementation of technology integration in the next few years.

Second, a number of research studies had been conducted consistently from 1999 to 2003. For example, a number of faculty members and the instructors were devoted
to the area of the web-based portfolio. They included Dr. Zimmerman, Dr. Donahue, Ms. Aberdeen, Ms. Friedman and Ms. Hess. They co-authored research articles and co-presented at conferences during those years. In addition, Mr. Bell pursued his research on an online collaborative environment for a long-term inquiry-based investigation in the ANGEL system and built his dissertation on it in 2002-2003.

In the change process, research served as a basis for people within the context to examine whether technology integration ensured better learning for the prospective teachers. Other people who had joined the program from 1999 to 2003 were able to contribute their ideas based on their expertise to form a rich, strong research agenda. The course improved as a result of such experience.

In short, a funded grant allowed the faculty members to obtain hardware and software and put their ideas into play in a systemic manner in 1999. The research community was also a facilitating factor to offer a framework for technology integration in the subsequent years.

2. Current state of technology integration in SCIED 458 in 2003

Claim: Continuing faculty and instructors’ interest and capabilities of emerging internet technology sustained the technology integration change process to reach the stage of institutionalization.

This section addresses current state of technology integration in SCIED 458 in 2002-2003, the sixth year in the change process. The technology tools included the web-based portfolio and science specific tools, such as data collection tools, simulations and modeling tools, and online collaborative tools. This section focuses on their influence on the elementary prospective teachers in science learning and teaching and how they were incorporated in class activities to allow more meaningful technology integration.
2.1 The Web-based Portfolio as a support for the prospective teachers’ metacognition

In 2002-2003, the web-based portfolio was developed and used by every prospective teacher. Mr. Bell said, “The web-based portfolio has been a part of the system before semesters that I have been here (Fall 2001).”

In 2002-2003, the web-based portfolio was a programmatic project within the Department of Curriculum and Instruction. It was used for the concurrent field experience class, CI 495B. In field experience, the prospective teachers visited school twice a week before student teaching. Ms. Hess explained that the collaboration was significant because other faculty members such as field experience supervisors could realize the efficacy of the web-based portfolio. It drew more and more people’s attention in believing in the efficacy of the web-based portfolio. The prospective teachers would have more opportunities to practice the web design skills and self-reflection. She said:

> It started as a science education thing. Ultimately we tried to get it to become a C&I or the Office of Preservice Teaching (CI 495B). We tried to move into the 495B experience. We did not just develop portfolio in science education 458. That became the portfolio for 495B because they were having to do a paper portfolio for 495B. So we ultimately got the web-based portfolio to be adopted by the 495B experience. Science education still provided the technology leadership. We helped a lot of supervisors become comfortable with technology. A lot of the supervisors took the leadership position. It did not move out of SCIED 458. It was not solely an assignment for SCIED 458. It became something that housed in 495B that encompassed the entire semester and all the courses.

The prospective teachers worked on the web-based portfolio throughout the semester. They posted all assignments online for grading as the semester went by. The syllabus also indicated that the web-based portfolio itself was not scored. The faculty members and the instructors claimed that because the web-based was shown as a useful vehicle to support the elementary prospective teachers to reflect on practices, it had stayed in the course over the years. Dr. Zimmerman explained, “That (the
web-based portfolio is a piece that has stuck because it has been so powerful in helping prospective teachers document and reflect on their own teaching.”

Dr. Donahue also described the web-based portfolio as a space for the prospective teachers to reflect on their teaching:

There are portfolios that are designed to give prospective teachers the thinking space, the intellectual space they needed to explain their theories, their personal theories of how children learn science and how they wanted to teach science…Our goal is that they learn from their work from developing the portfolio. They are learning about themselves, setting some goals, and engaging in professional development.

Ms. Hess explained that the organization of the web-based portfolio engaged the prospective teachers in deeper thinking because they collected various pieces of work purposefully over a semester as evidence to support their understanding. She said:

They started as a way for students to represent their understandings. I believe, as a way to represent their understandings of teaching and learning. Over time, that modified because as we learned more about how students were able to represent their ideas. It became a place for the portfolio, became a collection of evidence that supported emerging philosophy. And we wanted that philosophy to be evidence-based. We truly wanted the portfolio to represent their ideas. It became a philosophy where they were to represent their evidence-based philosophy of teaching and learning as a result of their experiences.

In addition, the web-based portfolio was powerful in that it enabled the elementary prospective teachers to build arguments to justify the pieces of evidence they selected to support the claims. The web-based philosophies were structured in the form of claims, evidence and justifications. Claims represented students’ beliefs about science teaching and learning. An example of a claim would be: students learn science by engaging in hands-on activities. This claim needed then to be backed up by evidence, which could be an example of a learning experience in K-12, an experience in college as students, a class they observed or any teaching experiences they had. A justification statement, about a paragraph long, needed to then be developed, and its role was to
explain how and why the specific evidence supported the claim they accompanied.

2.1.1 Added technical support for the use of web-based portfolios

In 2002-2003, the purpose of the web-based portfolio was clearly defined; the configuration of the web-based portfolio was set up for the prospective teachers; and the training of the web-based portfolio was designated to someone who specialized in technology. All instructors in SCIED 458 adopted it in their sections.

A separate web-based portfolio workshop was offered at the beginning of the semester where the prospective teachers learned how to create the web page using Microsoft FrontPage and publish it to the web site. They signed up in the first or second week of the semester. In the workshop, they were given a template that consisted of three files.

Before, the instructors were responsible for teaching Microsoft FrontPage and solving technical problems for the prospective teachers throughout the semester. However, the technology training of the web-based portfolio was transferred to a technology coordinator. All instructors regarded such change in a positively way. For the instructors, the shift of technology training enabled them to concentrate on teaching and guiding the prospective teachers in science teaching and learning. Dr. Stoker supported the change and said:

We [the instructors] have removed doing the training for web-based portfolios….Our office hours were largely spent helping them with their web projects not with science. Our office hours were devoted not to doing that. We kick the technology problems to the learning center. We no longer spend time teaching the technology. And they sign up for a two-hour workshop with Emy [the technology coordinator]. From then on, they have to post their assignments to web-based portfolios. That’s been a good thing instead of wasting our time teaching technology without teaching science. [laughter]

The shift of the technology training job could alleviate much pressure on the instructors. Mr. Bell explained:
We [the instructors] were moved away from that [technology training] and let the technology people help with the technology because it added the burden to people that already have more in place since 90% of us are graduate students.

So the instructors could now concentrate on improving the course. Before the change, the instructors were so busy with learning new technology or with solving technical problem from the prospective teachers but had limited time to direct them to focus on what the web-based portfolio intended to achieve.

Yet the shift of technology training placed a great influence on how the prospective teachers designed the web-based portfolio and what resources they could go to when having problems. Dr. Donahue, after observing a major change, said:

We used to spend two or three or four classes teaching them how to use homepage, how to scan, how to do digital image, and how to use PhotoShop. We just do not do any of that anymore. As a result, frankly for the image side, you look at students’ [the prospective teachers’] portfolios now, and they have very few images in it. Before the whole thing was organized around the images. Now there is almost none of that….Now, we do not provide support for the students directly. We expect them to attend the training workshop in the beginning of the semester and make sure how to use the software. I think it is two or three hours long. Then, if they have any questions after that, they go to some of the resources to get assistance. The university learning center usually wants our students to come and get help there.

2.2 Developing the use of science specific tools as empowering tools for science learning

Science specific tools were used throughout the semester. They referred to data collection tools, simulations and modeling tools and online science collaborative tools. Dr. Donahue viewed these tools as empowering tools in assisting the prospective teachers in science learning. He said:

We kind of stick to the categories of data collection tools like probeware, simulations and modeling tools, and collaboration tools. That is three areas that we kept a handle on. We thought tools are going to change with time as platforms change and operational systems change. But the categories of the tools are still very useful to helping prospective teachers learn about that aspect of science….

Dr. Zimmerman stressed that SCIED 458 focused on science specific tools rather than
general productivity tools because science specific tools were designed to help and enhance a better understanding of science in different ways. She said:

The ultimate aim of SCIED 458 is to help prospective teachers develop an understanding, abilities, and dispositions needed to support children’s science learning. Technology is used as deemed as appropriate for enhancing science learning. As a result, we focus on science specific tools rather than generic ones, like Microsoft Word.

2.2.1 Data Collection Tools and Simulations and Modeling Tools

The following paragraphs describe how data collection tools and simulations and modeling tools were used in SCIED 458 throughout the semester. In data collection tools, the prospective teachers were able to efficiently and accurately collect data points in real time. The PASCO probeware is one example. In simulations and modeling tools, the prospective teachers were able to formulate hypotheses, create simulations, and run experiments that may normally require equipment and resources not readily available. Tom Snyder Science Court is one example.

In the beginning of the semester, the PASCO probes, and PASPORT, were introduced within modules in class. The tools were to help the prospective teachers visualize and collect the data in real time. Without the tools, the prospective teachers might spend a long time collecting the data or waiting for the result of experiments in the laboratory. Ms. Hess explained how the prospective teachers learned and experienced technology as a learner might have with her assistance:

We used the probes in class, in activities for them to experience as a learner really representations of data in a way that they could not otherwise do, you know, could not otherwise experience. The ease of data collection as well as data representation.

In the beginning of the semester, Science Court was used by the instructors as a package to introduce the inquiry units with the prospective teachers. Although Science Court was a loose example of a simulations and modeling tool, a number of faculty members and the instructors viewed Science Court as valuable and used them in class,
as Mr. Bell described. He illustrated the pendulum activity from Science Court in engaging the prospective teachers in thinking about the influence of different variables on scientific phenomena and suggested a number of topics in Science Court. He said:

Science Court, we use it as a part of a pendulum activity. We do not use as it is written. But we show the beginning part of the video and ask the question about what is going on with the pendulum. Can the amount of sand in the bucket really affect the swing rate? But then we turn the loose on the inquiry-based activity, when they [prospective teachers] build up an investigation to find out what they know, when happens to the pendulum when you change the length of the string and the mass of the bottom of the string? Students then get to see the second part of Science Court where the court trial takes place. And they get to find out what the results are. So we use that not so much as interactive type of technology but in a neat way to add a different twist to a pendulum activity, which is a lot of fun. We show off some other Tom Snyder stuff that they have. They have forces and motion, some other types of CD-ROMs that are available to use in the classroom.

Dr. Donahue explained that the faculty members and the instructors spent much time looking for simulations software that would be appropriate for elementary children. Because the software was not easily available, Science Court seemed the best choice for elementary levels because it contained some simulations components. He said:

Science Court does not exactly do that but has some simulation pieces built into parts of it and certainly helps the inductive thinking that is consistently with the inquiry-based science.

Toward the middle of the semester, the prospective teachers were asked to use the probes in STEPS Days, an event that invited elementary children from the local schools to the university for the prospective teachers to teach under the guidance of the PSU instructors. The selection of the probes in STEPS was based on different interests each semester in STEPS. The topic in spring semester of 2003 was about watershed. Ms. Aberdeen detailed what probes the prospective teachers planned and used in the lessons in STEP Days:

Specifically, I used probeware during STEPS (science and technology experiences at Penn State) when elementary school students visited my classroom. My students taught a lesson on watershed and we used the
temperature sensor and the ph sensor in order to investigate the quality of the water at upstream and downstream.

In addition, the prospective teachers integrated Science Court in STEPS Days. They used Science Court as a motivation tool for elementary children to understand science concepts. The majority of the prospective teachers commented on the use of Science Court in STEPS Days in the feedback form:

Although Science Court did enhance the lesson— elementary students were interested in the cartoon— it was not essential to the learning of the concepts… Yet, I could see the excitement in the students’ eyes while using the technology.

By the end of the semester, the elementary prospective teachers were required to teach science lessons with technology in their field experience classrooms. They needed to negotiate a topic that could fit in the curriculum in school with their mentor teacher. The prospective teachers were required to select appropriate software from data collection tools and simulations and modeling tools. They would have a second opportunity to plan and implement different science lessons with technology with less guidance of the instructors because they practiced once in STEPS Days and got feedback from the instructors to improve the drawbacks.

2.2.2 Adoption of different technologies for each strand

Some probes were easy to learn and had great interface; some probes needed more instructions to operate. Dr. Donahue explained that if the instructors lacked experiences and had technical problems, they would stop using it and just quit. He said:

The sound probe is very complicated in fact. It gives us a lot of misreading. You have to really understand more about the probe than you need to, everything you should need to in order to use it. Like the temperature probe is pretty straightforward. The heart rate probe, if you catch correctly to your earlobe or your finger, it works great. But typically you move a little bit, you get misreading. People who have little experience with the probes look at the graph of the data and totally misinterpret it….
Mr. Bell pointed out that the technical problem inhibited him from using the probes and sought for an alternative way. He said:

We had a lot of frustration with them working sometimes, not working sometimes. We did have instruction sheets but they were not always able to answer all the questions that the instructors had….And I think it is the level of frustration. For me at least with the technology because I have not played with it enough to complete comprehend how to use it….Over the course of the last four semesters, we moved away from probeware a little bit and started to use some interactive simulations online.

Overall, the probes were integrated into SCIED 458 curriculum and remained a critical technology strand in class. There were a few technical problems emerging but the instructors saw the value in helping prospective teachers experience the real time data collection process. Yet, the use of the probes seemed to decrease. Dr. Donahue described a trend that there were more and more web sites online that could achieve the goal similar to the probes. Dr. Donahue said:

It [the probeware] is more integrated in SCIED 458. So I think we have made some progress here….We probably did much more of early on and we do not do as much of anymore….In recent years, there has been more with webquest and more internet-based investigation work, looking at the extended existing data sets on the internet and using.

Dr. Stoker illustrated a good example of the web site used by one previous prospective teacher. She said:

Most of them, the prospective teachers, do use the internet sites and interactive sites or virtual museums; I mean, you name it, it’s out there. WebQuest have been developed, and just a lot of interactive things on the internet. Here’s a good example. One of the students was trying to explain about a canal, then she found a website that actually showed it. The kids could go in a canal, out of canal, you know, show how they pump water in, and the boat goes up. They, elementary children, are more interested and more excited because they could understand it better. That was sixth grade. That’s just one of many stories.

In 2002-2003, the strand of simulations and modeling tools remained a critical technology strand in class. Yet Science Court was more heavily used in 1999 than 2003, similar to the probes. Dr. Zimmerman pointed out a trend of less use of Science
Court in STEPS Days. She said:

Some years, instructors like it and use it. Lately, it seems like that there has been less use of Science Court associated with STEPS. I am fine with that as long as people are having some way to experience simulating and modeling.

In short, the strands of data collection tools and simulations and modeling tools remained strong because they possessed the critical components that enhanced science inquiry. Yet more and more resources on the internet and software that fit under each strand were emerging.

