

A case study of enabling factors in the technology integration change process

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ABSTRACT

The purpose of this qualitative case study was to analyze enabling factors in the technology integration change process in a multi-section science methods course, SCIED 408 (pseudonym), from 1997 to 2003 at a large northeastern university in the United States. We used two major data collection methods, in-depth interviewing and document reviews. We interviewed seven participants who played the role of change agents twice during the six-year period of time and examined documents related to integrating science specific technology in this multi-section course. The formation of a sustained, shared leadership team, the formation of a learning community, and the positive influences from educational systems emerged as three enabling factors to facilitate and sustain the technology integration change process. The interaction of the three factors also appeared to encourage greater capacity to deal with change.

Keywords

Teacher education, Educational change, Educational technology, Educational leadership

Introduction

The influence of technology integration on broader educational change efforts is an important area of concern for the future progress of the field (Holloway, 1996; Surry & Ely, 2006). In light of the potential of technologies in helping students' understanding of new concepts, initial efforts focusing on technology integration in teacher education programs have been undertaken nationwide. From 1999, the Preparing Tomorrow's Teachers to use Technology (PT3) initiative has funded numerous teacher education programs in the United States. Technology integration into these field-based preservice teacher education programs have shown preliminary successes in modeling preservice teachers' use of technology, fostering their collaboration by use of technology, and increasing their confidence and enthusiasm in using technology (Brush, Glazewski, & Rutowski, 2003; Seels, Campbell, & Talsma, 2003).

However, the complexities of technology integration make it difficult to facilitate and sustain the change process. Although these reports shared successful aspects of the ongoing projects, they also indicated numerous barriers to integrate technology in teacher education programs. For example, faculty leaders encountered and overcame numerous difficulties, which included incompatible software purchases, limited access to computers, preservice teachers' and in-service teachers' initial resistance, and the lack of time (Brush, Glazewski, & Rutowski, 2003; Seels, Campbell, & Talsma, 2003). Furthermore, these reports did not address subject specific technology and were conducted in too wide of a context (program, general type of technology such as video production, HyperStudio, web sites) to provide knowledge about what strategies that faculty leaders could adopt to facilitate and sustain the process.

Thus, the purpose of this study was to analyze enabling factors in the technology integration change process in a multi-section elementary science methods course, SCIED 408 (pseudonym), from 1997 to 2003, the time this study was conducted, from the perspective of change agents. Havelock and Zlotolow (1995) defined change agents as "solution giver," "process helper," and "resource linker" (pp. 9-10). In this study, change agents are the faculty members and course instructors who initiated and led the technology integration change process.

We selected SCIED 408 for two reasons. First, in the last two decades, science education has embarked on a major reform, recognizing that technology integration in science education could enhance science teaching and learning (National Research Council, 2001). Research has addressed three major types of technology tools, referred to as inquiry empowering technologies or science specific tools (Linn, 2003; Windschitl, 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 include data collection tools, simulations and modeling tools, and online collaborative tools. Data collection tools enable students to collect data efficiently and allow them to perform multiple analyses of the data set in a brief period of time. Simulations and modeling tools enable students to focus on exploration and representation of scientific processes and conceptions. Online collaborative tools are intended to create a learning community that students can share resources and explore scientific phenomena with communities beyond the confine of their own classrooms. Although these tools have shown potential to support students' development of science inquiry skills, they are rarely used or seen in college level science methods courses (Linn, 2003; Windschitl, 2000; Zembal-Saul, Munford, & Friedrichsen, 2002). SCIED 408 would be an exemplary case to study because the faculty members and course instructors made endeavors to integrate science specific technology tools into SCIED 408 from 1997 to 2003.

Second, Fullan (2007) 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 six-year time period (1997-2003), suggested by Fullan, is a significant milestone to examine how the case had evolved. Thus, the elementary science methods course, SCIED 408, makes an appropriate case in this study. Examining this case could contribute to an understanding of the technology integration process in an educational context and lead to identification and understanding of the factors that support sustainable change. The major research question for this study was: What enabling factors might have helped to facilitate and sustain the technology integration change process from the perspective of change agents (faculty members and course instructors)?

Theoretical framework for inquiry

We framed this research report by using systems theory as a basis to examine the factors and relationships that might have helped to sustain the technology integration change process in SCIED 408 from 1997 to 2003. The application of systems theory in education was pioneered by Banathy (1991, 2001) and popularized by Reigeluth (1994) as systemic change. Although a number of theoretical frameworks have discussed systemic change in different educational change contexts (Joseph, Jenlink, Reigeluth, Carr-Chellman, & Nelson, 2002; Rowland, 2004), empirical research is needed to examine the complexities, interrelationships, and interdependencies in a change process, particularly in the context of technology integration. Additionally, we identified three key components associated with systemic change—shared leadership, learning community, and educational systems—and we describe their contributions in the next section.