2.3 Web-based online collaborative tools to support online communities of learners

As a more recent major project, ANGEL enabled the instructors to create a learning environment that engaged the prospective teachers in science inquiry by participating in a long-term problem-based investigation project throughout the semester. Initiated by Mr. Bell in 2002, the sixth year in the change process, ANGEL, a classroom management system developed by the university, made its way to SCIED 458 as indicated in the last column of Table 6. Mr. Bell took Dr. Donahue’s suggestion and built a learning environment in ANGEL where the prospective teachers participated in a long-term problem-based investigation project outside the class. Dr. Donahue thought very highly of the learning environment that assisted the prospective teachers in collaborating on data collection, a critical aspect of science inquiry. Such an environment provided the prospective teachers a learning community for science learning. Dr. Donahue said:

Last two semesters, there has been an independent science investigation project that students have to do in that class. They utilized the ANGEL space for sharing data and sharing protocols on data collection, even just logistical conversations. Sort of extended class space but provided them a way to kind of compare data from different groups of students, which I think has been particularly useful.

Mr. Bell integrated ANGEL into his class and used it extensively with the prospective teachers. He had increased the use of it in the fall semester of 2002 and
the spring semester of 2003. There were a number of features in ANGEL that he used to achieve different purposes. He used it as a resource center and a safe environment that the prospective teachers could get access to. Mr. Bell said:

It used not so much message boards but as a place to put documents to look at. But 458, the students did put publish something in the message boards. We have them put children literature sharing. And I believe that was the class that I had the students put one resource for every science and technology standards. So the other students could look at it and summarize a complete list of that information. When we take pictures in class, the students might like to use. I put them on ANGEL since it is a secure environment. If we do have some kids with their faces showing, my students can access them but I had a little disclaimer says, “If you put this on the internet, you have to blur the faces” because of the problems with that (confidentiality).

He had the prospective teachers’ peer review each other’s work in ANGEL. He said:

I put message boards up there for them to pose their draft forms of the project there. I had other students review among the message boards. So we did peer review using the message boards.

It also served to organize the class materials and out of class resources by weekly folders:

What I do in ANGEL is to set up my lessons by weekly folders. So I have fifteen folders at the very beginning. I usually have a resources file at the very end where I stick things. Now, I have week 1. Then you open it. You get large group and small group. And large group, I stick the documents that we use in large group in there. So the students can access to it if they want them. If I tell them to get them before they come, they can get them. The small group, right now, I have that folder organized as in class, what we are doing in class, out of class resources, and assignment folder where I put the dropboxes, or message boards, as well as the description of the examples.

In addition, ANGEL was a tool to model and scaffold the prospective teachers’ learning about how to formulate research questions, how to conduct experiments, how to collect data and how to share the data from working on the long-term inquiry-based investigation project. Mr. Bell intended to create a collaborative environment where the prospective teachers could share data, give feedback, and provide support:

Week 9 has a part of that inquiry-based investigation in there. And I have documents up there. To add a driving question you can investigate is not always an easy task. So I have a list of questions that the students can ask themselves to
see if their driving question is doable in a time period we have and the materials we have and so on. So I have materials to scaffold their learning…. They can see stuff and get it whenever they want it. That was a very useful part of ANGEL…. The second important part of ANGEL, I am doing it again this semester but we have not done it yet because we are just starting the inquiry-based investigations. When they posted their materials to the message board, I had them post their experimental protocol, the procedures that they follow to investigate whatever topics…. Two or three students worked on each project. But then each individual students comment on at least three different protocols. Then they looked at their protocols to see if they controlled their variables, if they had designed the procedure that was easy to follow. If there was something that they can take much and do without that person telling them how to do that because experiment needs to be replicable across the scientific community. So we modeled some of that. The students really thought number one that it was good to get feedback. But they also thought it was good to see examples of how other people were organizing their investigations. Then students gathered the data. Data charts, some of them have not built their own charts before….So they had a chance to see data graphical, data organizers. Also students created graphs using Excel. Then put them on there. So that gave them a chance to do that.

Mr. Bell also considered ANGEL to be an effective way to communicate with and scaffold the prospective teachers as a twenty-four hours teacher:

I think it is a communication tool. Email could be done through there. But having the documents for the course online. They can access them 24 hours a day for anyone in the world. It is on the internet and the computer. I think that aspect of communication has lower distress levels and makes life easier for them.

A number of the instructors shared how they adopted ANGEL in their particular section and pointed out some technical problems in the ANGEL system and how that affected their use of the tool. Ms. Aberdeen reflected on her experience in the fall semester of 2002 and pointed out the drawbacks of ANGEL system. The technical problem caused her to stop using this system half way through the semester. She said:

We attempted to use ANGEL as a way to communicate with students, have them drop paper into folders and submit specific assignments that need not be on the web….However, I stopped using it after the first 4 weeks because I felt it was unnecessary and the use of email was adequate. Other drawbacks of ANGEL had to do with some students not being able to access it from home or the server being down at times.

Dr. Stoker described why half of the instructors stopped using the system in the fall semester of 2002:
Two out of four used that, and one used it extensively but that is dependent on the instructor…Because of its glitches and it is not quite to the point of no mistakes or no problems. There might have been maybe one of the five sections or two, maybe. They quit using it as the fall semester of 2002 went on.

In 2002-2003, the introduction of ANGEL was significant because this strand of technology tools was never strong in SCIED 458. Dr. Donahue was very positive about the change:

I think the science online collaborative piece where we are still the weakest on that. We never really got that going well. If the long-term inquiry-based investigation project in ANGEL is going well, then we have it going well now. Excerpt for the system’s technical problem, most instructors held positive attitudes toward the use of ANGEL to create a science community for the prospective teachers. They all believed that with time and practice, the system would do a better job achieving the goal. Dr. Stoker recognized the value. She said that she would try it again in the following semester if the technical problems could be rectified. She explained, “Because of the problems, some people just don’t want to deal with that. But I hope that keeps getting better.” Mr. Bell helped other instructors to integrate ANGEL into their classes and supported the use of such a learning environment. He explained:

Other people were not as comfortable with it maybe as I was….With ANGEL, I have become the expert on ANGEL because I spend the most time with it. So last semester [Fall 2002], I was on everybody’s ANGEL site as an administrator. …So I was one they came to for questions and things along those lines. I knew enough to be dangerous. You know just enough to get by yourself. You figure out a couple of tricks. But I am by no means an expert. That part, people come to me for technology. So I think my role has increased their [confidence] …I know there are glitches with ANGEL. But what I can tell the advantage of having that information online 95% of the time is worth any of the glitches.

Dr. Donahue explained that such environment was valuable in a way that it allowed the instructors to use the class time more effectively. He said:

I expect that [online collaborative tool-ANGEL] to continue. In fact, what I like here is that the ANGEL environment has now allowed us to use class time,
face-to-face time much more productively….

The long-term inquiry-based project in ANGEL was a major technology initiative in SCIED 458 in 2002-2003. The instructors used it throughout the semester to engage the prospective teachers in different phases of the project. The learning environment in ANGEL intended to strengthen the strand of online collaborative tools that had been weak over time in the past years.

In short, technology, such as data collection tools and simulations and modeling tools, was used in SCIED 458 in a systematic way to help the elementary prospective teachers in science teaching and learning. The strand of online collaborative tools had been week. But the importance of this strand of technology drew attention from Mr. Bell and was developed by him in 2002-2003.

3. Inhibiting factors that influenced technology initiatives negatively

This part identifies the technology initiatives, online collaborative tools and online discussion boards, which came and went and did not work very well in class and discusses the inhibiting factors involved in the change process as indicated in the fifth row in Table 6. More inhibiting factors of different technology initiatives are discussed in the subsequent part, part 4, because the inhibiting factors unlike the ones in this part did not cause the technology projects to be weak or terminate.

Claim: Lack of control over technical aspects and realization of the limitations of technology tools inhibited the development of technology integration initiatives.

3.1 Weak development of online collaborative tools

During 1997 and 1998, the first year in the change process, Dr. Donahue’s former advisor from his graduate program in another university developed an online collaborative tool, Connecting Communities of Learners (hereafter referred to as
CCL). CCL was used in logistical conversation early in its implementation. Although it was a good initial tool and a good precursor to allow online collaboration, a number of problems were encountered. The logistic issues overrode the purpose of using it for online collaboration. Because the CCL’s server was not at Penn State, the faculty members and the instructors had difficulty managing it. The faculty members and the instructors had little control or support to tailor the environment to meet their needs. Dr. Donahue explained:

Mainly it was not housed in any Penn State server. So the maintenance issues associated with that were becoming more complicated. We wanted the permissions to add or change students. We had to go through too many layers of people to do that….So the main reason is because we did not have as much control over the environment. We still had little control because it was not on our server. That was the main reason we did not continue. They were willing to let us have some of the scripts and to modify. So I wanted getting a book on PERL, and tried to read the programming in PERL because of a lot of it. [Laughter] They found a web site that had some scripts that were already on this and needed to be modified. I do not want to get involved in it. [Laughter] I never played that for a while….. And it was not doing exactly what we wanted to do. There was no sense continuing with it….We kept saying maybe we can program it ourselves. We can hire a person. It was not worth it. It was not worth it.

In 1999, the third year in the change process, the faculty tried to locate some online science collaborative tools but were not able to integrate them into the class due to lack of interest among the instructors. Due to these reasons, GLOBE was not adopted in class. Dr. Donahue explained:

We actually sent Dr. Stoker to GLOBE training because in order to participating in GLOBE, to own via participants, you have to follow the protocol. I mean, you have to be certified by them to be ok. You are not skewing the data by drawing bad data. After she came back, I think we had decided there was not really worth. We could not really find a decent internet-based collaboration project.

Dr. Stoker described her experience participating in the training offered by GLOBE and explained that she could not initiate the use of GLOBE in class because very few instructors participated in the training. Dr. Stoker said:

I did go to a GLOBE training in August a couple of several years ago. Ideally, it is taking measurements, data from the environment, temperature, pH and so on.
Most of the schools that were there had teams of teachers from the elementary and high schools. I liked it. We had a team of about five instructors at a time. I was not coordinating the course. I was just one of the instructors who attended it. Instead of dropping this on them, I said here is what we could do…. There just was not enough interest among the other instructors to put forth these efforts. I did put together a couple of activities that I had used….If I look back, I am wondering it would be more effective, if the whole team had gone, all instructors or at least more than one. When you want to try to adopt or implement or try new programs in a school, you do not send just one person. It is more effective if you send the team, then you have more onboard and you get different perspectives and there is strength in numbers.

The faculty members and the instructors had incorporated software, such as Connecting Communities of Learners and GLOBE that fit the strand of online collaborative tools over the past few years. Yet, due to logistical and technical problems, the software had not been implemented to fully integrate into the course. Thus this strand had been weak until 2002.

3.2 Termination of online discussion boards

In 1999, the third year in the change process, CourseInfo was adopted as a tool for the prospective teachers to communicate with other students and the instructors and reflect on readings, class work, and field experience. The relevant prompts were provided by the instructor outside class time for discussion in CourseInfo as shown in Dr. Stoker’s syllabus in 1999. The use of CourseInfo was terminated because a number of the instructors did not regard it as a powerful tool to help prospective teachers and CourseInfo was not housed in the university. Ms. Hess described that she used CourseInfo in class as a managerial tool rather than a learning tool. She pointed out that she could not monitor the large number of the students’ discussions online at the same time. She said:

Blackboard [CourseInfo] was not so much a tool for learning. Blackboard was something that I dropped in terms of learning. I guess I used it as a course management. I posted grades….It was just too difficult to manage….There are sections that were too large. We have thirty-five students in a class. If they were doing an online discussion, you cannot monitor threaded discussion. You cannot keep up with thirty-five people logging in and talking. I could not validate giving
them assignment to discuss online when I could not interact with them.

Dr. Donahue also pointed out the drawback of CourseInfo because the server is not at Penn State. He said:

We used the free blackboard site for that [CourseInfo]. Their server was pitifully slow. At least, the connection always was pitifully slow cause of the free version probably.

Because of these problems, online discussion boards had not been used in class since 2001.

4. Technology initiatives that had been sustained and the positive and inhibiting factors involved

This part identifies the technology initiatives that had been sustained and examines the positive and inhibiting factors involved in each technology initiative as indicated in the fourth and fifth rows of Table 6.

Claim: Pedagogical utility sustained technology integration in SCIED 458.

The majority of technology initiatives, such as the web-based portfolio and integration of science specific tools into class, STEPS Days, and Teaching Science with Technology in Field Experience, had been sustained although they underwent some revision and modification. Dr. Zimmerman characterized that most of projects had been in the course of evolution and modification. She said:

I think the big technology assignments that have been introduced during the past seven years are still there in some form. But they have been modified over time. Form year to year, nothing looks the same. There is very little that we keep without revision.

The evolution and modification of the technology projects were based on what the faculty members and the instructors had learned from the implementation process and if the prospective teachers could learn more effectively from these technology tools. There had been a number of versions of the organization of the web-based portfolio over time. The major reason for the changes was that they found that the
prior versions were unable to enhance the prospective teachers’ reflection on teaching. They would change to another version that might lead to more meaningful reflection. Dr. Donahue explained:

It has been a lot of evolution. Sometimes, we tried some aspects of technology integration. We never did it again because we were not feeling comfortable with it. But maybe a new version came out. So like the portfolios, as an example, how we kept modifying. We sort of eliminated one version. But we invented a new version. So I think that is probably more the case than actually completely eliminating….I do not think we abandoned all of those things. We modified or toned down or rebalanced.

For the development of the web-based portfolio, there were a number of factors that influenced the process. One was that this assignment became a required one in 1999; before that, it was an optional assignment. The grant proposal also indicated that without being a requirement, approximately 66% of the prospective teachers prepared a web-based portfolio in the fall semester of 1998. The assignment related to technology had to be incorporated into the course in order to strengthen integration. Dr. Zimmerman emphasized:

We had a few takers. But what we found is by not requiring it, students got busy, they got overloaded, then the last thing that they wanted to think about doing was adding this new piece, which is the portfolio. So a lot of students opted out of it because they were so busy.

Second was that web-authoring software such as Microsoft FrontPage was available for the prospective teachers around the campus and was offered freely by the university in the fall semester of 2001. Before, the software Claris HomePage, was only available in the science education program’s computer laboratory. Other software was tried such as Microsoft Word and Adobe PageMaker but they did not work very well for the prospective teachers because the software was not designed to create a homepage. The software needed to be available for use and be user-friendly for the prospective teachers to increase their chances of using technology.

The software also needed to be available for the prospective teachers in a way
that they did not need to purchase it or they had unlimited access to use the software. Dr. Stoker explained why Claris HomePage did not seem to be a good choice because the prospective teachers needed to purchase it. And when they decided not to purchase it, they had very limited access to the software in a computer laboratory located in the science education program because the lab was not always open. Dr. Stoker said:

They used that time Claris HomePage, which was not available at the CAC labs, labs on campus. So it was on the computers in 118, the lab in the science education program that we have. It was also required that the students buy it, purchase it. That is not something that helps sustainability. [Laughter]

For the PASCO probes, two factors were noticed. First one was the partnerships between the university and the PASCO manufacture since 1999. The partnerships between the college and the software corporations facilitated technology integration because the corporations would provide extra resources such as the amount of software and professional development and develop their tools according to the customers’ feedback and needs. Dr. Donahue explained:

They [the PASCO manufacturer] would be going to partner with us. We bought some. And then they gave us more. And over the years, then people like Dr. Stoker wound up getting involved with PASCO and became PASCO technology educator whatever they called it. Then they go up and do workshops or something with PASCO, which I think is great.