Shared Leadership

Differing from a traditional view of leadership, systemic change recognizes that leadership is shared among several key persons in organizations rather than being dominated by one person (Dexter, 2005; Lambert, 2002; Mullan, 2002; Reigeluth, 1994; Rowland, 2004; Senge & Lannon-Kim, 1991). The leadership team can consist of key persons at different levels or departments, including faculty, teachers, principals, or administrators. In their study of the influence of leadership on reforming inquiry-based science education in 13 Chicago elementary schools, Spillane, Diamond, Walker, Halverson, & Jita (2001) indicated that the leadership team consisted of the principal, the science coordinator, and the assistant to the coordinator. The principal appointed a specific classroom teacher as a science coordinator. The science coordinator, who was funded by the school district, worked with an assistant provided by the principal and worked with science teachers across all grade levels to integrate more inquiry-based science instruction. To empower change in science education, the principal doubled the weekly science instruction period, secured financial resources, established connections to external resources, including local universities, colleges, science institutions, and external science consultants. Another example of a leadership team is identified in another elementary school in North Carolina (Nesbit, DiBiase, Miller, & Wallace, 2001). In both studies, the leadership team showed a division in the functions of design, administration, and liaisons, although some of the functions may have overlapped.

Learning community

In systemic change, a learning community serves as a powerful incentive to sustain the technology integration change process (Joseph, Jenlink, Reigeluth, Carr-Chellman, and Nelson, 2002). According to Cibulka and Nakayama

(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).

A learning community learns and grows by collaborating on a variety of activities, including study groups, reflective dialogue, and research. In their qualitative study of an innovative change process in a secondary school in Queensland in Australia, Andrews and Lewis (2002) indicated that shared understandings that emerged from a professional learning community had an important impact on other teachers in a school change process. The professional learning community consisted of ten volunteer teachers, both junior and senior. The composition represented a wide range of backgrounds, experiences, and beliefs. Although the change process was full of ambiguity, the volunteers used shared dialogue across different departments to reconcile different perspectives on pedagogy, assessment, and ways to motivate students. In shared dialogue, they could think, reflect, draw on their professional experience, and listen to others’ ideology and belief systems. They also felt empowered to perceive themselves as guides for changing other teachers in the school. Each community member mentored two teachers and guided them through the change process. Another example of a learning community is identified in the FIRST (Fund for the Improvement and Reform of Schools and Teaching) project initiated in North Carolina (Nesbit, DiBiase, Miller, & Wallace, 2001).

Educational Systems

In an educational context, different levels of educational systems in a systemic change process include the local community level, the university level, the state level, and the national level (Reigeluth, 1994). At the local community and university level, it is essential to involve local school district teachers and students by involving the local school community in university-held events and delegating liaisons to regularly coordinate activities involving community and school district personnel (Grove, Studler, and Odell, 2004; Taylor and Wochenske, 2001). At the state level, the department of education plays a critical role in the technology integration change process because it dictates curriculum design and funding of resources to sustain the changes (Brown, 2007).

At the national level, various activities are needed to sustain change, including gaining recognition from accreditation agencies; attending national contests, reviews, and meetings of professional organizations; disseminating experience by authoring articles in journals; and developing partnerships with educational software companies for appropriate support. Brooks-Young (2007) suggested the establishment of partnerships between the educational programs and vendors of educational software to ensure that students receive appropriate exposure to software. Brooks-Young further suggested the National Council for Accreditation of Teacher Education (NCATE) and other organizations that establish technology standards for teacher education standards could take the initiative to implement such arrangements with educational vendors.

The technology integration change process can involve different levels of systems. It is essential to identify the impacts of different systems on technology integration and to exercise strategies to reinforce methods to gain support from and tackle possible resistance from these systems.

Methodology

This study used a qualitative research methodology, specifically case study research design, to explore answers to the research question. The first author was the major researcher responsible for sampling the participants, collecting the data and analyzing the data. The first author was involved in the teacher education program as a field experience supervisor and course instructor but was not involved in the technology integration change process in SCIED 408 directly. The first author never taught SCIED 408. The first author never worked with any participants in any fashion.

Context- Restructure of SCIED 408

This study was conducted at a comprehensive, land-grant research university. The science education program is one of the programs in the Department of Curriculum and Instruction of the College of Education. SCIED 408, *Teaching Science in the Elementary School*, is a required course before Elementary and Kindergarten Education majors can

engage in student teaching. The course is taken concurrently with a mathematics methods course, a social studies methods course, and an elementary education field experience course. On average, six to seven sections of SCIED 408 are offered each semester. Approximately thirty preservice elementary teachers are enrolled in each section.

Based on a three-phase conceptual change model, SCIED 408 was restructured with three types of science specific technology tools (see Table 1). Three strands of science specific technology tools, including data collection tools such as PASCO Science Workshop probeware (PASCO Scientific, 2008) and Vernier PASPORT (Vernier Software Technology, 2008), simulation and modeling tools such as Tom Snyder Science Court (Tom Snyder Productions, 2008), and online collaborative tools such as Connecting Community of Learners (CCL) and A New Global Environment for Learning (ANGEL), were used in three phases in SCIED 408.