The partnerships provided numerous opportunities for the faculty and the instructors to grow and develop new expertise. Dr. Stoker described:

One way that I try to keep up with it is I became PASCO technology educator, which means I went out for training. When I go to NSTA [the conference], I work with those folks at their booth. [Laughter] selling probes. I am not really selling but bringing folks over and demonstrating the use of software. That helps me though. I know the folks now…. In fact, we are trying to arrange for one of the sales reps to come to us and do a demonstration to bring the new graduate students onboard with the technology.

Second was the advancement of a more user-friendly interface for the probes. Dr. Donahue suggested that the easier technology interface would facilitate technology
integration, particularly for the prospective teachers with limited technology background. Dr. Stoker also supported this point of view and explained that PASPORT was accessible not only for the prospective teachers but also elementary children in school. Dr. Donahue added, “So the PASCO developed a USB probe, which is much more elementary friendly. That has been very useful to use. I liked that.”

For Teaching Science with Technology in Field Experience, several obstacles emerged as a result of implementation between 1999 and 2003. A number of critical problems included lack of resources in the field experience classrooms and the school districts and limited guidance from the in-service teachers. Dr. Stoker conducted a study on what actually happened during 1999 and 2000 and reported major obstacles:

Some schools did not have computers in all the classrooms. Some teachers had computers in their rooms but did not know how to use them. Other teachers were knowledgeable about computer use but were limited by the computers they had. Some districts had older computers that did not support the software we were using. A few school districts had a technology coordinator who was solely responsible for installing software and very difficult to contact. Some schools had computer labs but they didn’t always house a projection device. This was a beneficial piece of hardware for use with both types of software we were providing for lessons, especially the Science Court. In some cases, there were designated times that cooperating teachers were to use the computer lab, and these times did not always coincide with the days that the prospective teachers were in the classroom.

Lack of funding was a challenge for the science education program because hardware and software needed to be updated. The faculty members strived to secure external funding to replenish the hardware and software since 1999 but did not receive any support either from the university or from the state department of education. Dr. Donahue showed his concern:

But the truth is our software packages that we have available are ancient at this point [2003], you know, three years old maybe. And some are useful of course but some maybe are not very appropriate anymore. We do not have a regular budget in the department for replenishing hardware and software that is science specific. We have to write a proposal every year for things that we need. So, you
know, not enough money to make a big difference. So it gets very difficult for us to do that. No one is really looking after that right now. So when we had a funded project, it was easier to look after that. …So programmatically we have not had any efforts since probably from four years ago.

In the preceding section, I identified both positive and inhibiting factors for each technology initiative. In summary, inhibiting factors were not always negative for the change process and they could be the sources of improvement to allow more meaningful technology integration in SCIED 458.

5. Factors that had sustained the change process

The technology projects that had been introduced during the past six years were still there in some form although they had been modified over time. From year to year, nothing looked exactly the same. “Evolution and modification” characterized the technology integration projects over time. This part discusses the overarching factors that sustained the change process as indicated in the last row in Table 6.

5.1 Key persons’ expertise in elementary science education and the ability to collaborate

Claim: Faculty’s expertise in elementary science education and their ability to execute the change initiated, facilitated and sustained the technology integration change process.

5.1.1 Coordinating efforts of three lead faculty members

Dr. Donahue and Dr. Zimmerman had consistent, strong ideas and high expectations about what they wanted to do in terms of technology integration into SCIED 458. They had the vision and foresight to realize what was a better way of using technology in elementary science education to help the prospective teachers in science learning and teaching. They recruited instructors who possessed the ability
and shared the similar ideas to teach and improve the course. Ms. Hess pointed out that Dr. Donahue and Dr. Zimmerman were two key persons in the change process.

Ms. Friedman also concurred that Dr. Zimmerman and Dr. Donahue were two major leaders who led the changes of SCIED 458. In addition, Dr. Donahue and Dr. Zimmerman recruited Dr. Stoker and instructors who had similar ideas and shared in their philosophy in elementary science education to help the implementation of technology integration in SCIED 458. Ms. Friedman explained:

I think I would say people were the critical factors of the changes. Dr. Donahue and Dr. Zimmerman had higher expectation. And I think that’s a big factor. Also, Dr. Stoker, she did a lot in this project. And I think instructors became comfortable with tools. Just the key people, I think.

In addition, stability of the key persons was shown as a critical way to continue the ideas over years. Dr. Donahue explicated the stable leadership team formed in the process:

I would say the number one stimulus was faculty members. …One is that there are stable people have been there that have allowed the notion of integration to continue. Dr. Stoker, as an example, she was there in the beginning and she is still there now. She understands what we are trying to do with that [technology integration].

Although Dr. Stoker’s role had changed over time, her stable and consistent involvement in SCIED 458 from 1999 to 2003 enabled her to develop more insight to what should be improved to better integrate technology in the course. Dr. Stoker said:

I guess it is nice to have someone, some consistency in the role….It feels now that we really do revise based on where we were last year instead of starting over every year. So it feels that hopefully we are building a better course because I have been there for a couple of years. Like in your classroom, by the time in your third or fourth year, you are really starting to look more closely at what is helping children learn. I mean I know we should be doing that from day one; [Laughter] however, you are so caught up in the details, the organization, the administrative type things. Then finally you can start looking at learning more critically. That would be the biggest thing that I have noticed. This is my class, and I am really trying to improve it. With the new instructors that join us, they bring neat ideas. I listen, I really listen because they are right in there. We are all in this whole experience together. So instead of looking at it as, I have ten
million other things to do, we are trying to do look at, this is my most important thing - technology integration in SCIED 458 - to do today, and I am going to do it well. So I guess it is taking more pride, or more ownership, or more concern for what is really happening in the course.

Over the years, the three key leaders, Dr. Donahue, Dr. Zimmerman, and Dr. Stoker, were involved in the change process. They each took different responsibilities, and contributed to various aspects in the process of technology integration at different points of time. Moreover, the key persons such as faculty members and instructors stayed in the program long enough to enable themselves to understand and realize the goal of the course in the program.

5.1.2 Teamwork of faculty members and course instructors

Team approach was a vital factor. The instructors worked very closely with the lead faculty members. They all followed the same syllabus and did similar things in class. There was less dissent among the course instructors in what they should teach in class. The faculty members and the instructors met on a weekly basis to discuss progress and next steps. At the end of the semester, they met to talk about what they needed to change for next semester. When Mr. Bell joined the program as a new instructor, he sat in Dr. Stoker’s class and observed how she taught. Such mentoring experience guided new instructors. Ms. Hess added how the instructors strived to design a better course for the prospective teachers. She said:

We, the instructors, have removed doing the training for web-based portfolios….Our office hours were largely spent helping them with their web projects not with science…We handed over the technology problems to the learning center. We no longer spend time teaching the technology. Our students sign up for a two-hour workshop with Emy, the technology coordinator. After the training, they have to post their assignments to their web-based portfolios. That’s been a good thing - not wasting our time teaching technology without teaching science. [laughter]

As a course coordinator since 2001, Dr. Stoker described how she worked with other
instructors on a regular basis and how she modeled new instructors in teaching:

We [Dr. Stoker and the instructors] hold the weekly meetings. I put my lesson plans up there for them to pull down. Then we revise those together and come up with ways to improve and they get better for the students. That’s what I brought about little problem-based learning groups. I guess I lay out the ideas that we need to cover and I assign the readings and so on. But then we come up with how to teach the class and work, three of us together or two of us, depending how many instructors are there. But, weekly meetings, we get together at the end of the semester and revise.

For example, the idea of the web-based portfolio was developed and put together by Ms. Hess and Dr. Zimmerman.

The commitment to trial and improvement was the prevailing attitudes held by the faculty members and the instructors. It was a highly reflective course regarding what was taught and the way in which things were taught. The faculty members and the instructors refined the aspect of the assessment as well as experiences in class with technology and without technology.

The faculty members and the instructors examined the practice and suggested ways to improve. Dr. Zimmerman explained that the web-based portfolio had been improved based on the feedback from the instructors:

That is something that is even with us today. So I would not say that anything about portfolios has been dropped. It has just been changed over time based on what we learned about what the task needs to look like to help prospective teachers learn.

Throughout the years, the lead faculty members and the instructors worked together to make the course stronger; they put together ideas as to what the course should cover and how the course should be refined in order to help the prospective teachers gain a better understanding of teaching science lessons with technology.

5.2 A five-phase technology integration model

Claim: A strong theoretical and pedagogical model guided the organization of the course and sustained the change.
A five-phase technology integration model provided a basis for guiding technology integration into SCIED 458. As one of the grant proposal writers, Ms. Friedman explicated five phases that guided the design of technology integration in SCIED 458:

A five-phase technology integration model was conceptualized that informed our curriculum revision of the science methods courses. In the first phase of the model, students are viewed as science learners and engage in scientific inquiry using the specified technology tool. In the second phase of the model, the students focus explicitly on the technology tool. During the third phase of the model, “Curriculum Planner,” the students examine existing exemplary curricula to integrate the use of the technology tool. In the fourth phase of the model, the students move from the role of science learner to that of science teacher. The fifth phase of the model, “Teacher,” occurs in a school setting as the students plan and teach technology-enhanced lessons for supporting children’s scientific inquiry.

The instructors followed this model to guide and scaffold the prospective teachers in technology integration.

Dr. Zimmerman added that it was a valuable model that provided the prospective teachers opportunities to reflect in science learning and teaching in a circular cycle.

She said:

We [faculty members] operated from the conceptual model of thinking about how people learn to teach in general, specifically how they learn to support children’s science learning and then what role technology has to play within that. The model where prospective teachers start as science learners and progress to independent teaching over five phases was useful. In guiding our discussions and planning, it is very heavy on reflection in terms of their own practices and their own learning over time.

Dr. Donahue added that this model served as a basis for the design of the course and facilitated the implementation of technology integration in SCIED 458:

We design the course in order to have opportunities in that course to support technology integration. And that is the process we found very productive. I should say that learning to be a teacher who uses technology tools is a new concept of teaching. So we needed to support that concept of teaching throughout their course. We used sort of a conceptual change model….And I think that model if you want to call it how to organize the class was one of the sustaining factors because we all believe in that.
The faculty members and the instructors found that the conceptual model was powerful in assisting them in integrating technology into SCIED 458. During the four years between 1999 and 2003, the model proved to be a strong in scaffolding the prospective teachers in applying technology into the science lessons in a systematic manner.

5.3 Research Community

Claim: The formation of a strong research community of faculty members and graduate students initiated, facilitated, and sustained technology integration in the design of the course.

Having an agenda for research that was connected to the course was an essential part in the process. People associated with the program, doctoral students and faculty members for example, did research in the context of this course to examine how the course supported the prospective teachers in learning science with the use of technology tools. Based on the research findings, certain projects were modified or changed. The course underwent constant tweaking based on the evidence the faculty members and the instructors collected about how the elementary prospective teachers learned. The constant cycle of research feeding back into the course made it look different. Dr. Zimmerman emphasized how research findings provided evidence to support that technology was a powerful tool in enhancing science learning and teaching:

It is the importance of our own research, our own practice in the context of 458 in terms of how we are modifying and changing assignments over time because we are constantly learning from that process…. As somebody who is responsible for program development in a scholarly way, as well as the research, the research piece to me has really been important…. Various components are sustained only to the extent that they fit with the model. If we do not have evidence supporting how our students are learning to teach science, then we would not keep it around. But what tends to happen is we get evidence of how we might help do things better. So certain projects get modified or changed. But the technology piece has
Dr. Stoker usually contacted Dr. Zimmerman at the end of the semester and discussed some ideas from her experience and research findings in technology integration. Dr. Stoker illustrated an example of research community. She said:

I try to touch base with Dr. Zimmerman. I like to get together, I think at the end of each year, sometimes at the end of each semester….sit down with her and just go over ideas that we had, and ask, “What can you tell us from your experiences?” These conversations were really helpful. So I looked at her for some guidance, especially from her research regarding how we can use that to improve this course.

5.4 Positive recognition from the accreditation institution and national reviews

**Claim: Recognition from the accreditation institution and national reviews**

empowered the technology integration change efforts to sustain.

Technology integration in the science education program had gained positive feedback from the department as well as the National Council for Accreditation of Teacher Education (NCATE). When NCATE did accreditation reviews, they appraised web-based portfolios. The science education program had gained more attention related to technology integration. Ms. Hess claimed that such attention focused the faculty members and the instructors on improving and had them sustaining their efforts in the change process. She said:

When NCATE came in and did accreditation reviews, one certain thing that they hailed. I think they liked the idea of web-based portfolios. The science education program was getting attention, positive attention. They were related to the technology. So it almost became something that we cannot quit now. So we need to keep striving. We need to keep trying to do better. There was political attention that, I think, helped sustain it.

In the process, state standards placed a great deal of influence on technology integration. Dr. Zimmerman stressed how state academic standards in science informed their selection of topic for a long-term project every semester. For example, the instructors designed the units of lessons on watershed to respond to the new
standards from environmental ecology. Accordingly, they selected technology tools such as the probes to fit in the topic.

Positive attention and recognition served as a positive reinforcement for the faculty members and the instructors to continue their ideas. Because the change process took such a long time, people tended to give up if no encouragement was given. The recognition drove them to move on.

5.5 Reduced prospective teachers’ resistance

Claim: Reduced resistance to technology facilitated the change process of technology integration.

Previously, the elementary prospective teachers had very little experience with the science specific tools and they had not encountered them in elementary school or high school. The science courses offered by other colleges that they had taken before SCIED 458 tended to be large lecture introductory classes. Typically, their technology skills were not as strong as students in other areas based on a number of instructors’ observation.

One of the issues that the instructors encountered was that prospective teachers in general came to the program with a fear of science as well as technology. Basically, the intent of the course was to help the prospective teachers become more confident and comfortable as learners in science, get excited about and think about developing a framework for supporting children in science learning.

Dr. Zimmerman and most instructors claimed that since 1999, the elementary prospective teachers left this course with improved confidence in how to use technology and how to support children in science learning. In addition to instructors’ observation, the survey that was conducted with prospective teachers in 2000 also indicated that the prospective teachers gained confidence in integrating technology in
science teaching as a result of this course. Dr. Zimmerman explained that if the prospective teachers could not take advantage of a scaffolded learning environment to integrate technology into their lessons, there would be very few chances that they would integrate technology into science curriculum when they become in-service teachers. She said:

> If they are not comfortable with it [teaching science with technology], they are not going to consider it when they become in-service teachers. That [improved confidence] may sound really superficial, but I think it is really important. We wanted them to become critical consumers of science and technology. To help them realize the value added with technology is important. They should not use technology merely because it is there. They should be able to make an informed decision about whether they should use it or not. That is a piece that we are really pushing. We need to work on that.

The resistance from the prospective teachers had decreased over time and their attitudes had become more positive about technology integration. Ms. Aberdeen concluded that her students came in the class with more technology experience every semester, particularly in web-design.

Dr. Zimmerman expected that the prospective teachers could select technology purposefully to integrate them to the lessons to enhance children’s learning after taking SCIEd 458. Dr. Stoker also observed the more positive attitudes in recent prospective teachers. She said, “They resisted it heavily in 1999 because it was new. It was like integrating technology, and now you don’t hear one complaint because they are used to it.”

Dr. Stoker described that the influence of technology integration into science lessons was more on student teaching. She said:

> We find that the students like that so much that they tend to then borrow that software and use it in their field experiences even into their student teaching. I am a student teaching supervisor this semester. I had theses students in the fall in my science methods course, and now I am their student teaching supervisor, and they are borrowing the Science Court more now than they did then!
Dr. Donahue regarded that increased integration of such experience into student teaching was a positive factor that facilitated technology integration. He said, “Belle school district now is using all PASCO probes. I think that is the result of us having an influence there. So I think that is healthy.”

Over the years, the elementary prospective teachers showed reduced resistance to technology integration in the course. Ms. Aberdeen pointed out several factors that might contribute to their reduced resistance, such as more exposure to technology in their generation, the change of their attitudes facilitated the technology integration in the course.

5.6 Increased availability and sophistication of technology resources

Claim: Increased availability and sophistication of technology resources exerted positive influence on facilitating and sustaining technology integration.

Technology tools have been advanced in a more user-friendly way by the software manufacturers. Dr. Zimmerman explicated that current technology tools were becoming very easy for the elementary prospective teachers to learn:

The technology changes. Some of the tools that we use for sciencing get more accessible for the elementary classroom. The probes were initially in the secondary classroom, but now things are more elementary friendly….And as new stuff comes out, we are willing to try those new things in the classroom and then learn from them.

The manufacturer of the probes worked hard to accommodate the technology tools to elementary levels. Dr. Stoker said:

The company PASCO where we brought most of our probes, they have adapted, they have evolved in their thinking of what kind of probes are best use for middle school, and they are actually trying to reach down to the elementary grades.

The evolution from Hypermedia portfolios to web-based portfolios also depended on the development of the internet. In addition, the university’s support influenced technology integration projects indirectly in a number of ways. Dr. Stoker
explained that FrontPage was available in all computer labs on campus. The major reason that the software shifted from Claris HomePage to Microsoft FrontPage was because the prospective teachers could get access to it twenty-four hours a day, seven days a week. The university provided more server space so the prospective teachers could use a variety of pieces of evidence, such as lessons and pictures taken in school, to support their reflection on the internet.

Resources available in local elementary schools were a factor that facilitated technology integration. Over the years, the local elementary schools had gained more resources from different sources such as state and federal, which made the prospective teachers to teach science with technology in field experience more easily. Dr. Stoker said:

Most schools have technology now. There is not a school that I can think of that I have to take a computer into, and that’s a product of grants, both state and federal, whose goal was to get technology into the classrooms.

In short, the change process involved more than what was in place in the immediate environment, in this case, the science education program. The development of software and the internet and the support from the university and the local school districts played a part in the process.

In this part, I identified six overarching factors that influenced the change process positively. They included the key persons’ ability to identify issues related to technology integration, a five-phase technology integration model, the key persons’ commitment and collaboration, the research community, positive recognition from the accreditation institution and national reviews, decreased resistance from the elementary prospective teachers and increased availability and sophistication of technology resources.
6. Summary

This case provided a comprehensive examination of the dynamics of the process of technology integration in SCIED 458. I described technology initiatives from 1997 to 2003 and the current status of technology integration in SCIED 458 in 2002-2003. Then I explored a number of the factors that had a positive influence on the initiatives and the inhibiting factors that caused the initiatives to terminate or to improve. I concluded with six overarching factors that sustained the change process of technology integration in SCIED 458 from 1997 to 2003. After sharing the big picture of this case, I provided a better understanding of a sequence of stages that consisted of the change process, in this case, and the factors that contributed to the sustainability of technology integration in the next chapter.
Chapter 6 Discussion of Findings

The purpose of this study was to describe, interpret, and analyze what had occurred in the change process and develop a framework for understanding the factors that contributed to the change and sustained the change of technology integration in a science methods course, *Teaching Science in Elementary Schools (SCIED 458)*, from 1997 to 2003. This chapter starts with identifying and discussing a sequence of the stages that emerged from the research findings. The second part of this chapter focuses on a number of major factors that initiated, facilitated, and/or sustained the change process and how these factors interacted in the change process.

1. **The stages of adoption and diffusion, implementation, and institutionalization**

   Based on the findings, the change process of technology integration in this case had evolved through a sequence of stages from 1997 to 2003: adoption and diffusion, implementation, and institutionalization. Therefore, this section consists of three major parts: the stages of adoption and diffusion, the stage of implementation, and the stage of institutionalization. In each part, I reflected on a number of the change process models and provided the rationale for categorizing a certain period of time at a certain stage. I generated major indicators to characterize the state of technology integration in each stage. Figure 4 presents a schematic to indicate a sequence of stages that the change process had evolved through in this case from 1997 to 2003.

![Figure 4. A Sequence of the Stages in the Technology Integration Change Process from 1997 to 2003](image-url)
1.1 The stages of adoption and diffusion

Surry and Ely (2001) defined that potential adopters form an initial decision to use an innovation in the stages of adoption and diffusion. Van de Ven and Rogers (1988) suggested an innovation process that was divided into two sub-processes. The first sub-process includes the two initial stages, agenda-setting and matching, that involve the information gathering, conceptualizing, and planning for the adoption of an innovation, which leads to the decision to adopt.

Rogers (1995) stated that “such decision marks a watershed in the innovation process between initiation and implementation where all of the events, actions, and decisions are involved in putting an innovation into use” (p.394). In short, the potential adopters undergo the decision making process to reject or adopt an innovation when they experience innovations in the stages of adoption and diffusion.

Rogers (1995) also described the S-shape adoption curve to explain the growing number of people involved as the stages of adoption and diffusion develop. He pointed out that the process goes through a period of slow adoption before experiencing a sudden period of rapid adoption and then a gradual leveling off. In short, the number of the potential adopters is small but grows slowly in these stages.

There is a wide range in the rate of adoption of educational innovations. For instance, it took kindergarten schools about fifty years to reach complete adoption by U.S. schools (Mort, 1953). But driver training needed only eighteen years (from 1935-1953) to reach widespread adoption (Allen, 1956). And modern math took only five years, from 1958 to 1963 (Carlson, 1965). The widespread acceptance of the World Wide Web took five years, from 1995 to 2000 (Surry and Ely, 2001). As indicated in several studies by the Minnesota Innovative Research Program (1996), these stages required an extended period of time.
Reflecting on these theoretical frameworks and studies, I categorized the period between 1997-1999 as the stages of adoption and diffusion because of two reasons. First, few faculty (i.e., Dr. Donahue, Dr. Zimmerman) and instructors (i.e., Ms. Hess) participated in the process. Second, they were involved in the decision making process to reject or adopt technology tools. In this case, the stages of adoption and diffusion took about two years, which seems to be shorter than most studies. A possible reason might be that this study was concerned with small-scale change.

In the following section, I discuss the state of technology integration prior to the 1997-1998 academic year and between 1997-1999. Starting from 1997, technology initiatives had been increased in SCIED 458 progressively.

1.1.1 State of technology integration

In terms of technology integration, prior to the 1997-1998 academic year, there was no consistent technology integration. A variety of software and hardware had been tried out in different semesters depending on the interest of the faculty or the instructors. For instance, the Vernier probes were introduced one semester but were not considered for further use because the features were not appropriate for the elementary prospective teachers.

Between 1997 and 1999, more trial technology initiatives were introduced into SCIED 458. The portfolio project underwent a number of radical changes in terms of the authoring software (i.e., HyperStudio, Claris HomePage) and the form (i.e., paper portfolios, e-portfolios, web-based portfolios). For data collection tools, Dr. Zimmerman incorporated the old versions of Vernier probes in class activities in the summer of 1997. Dr. Donahue introduced an online collaborative tool, Connecting Communities of Learners, in 1998. These technology tools made their ways to the course. And the technology initiatives began from one section of the course and
diffused to other sections. In other words, the selection of technology tools looked sporadic and the extent of technology integration had been increased slowly because there were a few appropriate technology tools for elementary science education and because of lack of a framework for supporting technology initiatives.

Havelock & Zlotolow (1995) described the first stage, zero, in the CREATER (Care-Relate-Examine-Acquiry-Try-Extend-Renew) model as “establishing the need for action.” In “A Study of the Change Process Utilized by Colorado High School Principals,” Wildemuth (1992) studied forty-three adoptions of computer-related innovations in three large corporations and found that an identification of organizational problems did not occur. As a result, after the hardware and software were purchased, there were no specific plans for its use. Rogers (1995) also pointed out the pro-innovation bias in diffusion research and cautioned those involved in change efforts against thinking that adoption of innovation is always good or appropriate. Rather the objective, tangible advantage to adoption should be evident. Van de Ven and Rogers (1988) described that an organization must seek to establish the need for an innovation. These theoretical frameworks and studies suggested that a problem or a need of technology to solve the problem must be established in order to initiate the changes. Furthermore, this study indicated that in addition to the identification of a problem and a solution for using technology, appropriate technology tools must be available at the same time to initiate the changes.

1.2 The stage of implementation

Fullan (1996) defined implementation as “the actual use of an innovation in practice” and called the implementation perspective “both the content and process of dealing with ideas, programs, activities, structures, and policies that are new to the people involved” (p. 273). Van de Ven and Rogers (1988) explained that
implementation is involved in the events, actions, and decisions in putting an innovation into use. Rogers (1995) also described that implementation occurs when an individual also puts an innovation into use. He further explained that implementation may continue for a lengthy period of time, depending on the nature of the innovation. In short, these theoretical frameworks concluded that a majority of people in an organization adopt an innovation at their workplace and think about how to use it to better improve their current practice in the stage of implementation.

Reflecting on these models, I categorized 1999-2003 as the stage of implementation because of two reasons. First, the instructors adopted the technology tools in their course sections. Second, the faculty members and the instructors strived to achieve the goal of helping the prospective teachers integrate technology in science teaching and learning. They were engaged in the process of thinking about how to integrate technology tools and how to incorporate these technology tools within different class activities constantly. This stage took four years in this case.

In this stage, the state of technology integration into the course is as follows. The web-based portfolio was fully developed. An online discussion board, CourseInfo, was introduced. Science specific tools such as the PASCO probes, Tom Snyder’s Science Court and online collaborative tools were integrated into class. Also, STEPS Days and the field experience classrooms based on the technology integration model were initiated.

1.3 The stage of institutionalization

Miles and his associates (1987) stated that institutionalization takes place when an innovation is assimilated into the structure of an organization and changes that organization in a stable way. Eiseman, Fleming, and Roody (1990) proposed six indicators of institutionalization: acceptance by relevant participants, the innovation
being stable and routinized, widespread use of the innovation throughout the institution or organization, firm expectation that use of the practice and/or product will continue within the organization, continuation depending not on the actions of specific individuals but on the organization, structure and procedures, and routine allocations of time and money. Havelock and Zlotolow (1995) presented one of five commodities to be considered in pursuing transformational, systemic change efforts in the renewal stage: more differentiation, which means that different tasks should be assigned to specialists. This study identified five indicators as follows.

1.3.1 Structural integration of technology

In the school year of 2002-2003, it was evident that there was structural integration of technology into the course, which corresponded to a combination of the indicators of acceptance by relevant participants and the innovation being stable and routinized as proposed by Eiseman et al. (1990). Specifically, the web-based portfolio became a required assignment for the elementary prospective teachers in order to for them to reflect on their teaching during the semester. Science specific tools, including the PASCO probes and Tom Snyder Science Court, had been used routinely and consistently by all instructors; although, some minor modifications were made. Furthermore, these tools were also incorporated into two major activities related to technology, including STEPS Days and Teaching Science with Technology in Field Experience.

1.3.2 Revisiting and solidifying the weak strand of technology

The strand of online collaborative tools was revisited and solidified in 2002-2003, which indicated that the program had firm expectation of technology integration in SCIED 458. Revisiting and solidifying the weak strand of technology showed the
commitment to technology integration and was another way to represent the expectation of technology integration. Dr. Donahue and Mr. Bell attempted to integrate an online web-based collaborative tool, ANGEL, and put together an online inquiry investigation project by using the ANGEL system in 2002-2003. This strand was present for a number of years, from 1997 to 2002, but was not implemented very well in class. However, with the advent of ANGEL and the long-term inquiry-based investigation project in place, the instructors were able to enhance the prospective teachers’ understanding of using online collaborative tool to enhance the science learning experience.

1.3.3 Widespread of influence of technology

Eisemen et al. (1990) proposed that widespread use of an innovation in an institution is characterized as the stage of institutionalization. Technology integration in SCIED 458 was diffused to the schools in local school districts. Furthermore, the prospective teachers began to carry the experiences of teaching science with technology when they entered student teaching. Dr. Stoker illustrated that more and more students integrated the PASCO probes and Tom Snyder Science Court into the science lessons when they were student teaching in 2002-2003. The program’s efforts had a heavy impact on its’ surrounding environment and the prospective teachers, which created greater integration in one sense. Thus, in this case, the influence was not limited to SCIED 458 but also extended outside the institution, that is, the local school districts in the stage of institutionalization.

1.3.4 Specialization of workforce

Because technology aspect was assigned to the consultant and then was distributed to the university, the instructors possessing the expertise in science
teaching and learning were able to concentrate on their jobs. The findings were congruent to the study of Havelock and Zlotolow (1995). The technology training job was completely taken over by the technology coordinator. At the beginning of the semester, she held a workshop to teach prospective teachers to use the web authoring software, Microsoft FrontPage. The university had resources that the prospective teachers could approach for help if the prospective teachers had further questions.

This case agreed that separation of technology training and subject teaching facilitated the change process. However, this case raised a concern that technology consultants should be an insider or outsider. In this case, the technology coordinator from the College of Education and technology staff from the university had difficulty tailoring their assistance to meet the prospective teachers’ needs in the web-based portfolio.

Zaltman and Duncan (1977) found that the rejection of outsiders who take a leadership role is always an obstacle to change. Research (Aoki et al., 1977; Fullan & Stiegelbauer, 1991) also supported that the outside expert usually fail to be aware of actual situation, which inhibits the change.

Thus, this study suggested that school reformers should identify an insider in the field as a window who works with the outside technology expert constantly. Or school reformers should identify an insider who shows competency in technology literacy and offer technology training. This person can offer help to other colleagues.

1.3.5 No external funding

There was no consistent funding from the college, the university or the state Department of Education throughout the six years represented in this study. The program was awarded a major grant in 1999 from the state Department of Education. Since then, there was no other support; although, the key faculty members Drs.
Zimmerman and Donahue had tried hard to seek internal or external funding. In other words, there was interest in exploring additional resources and funding for implementing technology integration. Routine allocations of time and money are an important indicator in the stage of institutionalization (Eisemen et al., 1990). In this case, the routine allocation of money did not occur.

Pipho (1994) pointed out that state control over education funding makes true revolutionary reform of the education finance subsystem very difficult. Hirth (1996) supported his view on the importance of the finance system on educational reform. These studies concluded that the external funding plays a role in sustaining the change process.