In the first phase of SCIED 408, preservice teachers experienced technology-rich science as learners and became familiarized with the aforementioned technology tools. In the second phase, preservice teachers taught a small group of children using exemplary science curriculum infused with appropriate technology tools under the guidance of the methods instructor in an event, Science and Technology Experience at P S (STEPS) Days, where the science education program invited local elementary students to the campus. In the third phase, in their field experience classrooms, preservice teachers taught technology-enhanced science lessons using technology resources from the program or from their field experience site. Throughout the course, preservice teachers reflected on their teaching by authoring web-based portfolios.

Data Collection

There are two major data collection methods in this study: in-depth interviews and review of documents. 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 played or were currently playing the role of change agents. The following section provides a brief outline of the profiles of the seven participants and their qualifications and involvement with the project.

Participant Profiles

Dr. Zimmerman (pseudonym) joined the science education program as an assistant professor in May of 1997, the first year in the change process. She played a variety of roles in the change process of technology integration from 1997 to 2003: lead researcher, course instructor, course coordinator and consultant. As an associate professor, Dr. Donahue (pseudonym) had been in the science education program for a number of years prior to 1997 and played a number of roles: course instructor and the coordinator of the science teacher education program.

Dr. Stoker (pseudonym) joined the science education program on the state level grant in 1999, the third year in the change process, as liaison between SCIED 408 and the local elementary school districts. She was the course coordinator for SCIED 408 and had been a course instructor since 1999.

Ms. Hess (pseudonym) had been a course instructor from 1998 to 2001. In 1998, she conceptualized different technology projects with Dr. Zimmerman, planned how to integrate the technology projects into the design of the course, and trained the preservice teachers to learn these tools. 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 state level grant proposal for technology integration in 1998 with Drs. Zimmerman and Donahue.

Ms. Aberdeen (pseudonym) joined the program in 1999 to pursue her master's degree and then Ph.D. degree. 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. Mr. Bell (pseudonym) joined the science education program in 2001 and had been a course instructor since that time.

In-depth interviewing

The first author conducted two rounds of interviews at different points of time (2001 summer, 2003 spring) in the technology integration change process in order to have a better understanding of the evolution of technology

integration in SCIED 408. The first author designed the interview protocols to indicate interview questions and closing comments (see Appendix A). The interview took about 90 minutes each. Before the interview, the first author presented each participant a copy of the informed consent form. The first author used a digital recorder to record the interviews and transcribed these interviews.

Review of documents

Documents were the second source of data collection in this study. Merriam (1998) defined documents as “an umbrella term to refer to a wide range of written, visual, and physical material relevant to the study at hand” (p. 112). The main documents that were reviewed were the publications, the presentation papers, the technology integration state level grant proposal, the syllabi, and the class Internet resources. The publications and presentations provided information about each participant’s research interest, how these participants collaborated on research studies, and theoretical framework of technology integration in SCIED 408. The technology integration state level grant proposal provided detail on the design differences of SCIED 408 before and after the grant was awarded. The syllabi provided information regarding the assignments and activities related to technology integration in class. In addition, the Internet resources offered the names of the school districts where the partnerships were established.

Data analysis

Data analysis followed the guidelines suggested by Miles and Huberman (1994), utilizing different levels of coding schemes. First, we coded transcripts with a start list of 24 codes for time (i.e., fall semester of 1999 as FA99) and technology integration project (i.e., simulations and modeling tools as SM), along with time and roles of people (i.e., SCIED 408 course instructor as CI, CC as course coordinator). The purpose is to describe the chronological history of technology integration and roles of people, which is a time series analysis strategy (Yin, 2002). The evolution of technology integration from 1997 to 2003 is presented in Appendix B. A matrix that details the roles of each interviewee during different periods of time in the change process is presented in Appendix C.

Second, we examined the matrices (see Appendix B and Appendix C) for trends and patterns of technology integration from 1997 to 2003. Following these trends, we identified interrelationships among faculty members, course instructors, and the technology integration projects in the change process by coding for themes, causes/explanations, relationships among people, or emerging constructs (Miles & Huberman, 1994). Thus, we generated a list of pattern codes. For example, three faculty members appeared to play a critical role consistently in the change process and thus were assigned a code.

Third, we then reduced, summarized, and synthesized, and integrated the data into an exploratory framework. In this step, we formed overarching themes by linking technology integration initiatives, faculty member and course instructors that emerged from the data analysis. For example, Appendix B shows that since 1997, a number of technology initiatives had been tried in class. By looking at enabling factors that sustained the change process, the data analysis indicated that three faculty members seemed to facilitate and sustain the technology integration change process by involving in various activities. Therefore, a theme “formation of a sustained shared leadership team “was derived from these data analysis processes.