Yet, the findings were somewhat contrary to the frameworks suggested by these change researchers. The change process sustained despite the fact that funding was only available for one year in 1999. This study indicated that the financial support from the state department of education was critical in providing the hardware and software necessary for technology integration in the initial stages. But after implementing, the funding played only a minor role in sustaining the change process. There were other factors that contributed to sustenance in this case. These factors are revealed in a later section.

These five indicators presented earlier were somewhat representative of the theoretical frameworks and studies that deal with institutionalization of change and extended the scope of these five indicators. There was structural technology integration in the course. In terms of tools, the weak strand was revisited and solidified, which represents a form of firm expectation of technology integration. In terms of process, it is evident that the influence of technology integration was spread widely to the local school districts. In terms of people, specialization of workforce
took place. In terms of the conceptual part, technology integration in this case reached a level of institutionalization in 2002-2003. However, there was still a level of institutionalization that had not occurred because routine allocations of money did not occur. Without continuing financial support, the technology integration project was not fully institutionalized, which leads to the posing of a lot of questions about what strategies can bring technology integration into the level of institutionalization completely and how long and what it takes to reach the level of institutionalization.

1.4 Summary

This section described the stages that the change process had evolved through from 1997 to 2003. They included the stages of adoption and diffusion, the stage of implementation, and the stage of institutionalization. This section also interpreted the state of technology integration in each stage. The next section analyzes the major factors that initiated, facilitated, and/or sustained the technology integration change process from 1997 to 2003.

2. Major factors that initiated, facilitated, and/or sustained the change process

In this section, I address the factors that initiated, facilitated, and signaled the change in individual stages as indicated in Figure 5 and the factors that sustained and were present throughout the stages but were not directly related to individual stages of adoption/diffusion, implementation, and institutionalization as shown in Figure 6. Because a number of factors played dual roles in initiating/facilitating and sustaining, I combine and discuss them in the same section.
Figure 5. Initiating/Facilitating and Sustaining Factors in the Technology Integration Change Process
Figure 6. Factors Sustaining the Change Process and Their Interrelationships
2.1 Gradual adoption of technology tools

This study suggested that gradual adoption of technology tools initiates and facilitates adoption and diffusion between 1997 and 1999, which may build a foundation for a large-scale reform in the near future. Take the portfolio, for example. After Dr. Zimmerman joined the program in 1997, she initiated the use of the e-portfolios along with Dr. Donahue, who had worked on paper portfolios for a few years, to better assist the prospective teachers in reflecting on their growth. In the summer semester of 1998, the task was moved to a web-based form and was piloted with a group of 16 students in a summer class co-taught by Dr. Zimmerman and Ms. Hess. Between 1997 and 1999, the portfolio was not a required assignment. Thus, the instructors and the prospective teachers participated in it voluntarily. No instructors were required to have their students complete this assignment. The faculty members and the instructors obtained the volunteers’ feedback on this assignment and examined if the task was helpful in assisting the prospective teachers in reflecting on teaching based on their research every semester.

Rogers’ (1995) fourth innovative attribute, trialability, refers to the extent to which a prospective adopter can try out an innovation before committing to full adoption. Slow adoption, a little at a time rather than all at once, should encourage the continuance of innovations. The Harvard Business School’s studies from the 1970s are an example. The cases were introduced as a single activity in a lecture-based classroom, and then infused over time as an integral part of the course (Ellsworth, 2000). Havelock and Zlotolow (1995) also proposed to put the tool to trial for the first time in the system, so called pilot testing, in order to see if the tool can be accepted by the adopters and if it can really work in an actual place where it should function. The decision of continuance or discontinuance was based on the results of the trial. In
short, gradual adoption of technology tools provides more opportunities for the potential adopters to adapt to their current situation. Technology tools are likely to diffuse more rapidly than those that immediately replace past practice completely. The findings are congruent to the theoretical frameworks and the studies. The web-based portfolio, for example, was piloted in one section for a few semesters and the results of the trial were used as a basis for improving the selection of software and the organization of the web-based portfolio. When more and more instructors realized how they could use the web-based portfolio with the prospective teachers and how it could help the prospective teachers in reflecting on their teaching, they continued to use it. The Vernier probes and CCL were also piloted with one section. But the instructors found out that these two tools were inappropriate and terminated the use of both tools in their section.

2.2 Formation of a transformational shared leadership team

The transformational, shared leadership team played dual roles in initiating and facilitating the stages of adoption and diffusion from 1997 to 1999 and sustaining the change process from 1997 to 2003. First, this study suggested that the formation of a leadership team in the early stage of the change process initiates and facilitates adoption and diffusion. Drs. Donahue and Zimmerman combined their efforts in the portfolio and further in technology integration in SCIED 458. They put their ideas together and co-authored the Link-to-Learn grant proposal in 1998. They acted as innovators who led the instructors to try various technology tools.

Rogers described that “the innovator, who readily adopts an innovation, plays a gatekeeping role in the flow of new ideas into a system” (1995, p. 264). Ely (1990) identified leadership as one of the eight conditions that facilitate an innovation’s diffusion and adoption, which is supported by subsequent research using both
qualitative (e.g., Newton, 1992) and quantitative (e.g., Bauder, 1993) methods. A number of field research studies (Corbett, Dawson, & Firestone, 1984; Ross & Regan, 1999) on the characteristics of effective consultant practice also informed the effective strategies for the people who seek to take a leadership role in the change process. For example, the leader should understand the innovation, its purpose, and the benefit it is intended to produce. In short, informed leadership is a stimulus that initiates the change process. Generally, change researchers discussed leadership from the standpoint of an individual leader. This study brought a new perspective of a leadership team in the stages of adoption and diffusion.

Second, a leadership team had been formed to sustain the change process since 1997. Shared leadership was formed by Drs. Donahue, Zimmerman and Stoker. Dr. Donahue had been in the science education program and had been a coordinator of the Teacher Education Program in the department for several years before Dr. Zimmerman came to Penn State in 1997. He understood very well the goals of the program and the logistics of the department, including people and resources. After Dr. Zimmerman joined the program in 1997, they combined their efforts and began to pilot several technology initiatives with a small group of students in the course. Dr. Zimmerman was in charge of the science education program and had strong ideas and expertise of how technology should be integrated into the course. In order to integrate the technology tools into the current course, Dr. Donahue and Dr. Zimmerman had developed a systemic plan beginning in 1999, including coming up with a technology integration model to guide the implementation of various technology tools and re-conceptualizing the course.

Leadership gradually shifted to Dr. Stoker and Dr. Zimmerman in the year 2001. Dr. Stoker joined the leadership team in 1999 and started as a liaison and an instructor.
She was able to familiarize herself with the program and the course and established the relationships between the science education program and the local school districts before she took the role of the course coordinator. She worked with Drs. Donahue and Zimmerman in terms of course design, research and teaching.

Ely (1999) identified eight conditions that facilitate the implementation of educational technology, and one of them is formal and informal leadership. One of the characteristics of leadership is vision that empowers people to accomplish the goal (Belesco, 1991; Evans, 1996; Fullan, 1993; Gardner, 1981). Other characteristics include possessing change management skills and exercising strategic plans. In addition, Fullan and Stiegelbauer (1991) suggested a number of major guidelines for the people who assume a change agent’s role, including empowering your faculty and staff, establishing and communicating a clear vision, building alliance with other groups of people, understanding the innovation with the benefit that it intends to produce, and being receptive to feedback. There were also a wealth of discussions as to three types of leadership- transformational leadership (Bennis & Nanus, 1997; Senge, 1990), participative leadership (Sergiovanni, 2001) and autocratic leadership (Owens, 2001). Perceiving the change as a new opportunity, transformational leadership shares values and beliefs on a deeper level with followers who are independent and self-critical. Zaltman and Duncan (1977) emphasized that one of the barriers that impede technology integration is the rejection of outsiders who take the role of the change agent. Furthermore, in terms of key players and the stakeholders, Ely (1990) claimed that commitment is the vital reason that sustains the implementation of an innovation.

The literature review concluded that commitment of leadership is critical in sustaining the change process. Furthermore, the sustainability of the change usually
occurs when the person who takes a leadership role is inside the organization. However, there is no answer to which leadership style is the best.

The findings provided a perspective on how leadership was formed in the context and the leadership style worked in the change process. First, Dr. Donahue, Dr. Zimmerman, and Dr. Stoker joined the leadership team at different points in time, but they were able to pass along their experiences to the person who was actually in charge of SCIED 458. Dr. Zimmerman and Dr. Donahue had high expectations and were committed to technology integration over time. They provided cognitive leadership in a way that they directed the instructors and graduate students teaching or researching technology integration within the context of SCIED 458. They also provided affective leadership in a sense that they worked with the instructors as a team and reinforced their efforts over time. The course instructors always looked to these three people as a leadership team. These three leaders possessed the common characteristics: sharing vision with people, being self-critical and independent, seeing the change as a benefit for the prospective teachers, and being insiders of the department and the program. The leadership team in this case was powerful in a way that each leader could contribute different expertise and interest and take care of the responsibilities in the levels of department, program, and local school districts. Thus, data analysis indicated that transformational, shared leadership played a critical role in stimulating the stages of adoption and diffusion and sustaining the stage of implementation in this case.

2.3 Use of powerful pedagogy and methodology

This study suggested that pedagogy and methodology are powerful factors that facilitated the implementation of technology integration since 1999. At a macro level, a technology integration model generated by Dr. Zimmerman and a group of graduate
students in 1998 informed the pedagogy. Based on this model, SCIED 458 was re-conceptualized into three levels. In these three levels, the instructors progressively scaffolded the prospective teachers learning about how to teach science with technology. Data collection tools, simulations and modeling tools, and online collaborative tools were introduced in class. Then the prospective teachers planned science lessons, incorporated data collection tools and simulations and modeling tools, and taught the lessons with elementary students during STEPS Days. By the end of the semester, they planned lessons based on the topic assigned by their classroom mentor teacher. They selected and integrated appropriate technology tools into their lessons and taught the lessons in their field experience classroom. They also used online discussion tools to communicate with the instructors or other prospective teachers outside class. Plus, they developed the web-based portfolio throughout the semester to reflect on their teaching.

Ellsworth (2000) pointed out that “a given innovation may well require other supporting innovations” (p. 36). A number of studies also supported that several coordinated and mutually reinforcing innovations, such as infrastructure, curriculum, pedagogy, and technology, are usually necessary to support effective, lasting change (Hinnant & Oliva, 1997; Hirumi, 1995). Rogers (1995) also pointed to the concept of technology clusters as the systemic notion of introducing multiple, mutually reinforcing innovations as a package. In short, these change researchers were concerned about facilitating the implementation by providing a structure that guides the use of different technology tools in a system and assists the adopters in using them as a package.

In this study, technology tools required other supporting innovations. Three levels of class structure reinforced the use of the science specific tools throughout the
semester. In the first level, the prospective teachers learned these technology tools as learners. In the second level, they planned science lessons with technology and implemented these science lessons with elementary children under the guidance of course instructors in STEPS Days. In the third level, they planned science lessons with technology and taught these lessons in their field experience classrooms. In addition, the web-based portfolio served as a feedback loop that reinforced and supported the use of the science specific tools in every level. The supporting innovation in this case was the three levels of course design that fostered technology integration model.

At a micro level, this study suggested that clear identification of software and conceptualization of the task facilitated the implementation of technology integration. In the web-based portfolio, for example, the selection of authoring software used to create the web-based portfolio and the conceptualization of the web-based portfolio had arrived at a stable stage during 1999 and 2003. During these four years, Claris HomePage or other software was used in the first four semesters and was replaced by Microsoft FrontPage in the subsequent four semesters. During 1999 to 2001, the framework to organize the web-based portfolio underwent some changes to enhance the prospective teachers’ reflection on their teaching. The web-based portfolio consisted of two parts, authoring software and the conceptualization.

Rogers (1995) described that an innovation “usually has two parts: (1) a hardware aspect, consisting of the tool that embodies the technology as a material or physical object, and (2) a software aspect, consisting of the information based for the tool” (p. 12). The findings provided a slightly different perspective of Rogers’ definition of an innovation. That is, the web-based portfolio was made up of two parts, authoring software and the conceptualization. Authoring software is a tool to create
the web-based portfolio; the conceptualization embodies the information the
web-based portfolio contains and intends to achieve. In short, technology integration
involves identifying what software is appropriate and the essential information the
technology task entails. They are complemented by each other. Without either one of
them, the task cannot be completed.

2.4 Formation of a learning and research community: Scholarship of teaching and
research combined

A learning and research community played dual roles in initiating and facilitating
the stage of implementation in 1999 and sustaining the change process from 1997 to
2003. In other words, a combination of scholarship of teaching and research is very
critical in this case.

In addition to these three faculty members, commitment of the key instructor was
another factor for initiating, facilitating, and sustaining the change process. Ms. Hess
had been an instructor for four years. Ms. Aberdeen and Mr. Bell had been instructors
for two years, a total of four semesters. In addition to a long period of involvement in
teaching SCIED 458, they contributed their ideas to the research agenda within the
context of SCIED 458.

The key leaders and the instructor team members worked as a learning and
research team. They all followed the same syllabus and did similar things in class.
They also held regular meetings to discuss what should be improved. A few veteran
instructors served as mentors for new instructors. Yet, it was not only a learning
community but also a research community. The faculty members Dr. Zimmerman and
Dr. Donahue and the instructors Ms. Hess, Ms. Aberdeen, and Mr. Bell did research in
the context of this course on a number of facets as to how technology tools enhanced
the prospective teachers’ ability for science teaching and learning. Their research
assisted the faculty members and the instructor team in understanding what was in place and further suggested how the design of the course and technology integration should be modified. In short, re-defining and re-clarifying of technology tools was useful, which provided an opportunity for the faculty members and instructors to examine and refocus on the goal and redirect their energy to the most essential technology tools.

Van de Ven and Rogers (1988) stated that the stage of implementation consists of redefining/restructuring, clarifying and routinizing. Redefining and restructuring occurs when the innovation is re-invented to accommodate the organization’s needs and structure more closely. An innovation is likely to continue if its purpose fits the organization after redefining/restructuring. Otherwise, it is likely to terminate. The timeframe of redefining/restructuring is generally short.

Havelock and Zlotolow (1995) described that one of the most common causes of failure in school reform has been that the different groups within the system were not united in their efforts. In his change model, Banathy (1994) asserted that “systemic design is a collaborative activity undertaken jointly by stakeholders at all levels” (p. 29). Reigeluth and Garfinkle (1994) elaborated on Banathy’s idea and discussed the issues surrounding systemic reform. In ensuring stakeholder involvement, they suggested the participants should coordinate efforts and work as a team.

This study was congruent to these theoretical frameworks and the studies, but it elaborated on what activities different groups of adopters should participate in. In this case, the faculty members and the instructors found opportunities for their research agenda and coordinated their research to better improve the design of the course as a feedback loop. There was collaboration on the design of the course, teaching, and various forms of the feedback loop such as researching findings, the instructors’
suggests, and the prospective teachers’ feedback that existed to strengthen the collaboration.

2.5 Separation of subject teaching and technology training

This study suggested that separation of technology training and subject teaching and the collaboration between them facilitated the implementation of technology integration. In 2002, the job of training students on authoring software for the web-based portfolio was moved from the instructors to a technology coordinator in the College of Education. Before that change occurred, the instructors used most of their time in teaching the prospective teachers how to use the authoring software and solve technical problems during office hours at the expense of spending more time teaching them science. The shift of technology training enabled the instructors to refocus their energy and time teaching the inquiry aspect of science. The instructors held a positive attitude toward such change. However, the technology coordinator only taught them how to use Microsoft FrontPage in one workshop at the beginning of the semester. The technology coordinator needed to contact the course coordinator regularly to keep abreast of the prospective teachers’ needs in every semester. The technology coordinator would not provide support after the workshop. The prospective teachers then went to the university’s computer center to seek help. However, because the technology specialists had no knowledge of the prospective teachers’ technology proficiency and what the web-based portfolio should entail, the technology specialists had difficulty in tailoring their assistance to meet the prospective teachers’ needs.

Fullan and Stiegelbauer (1991) discussed the different impact that external and internal consultants might bring into the organization in technology integration. External consultants have the potential to contribute advanced knowledge in the use
of technology. However, lack of awareness of the actual situation where technology is used inhibits them from contributing their knowledge. A number of research studies (Aoki, Langford, Williams, & Wilson, 1977) supported that internal consultants seem to do a better job in integrating technology than external consultants because internal consultants are aware of the situations within the organization. In short, the technology training job should be assigned to persons who possess technology expertise and have a certain degree of awareness of the settings. Further collaboration between external consultants and content experts can ensure the success of technology integration. Based on the findings and the earlier research, it seems desirable to delegate technology training and subject teaching to different people. In this case, the instructors were not able to concentrate on their expertise but had to spend much time in instructing the prospective teachers how to use software and solve technical problems. The technology coordinator from the College of Education worked very closely with the course coordinator. But the workshop she held was a one-time event and there was no way to follow through on the prospective teachers’ needs. Additionally, the technology specialists from the university did not collaborate with the course coordinator and thus had more problems working with the prospective teachers. In short, different delegation of technology training and subject teaching is important. Collaboration between them is required to facilitate technology integration.

2.6 Influence of the Immediate Environment

Ely (1990) defined resources as “the things that are required to make implementation work” (p. 3). Resources refer to money, tools and people that facilitate the change. A number of studies pointed out that several projects fail due to shortage of resources or lack of preparation regarding the allocation of resources (Wilbur, 1999; Jayasuriya, 1999; Eshelman, Juras, & Taylor, 2001). Clearly, the
resources in the system are critical.

In this case, the environment surrounding the science education program placed a great influence on sustaining technology integration into the course. The immediate environment refers to the C&I department and the university. For example, the C&I department contributed the space to construct a TEST lab and Resource Room, so the prospective teachers had opportunities to see the demonstration of the tools and borrow the tools for use in school.

The university contributed to technology integration in a number of ways. First, technology training of authoring tools was supported by the university, which removed the key instructors’ responsibility in this area. Despite the inability of the technology staff from the computer center at Penn State to tailor to the prospective teachers’ need in creating the web-based portfolio, which was still a significant resource for this process.

Second, the findings showed that the support of the university in hardware or software was critical. In terms of online collaborative tools, the university offered ANGEL as a tool for the instructors and the students to use. Before, the course used the tools such as CCL and CourseInfo that were offered outside the university, which failed to continue because of complicated logistical problems. In addition, in terms of authoring software, the university offered free copies of Microsoft FrontPage for the students and installed it in all labs on campus, which enabled prospective teachers to use it. Before, the authoring tool, Claris HomePage, was only available in the science education program’s lab and was difficult for the prospective teachers to access.

Third, the university provided more space for the prospective teachers to create their web-based portfolio online. Before, the limited availability of disk space prohibited prospective teachers from putting more materials online. The university
also kept offering a better way for the prospective teachers to upload their files online, which had earlier been a major barrier for most prospective teachers. Although the university’s support for these technology tools were not only for the SCIED program but for everyone in the university, it just so happened that the changes came at the time when it was most supportive of change in SCIED 458.

The findings suggest that to ensure the sustainability of technology tools, resources from all subsystems within one system should be sufficient enough to complement what the lower system does not have. In this case, the university’s support was very critical to complement what the science education program lacked to make technology integration sustain.

2.7 Influence of the External Environment

A system is defined as “a set or arrangement of things so related or connected as to form a unity or organic whole” (Webster’s Dictionary, 1979, p. 1853). In addition to the discussion of the immediate environment that had impact on the change process in this case, all levels of external environment should be considered as well. A number of authors examined different key components (subsystems) of any educational structure. For example, Reigeluth and Garfinkle (1994) discussed the subsystems of finance, local and state governance, and student assessment. Hirth (1996) also offered another perspective on the role of various non-instructional systems in contributing to lasting change. He presented a model to uncover the interrelationships among policy making bodies, reforms, and finance system components.

External environment, in this case, refers to the environment that exerted indirect influence on the change process. The external environment or the systems coupled with the science education program, starting from the small unit to the larger unit, included local school districts, the state department of education, the professional
organizations, and society. Each of them placed both positive and negative influence on the sustainability of technology integration into the course in a number of ways. This part discusses how each system placed impact on the change process.

2.7.1 The local school districts

During the first few years, 1997 to 1999, a large number of the prospective teachers had difficulties implementing their technology-enhanced science lessons in their field experience because the in-service teachers working with them had little or no background in teaching science with technology. In addition, the schools where they were placed lacked the software and hardware to support them. Yet, as time went by, the prospective teachers were able to implement the science lessons with technology and, furthermore, carry their ideas into student teaching because the program established partnerships with a local school district. In addition, with the efforts from the science education program and the state department of education, the school and the in-service teachers became very receptive to inquiry-based science with technology.

2.7.2 The state department of education

The science academic standards from the state department of education also played a role in dictating the design of the course. The program designed and adapted the science curriculum to meet the state’s standards in order to provide the prospective teachers a better understanding of what the state required of them after they graduated from college. The state’s funding also supported the elementary schools to have sufficient resources for implementing what the science education program was trying to accomplish in 1999.
2.7.3 Professional organizations

One of the conditions that sustain implementation is rewards or incentives (Ely, 1990). Ely added that whether the reward is intrinsic or extrinsic, it should be there in some form. Political attention tended to be a big drive for the faculty members and the instructors in the science education program. Over the last few years, the faculty members and the instructors had been very productive in publishing journal articles and presenting conference papers regarding the integration of technology into the SCIED 458 course. They also received the recognition from a national accreditation organization, particularly for the use of the web-based portfolios. In this case, positive attention from the outside organization was critical. The recognition by an accreditation organization, National Council for Accreditation of Teacher Education (NCATE), meant that the faculty members and the instructors gained confidence in how they integrated technology in the science methods course, SCIED 458. By means of journal articles and conference papers, they were also aware that what they were doing drew the attention and interest of people working in similar areas of research and their accomplishment was reinforced. This case informs us that in education settings, reward can be enhanced by a number of ways and it is not necessary to use money as a form of reward.

2.7.4 Society

Technology advancement in society is another factor that influenced the sustainability of technology into the course. In 1998, the portfolio moved from an electronic to a web-based environment because the internet became more mature. Authoring software packages such as Microsoft FrontPage became easier for the prospective teachers to access, and thus it was easier for them to create the web-based portfolio. Initially, the university software used for uploading software was difficult
for the prospective teachers to use. Yet, with the advancement of file transfer software, it was no longer a major issue for the prospective teachers to upload their files for the web-based portfolio.

In addition, more and more software companies were devoted to create instructional technology for elementary levels. PASCO and Tom Snyder were very supportive of what the program did and provided more tools and professional training for the faculty members and the instructors. PASCO worked hard on developing USB compatible and more elementary friendly tools in recent years.

2.8 Reduced resistance of the elementary prospective teachers

Zaltman and Duncan (1977) discussed four major categories of resistance to technology focusing on increasingly smaller units: cultural, social, organizational, and psychological. Four examples that fall into psychological barriers to resistance include perceptions, homeostasis, conformity and commitment, and personality (Zaltman & Duncan, 1977, p. 81-88). Particularly, selective perception causes individuals to note or retain only certain facts about the innovation, usually supporting a view they always hold (Zaltman & Duncan, 1977, p. 81).

For the prospective teachers in the early years of SCIED 458 implementation, resistance was an issue, while for the prospective teachers in the later years, it wasn’t so much an issue. The prospective teachers’ resistance mainly came from their inexperience of inquiry-based science and technology, which falls into the category of psychological barriers to resistance. Their inexperience caused them to perceive that teaching science with technology was an impossible mission. Before their senior year, most of them took science courses that tended to be large lecture introductory classes and lacked technology.

A possible reason might be that the prospective teachers grew up in an
environment where they were exposed to more and more technology tools. Thus, they were not afraid of technology anymore and were more receptive to learn how to use technology. Teaching science lessons with technology had been mandated since 1999. Due to teachers’ reduced resistance to technology, they were more willing to negotiate with their mentors in field experience classrooms and overcome logistical or technical problems they encountered in school. Because of more experience with technology, they needed less technology training, which means that instructors did not need to invest most of their time teaching technology. With their increased confidence of integrating technology into science lessons, it was likely that the prospective teachers would use it again in student teaching or in their future classrooms, which helps sustainability.

2.9 Summary

Systems design theory provided a basis for extracting eight factors in this section. There are a number of perspectives on systems design theory and the commonalities are as follows. Effective change must consider all members and components of the system, their interrelationships, and their relationships to other systems, as well as the relationship of the system as a whole to larger system of which it is a part of with which it interacts (Banathy, 1994). Hammond (1997) found the connections between school organization, professional knowledge, and the teacher education and development subsystems in systemic reform. This section explicated the members, the components, their interrelationships, and the change management strategies within the SCIED 458 context.

These eight factors concluded that the change process in this case involved people and other systems outside the course. Here the key members were the faculty and the instructors. Although the prospective teachers were not the key members, their
reduced resistance to technology helped sustain the change process. The systems that had direct and indirect impact on the process included the college, the university, the school districts, the professional organizations, the state department of education, and society.

3. Summary

Before I studied this case, I asked, “What is the right system to integrate technology?” This study provided an insight to a variety of complex factors related to people, tools, and process in a sequence of the stages of the change process. This study also recognized that systemic reform requires considerations of the members and other systems outside the course. These components should be viewed holistically in order to sustain change efforts. Drawing on the study of this six-year case, the framework for integrating technology is presented in Chapter 7.
Chapter 7 Implications and Conclusion

The ultimate goal of this study was to provide a framework for integrating technology in educational settings. Combining the schematics in Chapter 6, I start chapter 7 by presenting the mechanisms and processes to sustain change in educational context. This chapter also addresses the implications for case studies research methodology, systems and change theories and elementary science education research. In particular, I recognize a number of areas that need to be examined and provide recommendations for further study. I conclude this chapter by summarizing my four-year experience inquiring into this study.

Initiators (e.g., identify a problem)

Figure 7. Framework for Integrating Technology in Educational Settings
1. Framework for integrating technology

As shown in Figure 7, the framework is meant to inform change mechanisms in terms of planning and implementation of technology integration. Specifically, the framework includes the elements that are constant and essential influences for sustenance of a change process. The reasons for developing the framework would be to describe different stages and maintenance and inclusion of certain types of factors to make change happen and furthermore explicate how the framework could inform both research and practice in this area. In short, this framework provides a systemic perspective of planning the technology integration change process.

1.1 During the stage of adoption and diffusion

In this section, the initiators of the change process and four factors essential to make and sustain change during the stage of adoption and diffusion are discussed. Outside the box of the framework are the initiators of the change process. In reality, the initiators of change could be anything. In this specific instance, the change came from the identification of an instructional problem.

The first factor is the identification of key persons within the institution who view technology as a desirable tool to the problem and recruitment of these key persons to form a leadership team. This team would ideally possess expertise in subject matters and show their commitment in integrating technology to optimize learning and performance. The joint effort of these key persons is a powerful force to mobilize the institution to change because they can delegate their responsibility to deal with different aspects in the technology integration change process and pass along their experience. In this case, Dr. Donahue worked with Dr. Zimmerman as a leadership team in terms of course design, research, and technology integration. Dr. Stoker joined afterwards as a liaison to bridge the relationships between the science
education program and the local school districts. Research conducted by Mize and Gibbons (2000) indicated that leadership level played a critical role in technology integration in their case studies of three public school classrooms. Their study revealed that the persons at leadership level should not communicate their vision in the form of mandates and rather should communicate it by example. Thus, the formation of a leadership team is indeed a critical factor because they not only share vision with each other and also set example for their subordinates.

After initiating the technology integration change process, it is important to build a rationale for using technology that is visible and explicit for the potential users or learners. It is easy to convince the potential users or learners to learn innovative technologies when they believe that using technology is the best way to enhance their performance. There is also a need to justify the use of technology before the potential users or learners buy into the solution. It is essential to avoid using technology for technology’s sake. A study conducted by Evans (2000) indicated that a sound rationale for the use of technology had positive influence on teaching and learning mathematics in community colleges. In order to persuade people of its soundness, the rationale was grounded in theory, empirical data, and practice. Thus, potential learners tend to be more receptive to technology integration when a rationale is offered.

In addition, to justify a rationale for integrating technology, it is important to search for different possibilities of hardware and software and pilot test them with a smaller group of the learners or users that are representative of the actual users or learners for a lengthy period of time. There are a variety of technology tools, such as subject specific tools, general productivity tools, or web-based synchronous or asynchronous software applications. The next step is to select those technologies that suit the goal, are compatible with the institution’s existing infrastructure, and are
friendly for the potential users or learners. In this study, the key persons selected science specific tools because the elementary prospective teachers were able to engage in authentic science learning by using these tools. Moreover, because the course instructors and the elementary prospective teachers were not able to operate complex technology tools, the technology tools used in class had to be user-friendly for them.

The next essential step is to pilot-test the technology tools. There are three sources that provide feedback to refine the design of the project, including course instructors, students, and researchers. Course instructors can inform how they feel about using the tools and how technology tools can be integrated into class and curriculum better. They provide the assessment data that support the utility of technology tools in enhancing learning. In addition, they can point out students’ technical and conceptual problems and suggest ways to help. Students can add if they learn better by using technology tools and if the technology tools are easy to operate. Researchers can assess the project holistically in terms of technology integration and conceptualization of curriculum. The feedback offers opportunities to modify the project to ensure that the project takes care of pedagogical methods, technical aspect, and logistical aspect. For example, Drs. Donahue and Zimmerman piloted different technology projects with a small group of elementary prospective teachers for a lengthy period of time before they actually used the tools with the whole group of prospective teachers. During the course of pilot-testing, they conducted numerous studies to refine their design. Driscoll (2002) suggested to pilot test the project and recommended a detailed list of steps to implement a pilot in web-based training program. Thus, pilot-testing is necessary in different kinds of innovative learning environments.