This study adopted triangulation, member check, peer debriefing, and thick description to ensure trustworthiness had been met (Lincoln & Guba, 1985). Multiple data sources, including interview transcripts and document reviews, were compared to confirm the emerging findings. In addition, interview transcripts and document reviews were brought back to the persons who participated to see if the interpretation was correct and the results were plausible. In peer debriefing, the two researchers consistently shared the emerging findings with each other and explained our thinking process to each other to solve disagreement. In other words, the researchers made explicit the decision process regarding how to interpret the data and generated the findings. The researchers provided very detailed descriptive data to support readers’ decision making.

Dependability and confirmability refer to the extent to which the research process can be replicated. The first researcher kept a reflective 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 diary that provided opportunities for reflection on

both researchers' values, interests, and biases, and (3) a methodological log with methodological decisions and rationales.

Findings and Discussion

The purpose of this study was to analyze enabling factors that might have helped to facilitate and sustain the technology integration change process in a multi-section elementary science methods course, SCIED 408, from the perspective of change agents (faculty members and course instructors). Figure 1 describes the three major factors as well as their interaction.

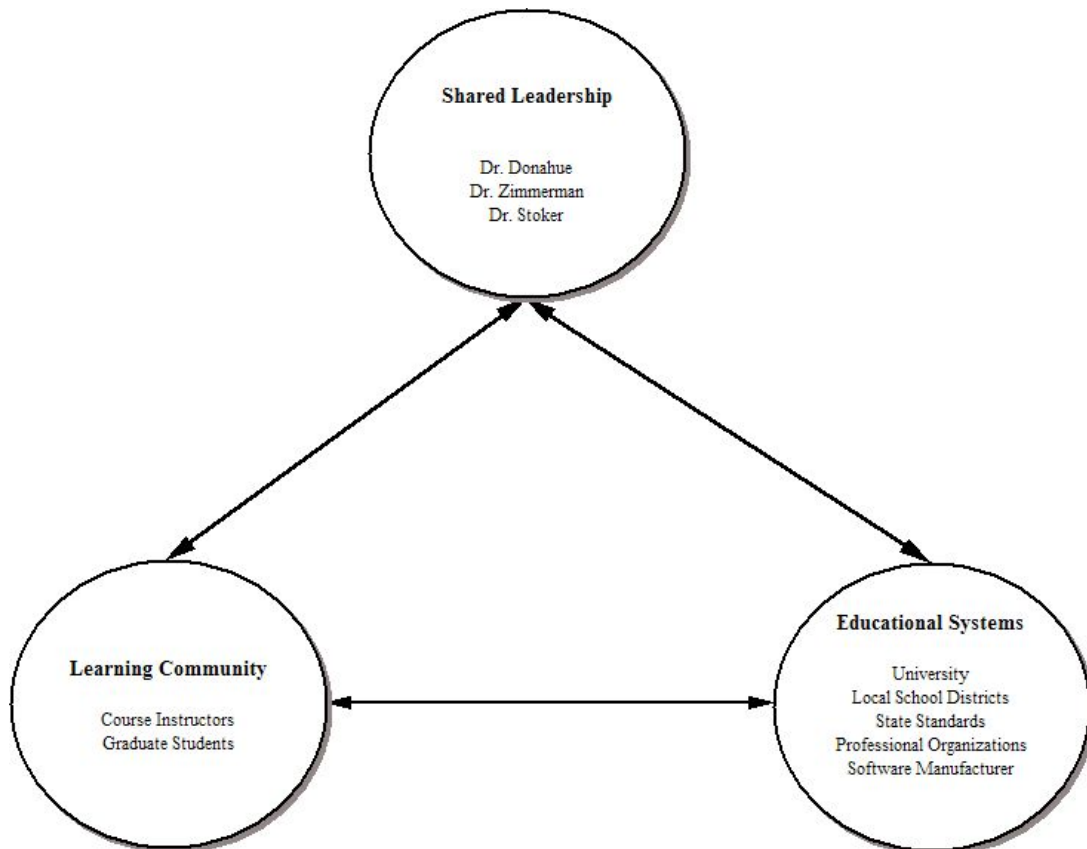


Figure 1. Enabling factors and their interrelationships

Formation of a sustained shared leadership team

It is essential that leaders possess a number of traits to mobilize and lead change in a technology integration change process. Consistent with the discussion of the important traits of leaders in previous research (Mullen, 2002; Spillane et al., 2004), this study illuminates a number of important traits and elaborates on each of them. These traits include strong expertise, skillful deployment of change strategies, and a shared vision.