The formation of a research community serves as powerful strategy to facilitate
technology integration in the early stages of the change process. Conducting research within the context of integrating technology to examine practice critically helps generate better practice. When more people are involved in research activities, more results can be produced to support better practice that draws on research-based evidence. The research community is ideally formed by college faculty and graduate students who established close relationships with classroom teachers. In this case, the conceptual model for guiding technology integration was put together by Dr. Zimmerman and a number of graduate students. The framework for developing the web-based portfolio underwent several revisions based on research every semester since 1997. Research conducted by Balach and Szymanski (2003) investigated the dynamics of a learning community through collaborative action research. This study revealed that the dynamics of collaboration, inquiry, parity, reflective dialogue and shared vision shape the progression of the group. The research community in this case truly reflected these characteristics. In addition, according to Cibulka and Nakayama (NPEAT, 2001), a learning community is “a group of educators committed to work together collaboratively as learners to improve achievement for all students in a school...one that consciously managed learning processes through an inquiry-driven orientation among its members” (p.4). More specifically, a research community is one type of a learning community because they strive to improve students’ performance by involving them in research activities.

In short, the critical point that determines whether the stage of adoption and diffusion will evolve to the stage of implementation depends on how to expedite the potential adopters in the process of decision making of adopting technology and how to increase the number of the actual learners or users. It is important to be aware of these strategies to empower the progress of the change process. Otherwise,
technology integration might be in the process of termination.

1.2 During the stage of implementation

In this section, five factors essential to make and sustain the changes during the stage of implementation are discussed. In the stage of implementation, it is essential to integrate pedagogy and methodology that can provide a structure for technology integration at macro and micro levels as indicated in Figure 7. At the macro level, it is important to offer a number of guidelines or a blueprint of integrating technology into the current institution’s structure or class’s structure. In this instance, a conceptual model was generated to provide a structure of integrating three types of science specific tools into class’s structure in three progressive stages in SCIED 458. At the micro level, it is important to conceptualize appropriate instructional strategies, assignments, activities, and assessment that integrate subject matter and technology and reinforce the use of technology with students consistently. In this instance, a variety of different learning activities, including assignments done in class with elementary prospective teachers’ fellow students and in field experience classroom, were required in order to provide them more opportunities to integrate technology into their lessons.

A number of studies have suggested that a framework for integrating technology is needed no matter how large the reform scale is. Whitehead, Jensen, and Boschee (2002) provided a framework for bringing computers into the classroom and issues that teachers, through administrative support, need to address in trying to develop a closer link between computers and the curriculum. Driscoll (2002) also offered a framework for teachers for thinking about how technology can support their instruction. In short, a framework that can deal with the levels of institution’s structure and curriculum itself is necessary in the change process of technology
integration.

The next factor that facilitates the implementation of technology is specialization of workforce, that is, separation of subject teaching and technology training. Yet, there must be methods to bring collaboration between two tasks. One method is to identify an insider in the field as a liaison who works with the outside technology experts constantly. Or the alternative is to recruit a teacher who shows competency in technology literacy and offer technology training. This person can offer help to other colleagues. In this instance, course instructors recognized that it is a desirable change to shift software training to a technology coordinator from the College of Education and technical staff from the university. Because the technology coordinator and the technical staff were not able to accommodate their training to the need of the elementary prospective teachers, the need of careful collaboration between two tasks was recognized. Research conducted by Ediger (2002) also pointed out that one of the reasons why technology was not increasingly used to improve reading curriculum in the public setting was the failure to allocate a technology coordinator to help train in-service teachers and coordinate technologies. Thus, the collaboration between subject teaching and technology training is one of the determinants for the success of technology integration. In order to enable the stage of implementation to move to institutionalization, the critical point is to enable the stakeholders to realize the value of technology in teaching and learning.

Third, in addition to the formation of a leadership team in the early stages as an initiator, continuing commitment of a transformational leadership team sustains the change as indicated in Figure 7. The transformational leadership style in this study truly reflects Senge’s view on current view of leadership in systemic change. Senge (1991) stated, “In systems approach, leaders’ roles will differ dramatically from that
of the charismatic decision-maker. They will be designers, teachers, and stewards.” Senge (1991) further explained that “leaders’ sense of stewardship operates on two levels: stewardship for the people they lead and stewardship for the larger purpose or mission that underlines the enterprise.” Thus educational reformers should adopt a similar leadership style. That is, it is essential to look for the persons at higher levels within the educational institution who hold the vision of technology integration, have commitment to a variety of change activities such as design, and are open to share ideas and beliefs with other capable subordinates. Then form a group at the outset of the change process and continue to work with each other to deal with issues that emerge throughout the change process.

Fourth, a combination of scholarship of teaching and research is a powerful factor in sustaining the change process. As Senge (1991) indicated, the formation of a learning organization is necessary in reforming an organization in systems approach. Banathy (1996) also advocated the design community in transforming education. Thus, key school reformers should work very closely with teachers or instructors and researchers in the field. A number of studies (Bransford, Brown, & Cocking, 1999; Toth, Klahr, & Chen, 2000) have shown that bridging research and practice is essential in improving students’ performance in classrooms. There are a number of collaborative activities: regular meetings, attending professional development workshops, and collaboration on research studies. It is essential to seek ways to communicate and involve the persons who take teaching and research roles in consistent, shared dialogue to sustain the change process.

Fifth, it is necessary to identify different levels within the educational system and non-educational system that place influence on the change process. This allows for adopting approaches to strengthen the synergy among these systems and tackle the
problems that may arise from these systems. At the university level, the university administration should be alert to the importance of the support that can contribute to the technology integration change process by establishing professional development programs and offering hardware, software, and research-based practice. At the state level, the state department of education plays a critical role in the change process. It dictates the development of educational programs by academic standards. Furthermore, it provides a financial source to expedite technology integration while financial support seems to decrease in recent years. At the local community level, it is crucial to involve local school districts’ teachers, students, and parents. It is essential to plan a variety of ways to establish relationships with the community, such as delegating a particular person to coordinate activities that involve local community and local school and district people on a regular basis. At the nation level, it is essential to identify means to gain recognition from accreditation agencies, to attend national contests or reviews or professional organizations and to author articles in journals to share experience. Outside the educational system, the focus should be on developing partnerships with software manufacturers for appropriate support. The companies can provide technical assistance and buy-in. They can also offer professional development workshops for the potential users and learners.

Outside the school, community participation is essential to meaningful change. Hutchin (1994) emphasized the community in organizational categories: elected executives, legislatures, courts, education agencies, health and human services agencies, corporations, accreditation agencies, teacher and administrator training institutions, professional associations, and the public. Hirth (1996) drew connections among policy making bodies, systemic reform, and finance system components. Wasser (1998) explored the interrelationships between emerging technologies and
other components of the instructional system, such as curriculum, infrastructure, and professional development. In short, a systemic plan, considering the factors of people, systems, technology tools that are involved and their interrelationships, helps to identify appropriate strategies to approach the technology integration change process.

In this section, I discussed the factors essential to make and sustain the technology integration change process in different stages in this section. In the next section, I discuss the implications for case study research methodology.

2. Implications for case study research methodology

Holloway (1996) raised several concerns about research design of the studies of diffusion and adoption of educational technology. Although survey and correlational studies have revealed demographical factors and personal differences in change studies, these studies were unable to meet the requirements for explaining the process. Case studies, he argued, have the potential to explain why diffusion and adoption occur as they do. In this study, case study research methodology assisted me in describing, interpreting, and analyzing the dynamics of the technology integration change process over six years, drawing on multiple sources of data.

In addition, I would like to provide recommendations for types of design features that I adopted in this study. These design features can be used by other people who want to investigate sustenance of change. Some researchers ascribe to the view that case study research lacks rigor as demonstrated in other research methodologies. Yin (2003) pointed out that the problem occurs because there are not methodological texts that provide systematic procedures for case studies researchers as numerous as ones in other research methodologies. Yet, a number of researchers, such as Yin, have been instrumental in contributing systematic procedures to guide the case studies researchers. This study is one of these studies.
The first recommendation is to conduct a longitudinal study in sustenance of change. Holloway (1996) critiqued that most dissertation studies lacked longitudinal study. This instrumental case study was intended to overcome these criticisms and focused on a six-year case to illuminate the factors and issues involved in the technology integration change process in educational setting. Ultimately, this study presented a framework for understanding of the factors and systems involved in the change process and a number of factors to initiate, implement, and sustain the technology integration change process. Thus, a lengthy period of case study is recommended.

Second recommendation is to follow systematic procedures to collect, manage, and analyze the data and present the findings and conclusion with support of multiple sources of evidence. In data collection, this study detailed the interview protocol, the interview strategies that I used, the time and the length of interviewing, and the sources to obtain the relevant documents. In data analysis, a systematic procedure was used to analyze the data with the coding schemes and exemplary examples and charts to explain the procedure. In the process of writing, different sources of data were included in describing and explaining the themes in the study. This study strived to overcome the prejudice that most researchers hold against case study research methodology and contribute case study to create richness in the area of technology integration. The next section is the discussion of the implications for systems and change theories.

3. Implications for systems and change theories

This study enhanced a better understanding of systems and change theories. In terms of systems theory, Banathy (1988) described a comprehensive system of educational system and categorized it into four components: (1) the analysis and
description of educational systems, (2) the design and redesign of systems, (3)
systems development, implementation, and institutionalization, and (4) systems
management and the management of change. A number of models and methods
(Ackoff, 1981; checkland, 1981; Nadler, 1981) have contributed to the first and
second areas. This study contributes to the third and fourth areas. That is, in order to
strengthen the notion of systems development, implementation and institutionalization,
and change management, this study provides a framework for examining the factors
and systems that are involved in the technology integration change process in a
systemic manner. Thus research on systems inquiry is extended. The framework
extends Reigeluth’s (1994) discussion on how to change educational system
systemically. The framework includes cooperative relationships, team organization,
shared leadership, participative democracy, initiative, holism, and integration of tasks.

This study contributes a new perspective of the change process in educational
settings. Surry and Ely (2001) illustrated that the change process is composed of the
stages of diffusion and adoption, implementation, and institutionalization. The
literature indicates that numerous studies have discussed the stage of adoption and
diffusion such as Rogers (1995) comprehensive book, Diffusion of Innovations (4th
Ed.). This study gained an in-depth understanding of the stages of implementation and
institutionalization and, furthermore, the complete change process. Holloway (1996)
pointed out that the research design of most case studies research on technology
integration into organizations are limited to short time spans such as one or two years.
But by studying the six-year change process, this study provided detailed descriptive,
interpretive, and analytical insights into the context and the process.

One area that needs further examination is the relationship between external
funding and institutionalization. Pipho (1994) pointed out that state funding is a factor
in educational reform because the reduced funding might cause a barrier for true revolutionary reform of the education. Hirth (1996) supported his view on the importance of finance system on educational reform. These studies concluded that the external funding plays a role in sustaining the change process. In this study, the state department of education provided financial support for the science education program to purchase hardware and software in 1999 but was not able to continue with it, which was a major reason for non-institutionalization of technology integration. This study implied that the state department of education should be alert to such problem and finds other sources for support educational reform. However, the change process was still ongoing in spite of the lack of funding in SCIED 458. Thus, further research on major factors of institutionalization of technology integration, such as funding, is recommended.

4. Implications for elementary science education

This study was responsive to the National Science Education Standards (National Research Council, 1996, 2000, 2001a, 2001b), particularly to the Science and Technology Standard under the Science Content Standards, the Science Education Program Standards, and the Science Education System Standards. As Kiefer (1991) noted, information technology is a tool for reform. The use of educational technology should be specific to a particular subject area and curriculum should be modified because of technology integration, which requires more attention. Thus, this study focused on technology tools particularly used in elementary science education and also learned how an elementary science course, SCIED 458, had been transformed over time, which extends an understanding of integrating subject specific technology tools in educational settings.

This study suggested three areas that need further examination. The findings
indicated that one of the factors that sustained the technology integration change process came from reduced elementary prospective teachers’ resistance. Yet, I was unable to determine the reason for their reduced resistance. A number of interviewees also raised the same question. Moreover, I am concerned if elementary prospective teachers are able to transfer the experience in college to their future classrooms to benefit elementary students. If not, what are the factors that inhibit them from transferring their knowledge? These two areas require extensive research with elementary prospective teachers.

Third, studying the perspective of elementary prospective teachers in the technology integration change process is also recommended. In this study, I was unable to include them because I identified them as the recipients of the change process. It would be both interesting and useful to hear their voices and obtain their feedback because they were part of the change process.

5. Conclusion

This study described, interpreted, and analyzed what had occurred in the elementary science methods course, SCIED 458, from 1997 to 2003 at Penn State. Specifically, this case illuminated the factors of people, systems, and technology tools that were involved in the change process. I intended to enlighten people involved in educational reform to ensure the successful initiation, implementation and sustainability of technology innovations. Educational reform is a high-stake mission, particularly involving technology. The experience of this case study research helps inform what contributes to a long-lasting reform. The lessons learned from this case study contribute to the educational communities in developing systems thinking, a systems view and competency in systems design, and in building up an educational system with empowering technologies.
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the Society for Information Technology and Teacher Education conference, Orlando, FL.


Appendix A: Interview Protocol (I)

Project:
Time of Interview:
Date:
Place:
Interviewer:
Interviewee:
Position of Interviewee:

Questions:

1. How long have you been in SCIED 458 as a course instructor?

2. Could you describe current technology integration projects in SCIED 458, such as major technology activities and assignments?

3. Could you describe the history of each project (e.g., when was it started; why was it initiated or motivated; how has it changed)?

4. Are there any technology integration projects in SCIED 458 that were dropped and are not listed on current list? Why?

5. How has your role changed over time in terms of these technology integration projects in SCIED 458?

6. How have elementary prospective teachers’ perceptions about their roles and about technology integration in elementary science education changed (e.g., evidence)?

(Thank individual for participating in the interview. Assure him or her of confidentiality of responses and potential future interviews.)
Appendix B: Informed Consent Form for Social Science Research

The Pennsylvania State University

Title of Project: A case study of the change process of integrating technology into an elementary science methods course

Principal Investigator: Pi-Sui Hsu, 314D Vairo Blvd., State College, PA 16803 (814)2787484 pxh174@psu.edu

1. Purpose of the Study: The purpose of this research is to develop a framework for understanding the factors that contributed to the change and sustaining the change in the technology-integrated science methods course.

2. Procedures to be followed: You will be interviewed by me, Pi-Sui Hsu, for 90 minutes. Further interviews will be requested when additional information is needed.

3. Discomforts and Risks: There are no discomforts and risks in participating in this research.

4. Benefits:
   a. The benefits to participants include a better understanding of what sustained change caused by technology.
   b. The benefits to society include a good understanding of how to implement and sustain change, and integrate technology into elementary science teaching.

5. Duration/Time: It will take about 90 minutes.

6. Statement of Confidentiality:
   a. The audio types will be stored in a locked box by me, Pi-Sui Hsu, at my apartment.
   b. Only I will have access to the data. Each participant will be given a fake name when I transcribe and analyze the data, and write a research report.
   c. I will destroy the data by using a paper shredder by December 30, 2006 and the tapes will be burned.

7. Right to Ask Questions: Participants have the right to ask questions and have those questions answered. All questions should be directed to Pi-Sui Hsu at (814)2787484 or pxh174@psu.edu. If you have questions about your rights as a research participant, contact Penn State's Office for Research Protections at (814) 865-1775.