First, it is important that leaders possess strong expertise in technology integration to lead change. In this case, Zimmerman's doctorate training placed a heavy emphasis in enhancing preservice teachers' ability in integrating technology in science teaching and learning. Bringing the expertise in technology integration to the science program allowed Zimmerman to enrich the program and continue her interest. Dr. Zimmerman described her enthusiasm in technology integration in science education as she joined the program in 1997:

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

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

Donahue had a similar expertise and contributed to technology integration in the program prior to Zimmerman's arrival in 1997. However, Zimmerman's joining stimulated them to pool their efforts and initiate the development of the data collection tools (e.g., Vernier Probes), one of the technology integration projects in the early stage of the change process. Their similar interest and collaboration resulted in the development of their shared vision in technology integration and served as a precursor for large scale technology integration in a later stage of the change process from 1999. Donahue described how he combined his prior efforts with Zimmerman and both of their experiences shaped the development of the technology integration projects. Donahue said:

I had been working on different technology integration projects. Dr. Zimmerman had been working on different technology integration projects. And then she came here in 1997. We both decided that we would combine our efforts.

Ms. Hess said, "I would say the most important persons would be Drs. Donahue and Zimmerman [in early stage of technology integration] ." Ms. Friedman concurred that Donahue and Zimmerman were two major leaders who led the changes in SCIED 408 in the early stage, "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." Ms. Aberdeen recognized that Zimmerman and Donahue were major players who initiated the technology integration projects in the early stage.

This finding also reflected that leaders' expertise and learning actions have a heavy impact on the leadership behaviors. In their survey study of 312 respondents consisting of mid-level managers and working professionals across the high-technology corporations and managers enrolled in an executive MBA program, Brown and Posner (2001) found that respondents who reported using more frequently any one of the learning tactics (action, thinking, feeling, and accessing others) also reported engaging more frequently in leadership behaviors like challenging, inspiring, enabling, modeling, and encouraging.

Second, it is also critical that leaders deploy skillful change strategies to identify possible human and financial resources. For example, Donahue, Zimmerman and Friedman co-authored a technology integration state grant proposal in 1998. When the grant was awarded in 1999, the grant supported the hiring of Stoker, the purchase of technology tools, such as PASCO probes, and the revision of the course design. Stoker was hired to be a liaison between the program and the local school districts to facilitate preservice teachers' ability in technology integration in schools. She also built partnerships with these schools and coordinated the STEPS Days activity that invited the elementary students to university classrooms. Zimmerman said:

Typically there was a big disconnect there. 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 students locate the resources in their school districts. Dr. Stoker was the contact person. People would call. She was able to explain and mediate this process of teaching in school. We never had that before. ...There was no excuse for preservice teachers not teaching with technology.

Stoker said: "I put out this blanket: Welcome, please come. We had people from Lewis, Beaver, Boise, Pearson (all pseudonyms) that bring their children, their classes to us." Aberdeen identified the positive influence of the STEPS Days activity that Stoker coordinated. Ms. Hess provided a similar account of the positive influence on preservice teachers' ability to integrate technology and stressed that Stoker was the major person who built this activity.

Skillful change strategies involve more than identifying human and financial resources; encouraging rapport and trust among change agents and stakeholders becomes an important part of leadership. For example, Zimmerman and Donahue brought Stoker along in the change process. Dr. Stoker said:

I always looked at Drs. Donahue and Zimmerman for leadership because they were here beforehand....Drs. Donahue and Zimmerman had the vision, the foresight to realize technology integration in SCIED 408.

After Donahue's role was gradually shifted to the college level and Zimmerman's role became a lead researcher in the context of technology integration, Stoker looked to Zimmerman and Donahue for their prior experience in technology integration from early years. Donahue described the change of his role in SCIED 408 since 1999:

I am not as involved anymore because my jobs have shifted. ...I am able to help other faculty members in other areas to integrate technology, and try to persuade the college what to do so that helps all the students. Not just small numbers of students. Things like that. So I think my role is changed over time.

Stoker built on her experience and then took over the job of being a coordinator of the course, serving as a mentor for new course instructors. Mr. Bell described Stoker's other role as a course coordinator and instructor, "Two years ago, new instructors of SCIED 408 sat in Dr. Stoker's class and watched out how she teaches the course. New people copied off from her and used her ideas." Donahue explicated the stable leadership team formed in the process, particularly the involvement of Stoker:

I would say the number one stimulus was faculty members. ...One is that stable people have been there, which 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 Stoker's role had changed over time, her stable and consistent involvement in SCIED 408 from 1999 to 2003 enabled her to develop more insights into how to better integrate technology in the course, and she commented on the importance of a stable, long-term perspective:

...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. ...This is my class, and I am really trying to improve it....This is my most important thing - technology integration in SCIED 408 - 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.

Meanwhile, she learned from Zimmerman's research experience and led SCIED 408 to continuous improvement. Stoker stated:

I try to touch base with Dr. Zimmerman and ask, "What can you tell me from your experiences?" ...So I looked at her for some guidance, especially from her research regarding how I can use that to improve this course.

Such collaboration and trust enabled the successful transfer of knowledge and vision among leadership members. Keeping the three major leaders throughout the project's life enhanced such bonding and trust.

Third, vision is a powerful trait of effective leadership. In this case, shared vision appeared to be a significant factor in sustaining the technology integration change process. A shared vision was developed by Zimmerman and Donahue because of their passion, enthusiasm, and stubbornness in technology integration in early years of the change process. A shared vision was diffused to Zimmerman and Stoker. Although Stoker initially seemed to assume the role of a follower, she built on Zimmerman and Donahue's early experience and became an active and stable participant in improving SCIED 408. A shared vision was evolved to a degree that faculty leaders, course instructors and graduate students viewed technology integration as a visionary direction to follow. As Hess described, they had to do it and there was no way that they could stop doing it. When the people joined the change process in later years of the change process, they viewed technology integration as a positive practice. Therefore, such influence encouraged people to bring more ideas of technology integration into this course, such as Bell's interest in building an online collaborative learning environment to facilitate scientific inquiry.

These findings supported characteristics and traits that are attributed to transformational leaders (Bennis & Nanus, 2003; Mount & Barrick, 1998). In their meta-analysis study of examining the relationship between the Big Five traits and the performance in different types of jobs, Mount and Barrick indicated that Conscientiousness, Extraversion and Openness to Experience correlated positively with job performance because individuals who are dependable, persistent, goal-directed, organized, active, and sociable tend to be high performers. Their findings also demonstrated that Emotional Stability, Agreeableness, and Conscientiousness are indicators of high performance in types of jobs that require interactions with other people because individuals with these traits tend to be more confident, independent, flexible, cooperative, and caring. As evident in this case, Zimmerman, Donahue, and Stoker had a

combination of these traits described above: persistent, goal-directed, confident, independent, cooperative, caring, and encouraging.

A shared leadership team in systemic change is necessary and productive (Lambert, 2002; Reigeluth, 1994, Rowland, 2004). Consistent with the discussions of the role of a leadership team in a change process in a number of studies (Nesbit et al., 2001; Spillane et al., 2004), this case shows that a division among the functions of design, administration, and liaisons among leaders and further illuminates how different expertise and change management strategies needed to lead change were distributed across different leaders. It is evident that a leadership team rather than the individual leader is more appropriate in leading change in this case.

Formation of a learning community

In the technology integration change process, it is a powerful force when these change agents and stakeholders put their expertise together as evident by the learning community in this case. Consistent with the discussions of the importance of a learning community in a change process in previous research (Andrews & Lewis, 2002; Joseph et al., 2002; Nesbit et al., 2001), this study indicates that the formation of a learning community bolstered the change efforts, sustained the change process, and suggested a number of ways to form a learning community.

The first activity was to identify a three-phase conceptual change model to lead the technology integration change process. Zimmerman, along with SCIED 408 course instructors and graduate students in the program, synthesized a three-phase conceptual change model for technology integration that guided the implementation of technology integration in SCIED 408 since 1999. Zimmerman added that the model was valuable in providing the preservice teachers with opportunities to reflect on integrating technology into science learning and teaching in a circular cycle. She said:

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 preservice teachers start as science learners and progress to independent teaching over different 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.

Donahue added that this model served as a basis for the design of the course and facilitated the implementation of technology integration in SCIED 408:

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. I think that model was one of the sustaining factors because we all believe in that.

Friedman also stressed that "the technology integration conceptual change model draws the directions. People paid attention to the scaffolding in the model." Stoker pointed out that the technology integration change model is "an excellent way of helping preservice teachers to see how they should use technology to enhance learning. The model continues to be important." Hess also said that "the model drove the organization and served as a way to support preservice teachers in teaching science with technology."

The second activity was collaboration on a technology integration state grant. Zimmerman, Donahue, and Friedman co-authored a technology integration state level grant proposal in 1998 based on the model discussed above, and the grant was awarded in 1999. A number of supportive elements of the grant facilitated the changes, including revision of the course, the ability to buy appropriate technology tools, and the ability to hire key personnel to support important functions. Zimmerman described:

The state grant was instrumental in many ways. ...The grant provided resources that allowed us to make use of cutting edge technologies in a systematic way.

Hess added:

The grant was really the stimulus for implementing the technology. We were able to buy a lot of the technology and modify the course to be technology intensive....When I first started in 1998, we did

not have STEPS Days. STEPS Days was the result of the technology integration grant. So part of it we wanted them to have opportunities to teach with technology and guided environment which would be on campus before the preservice teachers went out to the classroom and try to do it with the students. That is the idea.

Stoker also said,

When I came here on the technology integration grant in 1999, I worked with many elementary schools. Whenever preservice teachers would be going for their field experience and wanted to use the probes, Science Court, or did not have computer in the school, I was holding computers or software out there for them to be able to use in the field experience classroom.

The third activity was the establishment of a research team. Zimmerman and Donahue conducted research in the context of this course with the instructors and graduate students, including Friedman, Hess, Aberdeen, and Bell. Friedman called it “the research community.” Working with Zimmerman, Friedman, Hess, and Aberdeen’s research interest centered on the influence of various science specific tools on science inquiry and reflections. Bell’s research focused on the perceptions of elementary preservice teachers of science inquiry in an online collaborative learning environment. Zimmerman emphasized the role of research findings in providing evidence to support the proposition 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 408 in terms of how we are modifying and changing assignments over time because we are constantly learning from that process.... Various components are sustained only to the extent that they fit with the model. If we do not have evidence supporting how our preservice teachers 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 not gone away because it is pretty powerful.