8. Compensation: No compensation will be given to participants.

9. Voluntary Participation: Participation is voluntary. Participants can withdraw from the study at any time by notifying the principal investigator. Participants can decline to answer specific questions.

You must be 18 years of age or older to consent to participate in this research study. If you consent to participate in this research study and to the terms above, please sign your name and indicate the date below.

You will be given a copy of this consent form to keep for your records.

Participant Signature ______________________  Date ______________________

I, the undersigned, verify that the above informed consent procedure has been followed.

Investigator Signature ______________________  Date ______________________
Appendix C: Interview Protocol (II)

Time of Interview:
Date:
Place:
Interviewer:
Interviewee:
Position of Interviewee:

1. Dr. Zimmerman told me that before she came, the science education program already had the probes. Could you talk about the extent of technology integration in SCIED 458 before she came?

2. She also told me that you had devoted to the studies of portfolios for a long time. Could you talk about it and talk about how Dr. Zimmerman and you combined your efforts in portfolios?

3. In terms of online collaboration tool, could you talk about CCL (Connecting Communities of Learners) developed by Ken Tobin? Why did you not continue to use it?

4. From talking to you last time, I had a sense that almost all the technology integration projects like web-based portfolios had been sustained over the years. What do you think were the factors that influenced the sustainability, such as people, tools, and process?

(Thank individual for participating in the interview. Assure him or her of confidentiality of responses and potential future interviews.)
Appendix D: Interview Protocol (III)

Time of Interview:
Date:
Place:
Interviewer:
Interviewee:
Position of Interviewee:

1. People told me that you attended the training for GLOBE, the online collaboration tool, to see if it was applicable in SCI ED 458. Could you describe this experience and talk about why you did not adopt it in SCI ED 458?

2. From talking to you last time, I had a sense that almost all the technology integration projects like web-based portfolios have been sustained over the years. What do you think were the factors that influenced the sustainability such as people, tools, and process?

3. Someone said that you were the coordinator of STEPS and you built it all. Could you talk about the importance of STEPS in technology integration and your role as a coordinator?

4. Since Dr. Zimmerman and Dr. Donahue shifted to other responsibilities, you were dealing with what is happening on campus. Could you describe your role in more detail?

(Thank individual for participating in the interview. Assure him or her of confidentiality of responses and potential future interviews.)
Appendix E: Documents

Publications

Portfolios


Conceptual Change-based Model


Link-to-Learn Grant


Presentations

Portfolios


Conceptual Change-Based Model


Thesis

Pennsylvania State University, State College.


**Syllabi**
1997 Summer  
1997 Fall  
1998 Spring  
1998 Summer  
1998 Fall  
1999 Spring  
1999 Fall  
2000 Spring  
2000 Fall  
2001 Spring  
2001 Fall  
2002 Spring  
2002 Fall  
2003 Spring  

**Internet Resources**
## Appendix F: Initial Coding of Transcript

<table>
<thead>
<tr>
<th>Transcript of Dr. Zimmerman</th>
<th>Codes</th>
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</thead>
<tbody>
<tr>
<td>They [web-based portfolios] were not been used when I came here. We [Drs. Donahue and Zimmerman] were not thinking web-based at that time.</td>
<td>SU97/WP</td>
</tr>
<tr>
<td>We [Dr. Zimmerman and Ms. Hess] were thinking electronic portfolios. The first time I had the opportunity to pilot that with a group of students within the spring of 1998. That was the second half of the first full year that I taught here. It was not web-based at all at that point. Elementary prospective teachers walked away with the CD-ROM, with their portfolio on it. I basically had developed the shell for the portfolio. Elementary prospective teachers plugged in their lesson plans, plugged in their videos of teaching, and plugged in their reflection. But it was the first attempt. We used HyperStudio. The idea that students would be able to walk away with the electronic portfolio that was developed around planning, teaching, and reflection as a way for them to organize some evidence in a coherent way. …What we were really trying to do is help elementary prospective teachers reflect on their learning and growth over time. I wanted to make it as open-ended.</td>
<td>SP98/WP</td>
</tr>
<tr>
<td>Ms Hess is the one who taught me (Laughter) how to use Claris Home Page, how to begin to think about a web-based form for electronic portfolios….I think that was the last time we actually taught 458 in the summer. Ms. Hess co-taught that with me. That was summer 98. She is the one who learned Claris Home Page. And she ran the computer labs for students….We wanted to move to more of a web-based form. We left it very open-ended at that point in time.</td>
<td>SU98/WP</td>
</tr>
<tr>
<td>We made web-based portfolios optional with elementary ed majors during the following years. That has been 98, 99 year. We had a few takers. But what we found is by not requiring yet, elementary prospective teachers got busy, got overloaded, then the last thing that they wanted to think about doing was adding this new piece on, which is the web-based portfolio. So a lot of students were out of that is just because they were so busy. When we interviewed the students who did do it in the end, they said, &quot;this was a great experience, you should get everybody do this. I learned so much from being able to do this, and reflected on my growth and change over the course of the period of time, very valuable, glad you made me do it.”</td>
<td>FA98-SP99/WP</td>
</tr>
<tr>
<td>So the following year, the 1999-2000 year is the year we started requiring web-based portfolios of our students. That took on a lot of different configuration.</td>
<td>FA99-SP00/WP</td>
</tr>
</tbody>
</table>
### Appendix G: Initial Coding of All Sources of Data

<table>
<thead>
<tr>
<th>Coded Passages</th>
<th>Codes</th>
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<tbody>
<tr>
<td>Dr. Donahue has been starting the paper portfolio for many years before 1997. Dr. Zimmerman has been studying the electronic portfolio before she came to Penn State. They decided to combine their efforts and have their students develop electronic portfolios, which was not web-based at that time initially. (Sources: Transcripts of Drs. Donahue and Zimmerman)</td>
<td>B97/WP</td>
</tr>
<tr>
<td>They [web-based portfolios] were not been used when I came here. (Sources: Transcripts of Dr. Zimmerman)</td>
<td>SU97/WP</td>
</tr>
<tr>
<td>One of the DI Block requirements is a portfolio where you demonstrate through a purposeful collection of evidence what you have learned during the block. (Source: Syllabus)</td>
<td></td>
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<tr>
<td>We were thinking electronic portfolios. The first time Dr. Zimmerman had the opportunity to pilot that with a group of students within the spring of 1998. That was the second half of the first full year that she taught here….Students walked away with the CD-ROM, with their portfolio on it. Students plugged in their lesson plans, plugged in their videos of teaching, and plugged in their reflection. HyperStudio was used at that time. (Source: Transcript of Dr. Zimmerman)</td>
<td>SP98/WP</td>
</tr>
<tr>
<td>Prospective teachers were provided with an electronic template to structure the selection of artifacts around, planning, teaching and reflection. Analysis of these portfolios indicated that they had the potential to support thoughtful reflection. However, the Science Education Group at Penn State were interested in refining the process to assist prospective teachers in developing a framework for reflecting on key considerations for supporting children’s science learning. (Sources: Publications)</td>
<td></td>
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<tr>
<td>We wanted to move to more of a web-based form. We left it very open-ended at that point in time….Ms. Hess is the one who taught Dr. Zimmerman how to use Claris Home Page,,,Dr. Zimmerman was working on piloting them [web-based portfolios] with twelve students….They chose to use Claris Homepage because it was popular in schools. It was Mac platform. (Sources: Transcripts of Drs. Zimmerman and Stoker, and Ms. Hess)</td>
<td>SU98/WP</td>
</tr>
<tr>
<td>No structured guidelines were provided. Analysis of these web-based portfolios indicated that it was possible to differentiate among students based on the representations developed for their portfolios. Moreover, the findings supported the web-based portfolio can provide an effective vehicle for examining preservice teachers’ emerging understanding of subject-specific pedagogy. (Sources: Publications)</td>
<td></td>
</tr>
<tr>
<td>Assignment: web-based portfolio (10/100 points) (Source: Syllabus)</td>
<td></td>
</tr>
<tr>
<td>Analysis of these portfolios that are organized around the conceptual framework for the Elementary and Kindergarten Education Program at Penn State suggests that this approach indeed supported prospective teachers in reflecting on relationships among university work, field experiences, and their developing personal theories about how children learn science and the role of teachers in supporting that learning. (Sources: Publications)</td>
<td>FA98-SP99</td>
</tr>
<tr>
<td>There is approximately 66% of the elementary prospective teachers in science education courses (90 students) preparing a web-based electronic portfolio. (Source: Link-to-Learn grant proposal)</td>
<td></td>
</tr>
<tr>
<td>The 1999-2000 year is the year we started requiring web-based portfolios of our students. That took on a lot of different configuration. (Source: Transcript of Ms. Hess)</td>
<td>FA99-SP00/WP</td>
</tr>
<tr>
<td>Assignment: web-based philosophy project (15/100 points) (Source: Syllabi)</td>
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<td>------------------------------------------------------------------------</td>
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<tr>
<td>In order to move elementary education students beyond describing a collection of discrete pieces of evidence to using related pieces of evidence to demonstrate understandings, abilities and dispositions associated with the program framework, the web-based portfolio is organized around three main components: (1) a scrapbook, (b) program outcomes, and (3) a philosophy of science teaching and learning. That is basically the current version of the web-based portfolio. (Sources: Publications)</td>
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<table>
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<tr>
<th>So now apparently every prospective teacher is going to do it. And the web authoring software did switch over at one point. (Source: Transcript of Ms. Hess)</th>
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</table>

| All assignments for SCIED 458 are to be posted to prospective teachers’ web space in the SCIED 458 collection center. (Source: Syllabi) | FA00-SP01/ WP |
# Appendix H: Time-ordered Matrix of Technology Initiatives

<table>
<thead>
<tr>
<th>Technology Integration Initiatives</th>
<th>Before 97-98</th>
<th>97-98 Year 1</th>
<th>98-99 Year 2</th>
<th>99-00 Year 3</th>
<th>00-01 Year 4</th>
<th>01-02 Year 5</th>
<th>02-03 Year 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Paper portfolios</td>
<td></td>
<td>• Hypermedia, electronic portfolios by HyperStudio</td>
<td>Web-based portfolios</td>
<td>• Web-based portfolios with different framework</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Vernier probes</td>
<td>• Vernier probes</td>
<td></td>
<td>• Exposure to science specific tools (online collaborative tools, data collection tools, simulations and modeling tools)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Online collaborative tool</td>
<td>• Online collaborative tool (Connecting Communities of Learners)</td>
<td></td>
<td></td>
<td>• Online collaborative tool (ANGEL)</td>
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<tr>
<td>• Various technology tools</td>
<td>• Online discussion boards</td>
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<tr>
<td></td>
<td>• Interactive web sites</td>
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Appendix I: Coding for Patterns

<table>
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<tr>
<th>Coded Passage</th>
<th>Code</th>
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<tbody>
<tr>
<td>I do not think the portfolio task has really ever been the same twice because it has been such a rich area for research that we learned from the portfolio task. …When you started to see the publications and presentations that have come from portfolios and see of our names [Dr. Donahue, Ms. Hess, and Ms. Aberdeen] together….That is probably the theme that is coming up over and over again. It is the importance of our own research, our own practice in the context of SCIED 458 in terms of how we modify and change assignments over time because we are constantly learning that process….The research piece to me has really been important. The fact that people associated with our program, the doctoral students and faculty members do research in the context of this course had research connected to supporting prospective teachers science learning using technology tools….What tends to happen is we get evidence of how we might help do things better….The constant cycle of research into the course has made it look different. (Transcript of Dr. Zimmerman)</td>
<td>FIRES (research community)</td>
</tr>
<tr>
<td>One thing I would like to mention is research community. (Transcript of Ms. Friedman)</td>
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<td>At the end of each semester, I try to touch base with Dr. Zimmerman because of her role. I felt they are doing more research….I looked at her for some guidance and research wise. (Transcript of Dr. Stoker)</td>
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<tr>
<td>I basically built my dissertation and online support environment for a long-term investigation and inquiry-based type of investigation. (Transcript of Mr. Bell)</td>
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Appendix J: Different Types of Factors

Factors

A. People factors include
   (1) leadership was formed;
   (2) the key persons were stable and there was consistency in one position;
   (3) Team approach worked and research community was formed; and
   (4) Commitment to continue trial and improve was strong.

B. Tool factor
Integration of technology tools was guided by the conceptual model.

C. Systems Factors

Immediate environment’s influence existed, such as the university’s support.

External environment include:
   (1) technology advancement in society (e.g., web authoring software, USB probes),
   (2) local school districts’ influence,
   (3) state department of education’s funding and academic standards, and
   (4) the partnership between the science education program and the software companies.
Appendix K: Integrating the Data into Theory

How did I categorize the stages of the technology integration change process from 1997 to 2003?

The period between 1997 and 1999 was categorized as the stages of adoption and diffusion because:

(1) General types of tools were more developed in these stages;
(2) Technology tools were in the trial stage, such as the web-based portfolio, data collection tools, and online collaborative tools;
(3) There was no consistent use of software and no consistent organization of the web-based portfolio; and
(4) There was no consistent integration into SCIED 458, such as the web-based portfolio being used in one section of SCIED 458 and no requiring assignments related to technology.

The period between 1997 and 1999 was categorized as the stage of implementation because:

(1) Science specific tools, such as data collection tools, simulations and modeling tools, and online collaborative tools, were integrated into SCIED 458;
(2) All categories of technology tools were ongoing and underwent minor modification and improvement; and
(3) Guided by the conceptual change model, science specific tools and the web-based portfolio were in consistent level of use in SCIED 458.

There are five indicators that characterized technology integration in 2003:
(1) structural integration of technology,

(2) revisiting and solidifying the weak strand of technology,

(3) widespread influence of technology,

(4) specialization of workforce, and

(5) no external funding.
Appendix L: Interrelationships among the Factors

![Diagram of interrelationships among factors](image-url)
Journal (March 16, 2003, Sunday)

The daily schedule and logistics of the study
I interviewed Ms. Aberdeen today. I also got a chance to talk to Mr. Bell and make appointment with him. From Ms. Aberdeen, I collected a number of documents, including the syllabi and the articles related to web-based portfolios.

Reflection on what is happening in terms of my own values, interests, and biases

I modified the interview protocol in order to learn how long Ms. Aberdeen had been in the science education program as course instructor (see question number 1). When I asked her to describe current technology integration projects, she seemed puzzled. Thus I gave her some examples such as the web-based portfolio, probeware, online communication tool, and so on based on my studies of the documents. That is what Rubin and Rubin (1995) called steering probes. I summarized Ms. Aberdeen’s answers for each question because I wanted to make sure I did not misinterpret her statements. I found out that sometimes that could elicit more responses from her because the time I used to summarize the statements provided her some opportunities to reflect on what she had said to me. That was a good strategy for probing – called clarification probes (Rubin & Rubin, 1995). I followed up the question about her role and duties by further inquiring the changes of the syllabi and the contribution of her study because I learned that she had several publications and presentations about the web-based portfolio. I wanted to explore multiple facets of her role.

A methodological log with methodological decisions and rationale

The interview protocol is consisted of main questions, follow-up questions, and probes (Rubin & Rubin, 1995).
Vita

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