The fourth activity focused on the improvement of teaching. The course instructors held regular meetings to discuss improvements. A few veteran instructors served as mentors for new instructors. Stoker described how she worked with other instructors on a regular basis and how she modeled teaching practices for new instructors:

We hold weekly meetings. I put my lesson plans up in my web site for new instructors to pull down. Then we revise those together and come up with ways to improve. 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.

Hess emphasized why the change process had sustained:

I think the big part of that is the team approach. It is a team that teachers work very closely together. So, it is not like each individual does their own thing. We follow the same syllabus....

Zimmerman added, “There has to be a bigger commitment of the team in the process.” Bell also illustrated his experience of developing an online collaborative learning environment for other course instructors in recent years:

I have become expert on this online collaborative learning environment because I spent most time with it. So in the fall semester of 2002, I was on everyone’s site as an administrator. I was the one to whom other instructors came for questions. So I think my role has increased their confidence.

Influences from different educational systems

In investigating the technology integration change process, it is critical to look beyond the course to other educational systems with which the course interacts. It is also important to identify the shifts and changes at different levels of educational systems that may influence technology integration at another level. Previous research identified the influences from local school districts (Taylor & Wochenske, 2001), the university level (Grove, Strudler, & Odell, 2004), and the state level and software vendors (Brooks-Young, 2007; Brown, 2007); this study shows similar findings and illuminates more dynamics within each of the educational systems and explicates the interactions among them. First, although the university’s support for technology integration was not solely intended for SCIED 408, the changes came at a time when it was most supportive of change in SCIED 408. In terms of online collaborative tools, the university offered a university-wide course management tool, A New Global Environment for Learning (ANGEL), as a common instructional tool for the instructors and the students. Before, the course used tools

such as Creating Communities of Learners (CCL) that were offered outside the university, and which failed to continue because of complicated logistical and technical problems. Donahue explained:

Mainly CCL was not housed in our 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.

At the school district level, all participants repeatedly identified partnerships between SCIED 408 and the local school districts through the STEPS Days activity as a positive factor of sustaining the technology integration change process. Donahue also stressed the importance of establishing the partnerships with local school districts by Stoker:

Dr. Stoker's job turned out to negotiate with all the teachers and technology coordinators and others in the school districts. So students can integrate technology into their teaching. We had a loan at that time. ...So our students more or less were able to integrate technology into lessons without any difficulty.

The science academic standards from the state department of education also played a role in dictating the design of the course and drove the direction of the types of technology integrated into the curriculum. Bell said, "We wanted to do something that was environmental to reflect the environmental ecology standard of the State. Probably the sound probe works better for what we want to accomplish." Stoker and Aberdeen added, "The new assignment is on the watersheds. And that lends itself nicely to using the probes of temperature and pH. It is one of the new standards from environmental ecology."

Participants regarded that political attention from professional organizations was a big drive for the technology integration change process. Zimmerman, Donahue, Aberdeen, Hess, Friedman, and Bell had been very productive in publishing journal articles and presenting conference papers on technology integration into the SCIED 408 course, which drew the attention and interest of people working in similar areas of research and their accomplishment was reinforced. The program also received recognition from the National Council for Accreditation of Teacher Education (NCATE). Hess claimed that such attention sustained their efforts in the change process. She said:

When NCATE came in and did accreditation reviews, one certain thing [technology integration] that they hailed....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.

The partnerships between SCIED 408 and the software manufacturer sustained technology integration. The software development manufacturer, PASCO, provided more tools and professional training for the faculty members and the instructors. Donahue explained:

We bought some. And PASCO gave us more. And over the years, people like Dr. Stoker wound up getting involved with PASCO and became PASCO technology educator. Then they go up and do workshops, which I think is great.

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

One way that I try to keep up with is I became PASCO technology educator, which I went out for training. When I go to conferences, I work with those folks at their booth. Selling probes. (Laughter) I am not really selling but bringing folks over and demonstrating the use of software. ...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.

The manufacturer also accommodated the technology tools to elementary level in recent years. Zimmerman added, "So the PASCO developed a USB probe, which is much more elementary friendly. These tools for sciencing get more accessible for the elementary classroom."

It is noted that the links among the leadership team, the learning community, and educational systems facilitate the development of change agents' and stakeholders' expertise as well as help expand the resources available to the course. In this case, Stoker became the PASCO technology educator and worked with the manufacturer to share her experience with other schools at conferences. The software manufacturer also provided professional training for

course instructors and graduate students and improved their software geared more toward the elementary level. The benefit is reciprocal rather than one dimensional.

We have identified three enabling factors and described their interaction. These three factors complemented and enhanced each other. The three factors found in this study were similar to a number of transformational variables, such as external environment, leadership and individual and organizational performance, described in Burke and Litwin's (1992) organizational performance and change model. They identified that these variables have causal relationship among them and argued whether the change is caused by the forces of the external environment or leadership. In this case, it seems that the technology integration change was pushed by the university faculty downward. Based on the findings, we argued that the university faculty is in the best position to champion a technological change initiative and is in control of leading the technology integration change process.

Implications and Conclusions

The ultimate goal of this study was to provide a framework of technology integration for persons who play the role of change agents in educational settings. This section summarizes the findings and addresses the implications for this study. Additionally, I provide recommendations for further study.

As indicated in this study, continuing commitment of a transformational leadership team sustains the change. The transformational leadership style in this study truly reflects Senge's and Lannon-Kim's (1991) view on current view of leadership in systemic change. Senge and Lannon-Kim (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 and Lannon-Kim (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.

The formation of a learning community serves as powerful strategy to facilitate and sustain technology integration. Research conducted by Balach and Szymanski (2003) investigated the dynamics of a learning community through collaborative action research. This study reveals that the dynamics of collaboration, inquiry, parity, reflective dialogue and shared vision shape the progression of the group. More specifically, the research community in this case truly reflects these characteristics. A research community is one type of a learning community because they strive to improve students' performance by involving them in research activities.

It is necessary to identify different levels within the 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. For instance, 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. Additionally, the focus could 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.

There are a number of implications for persons who play the role of change agents. First, it is appropriate to provide training in leadership skills and change strategies for persons who lead the change. Specifically, the skills include identifying other 2 or 3 persons who might share the same vision and then assigning different responsibilities based on areas of expertise. Second, it is critical to inform persons who lead change of different leadership styles and model the effective leadership behaviors. Third, in order to bring collaboration among change agents and stakeholders, it is important to design activities at different stages of a technology integration change process and allocate specific, regular time for these activities. Fourth, it might be beneficial to assist persons who lead change and stakeholders in developing strategies in identifying the potential positive and negative influences from other educational systems and examine ways to combat or enhance these influences.

In addition, I would like to provide recommendations for future study. The first recommendation is to conduct a longitudinal study in sustenance of change. Holloway (1996) critiqued that most studies on the technology integration change lacked longitudinal study. This 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. Thus, a lengthy period of study on examining factors that affect the change process is recommended.

While the findings are limited to the perspectives of change agents, the second recommendation is to research on the perspectives from other stakeholders such as preservice teachers and school teachers in order to gain a holistic, systemic picture of a technology integration change process. The holistic, systemic view of a change process enables the people involved in change efforts to plan for the establishment of roles, structures, and resources to bring the people and educational systems together to facilitate and sustain technology integration in a long term change effort.

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Appendix A: Interview Protocol

Role of Participant

1. How long have you been in SCIED 408 as a course instructor?
2. How has your role changed over time in terms of different technology integration projects in SCIED 408?
3. How did you gain support from others who played different roles (e.g., other course instructors) in the change process?

Course

4. Could you give me a description of SCIED 408?

Technology Integration

5. Who initiated the ideas of integrating science specific technology tools into SCIED 408?
6. Could you describe current technology integration projects in SCIED 408, such as major technology activities and assignments?
7. Could you describe the history of each project (e.g., when was it started; why was it initiated or motivated; how has it changed)?
8. Are there any technology integration projects in SCIED 408 that were dropped and are not listed on current list? Why?
9. How have elementary preservice 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: Time-ordered Matrix of Technology Initiatives

	Time Periods						
	Before 97-98	97-98 Year 1	98-99 Year 2	99-00 Year 3	00-01 Year 4	01-02 Year 5	02-03 Year 6
Technology Integration Projects	Data collection tools (Vernier probes)	Data collection tools (Vernier probes)	Data collection tools (Vernier probes)	Data collection tools (PASCO probeware)			Data collection tools (PASCO probeware)
		Online collaborative tools (Connecting Communities of Learners)	Online collaborative tools (CCL)	Online collaborative tools (ANGEL)			Online collaborative tools (ANGEL)
				Simulations and modeling tools (Tom Snyder Science Court)			Simulations and modeling tools (Tom Snyder Science Court)

Appendix C: The Roles of Participants

	Before 97-98	97-98 Year 1	98-99 Year 2	99-00 Year 3	00-01 Year 4	01-02 Year 5	02-03 Year 6
Zimmerman		Course instructor Course coordinator Lead researcher	Course instructor Course coordinator Lead researcher	Course coordinator Lead researcher		Lead researcher	
Donahue	Course instructor	Course instructor	Coordinator of Science Teacher Education Program				
Stoker				Course instructor Liaison	Course instructor Liaison	Course instructor Course coordinator Liaison	
Hess		Course instructor				Graduated	
Friedman			Co-authored the state level grant proposal with Donahue and Zimmerman	Research associate		Graduated	
Aberdeen						Course instructor	
Bell						Course instructor	