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A Systemic Plan of Technology Integration

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ABSTRACT
The purpose of this article is to suggest a research-based systemic plan for educational researchers, practitioners, and policymakers involved in the change process to implement successful technology integration in the context of teacher education. This article provides a background about reform efforts in science education in the United States in recent years. This article also addresses technology tools that are responsive to reform efforts in the elementary science education and indicates the challenges of modifying elementary preservice teacher education to meet technology reform needs. The technology integration change process takes time and efforts; not all change can be sustained. Thus, a systemic plan that considers three major components, including people, process activities, and systems, to ensure successful technology integration is suggested.

Keywords
Technology integration, Science education, Preservice teacher education, Systemic inquiry

Introduction

This article is to suggest a research-based systemic plan for educational researchers, practitioners, and policymakers involved in the change process to implement successful technology integration in their contexts. We begin by describing the background of reform in science education in the United States, especially the changes that led to the emphasis on teaching science as inquiry. Next, a number of major types of technology tools that have the potential to support reform efforts are addressed. However, these technology tools are still rarely seen at school nowadays, which reflects a lack of technology integration in elementary science teacher education programs that play an important role of shaping school practice. The challenges of preparing elementary preservice teachers to teach science with technology are described and we end by proposing a systemic plan for technology integration in elementary science teacher education programs.

Reform in science education

In recent years, the United States has called for reform on science education in response to students' poor performance in science tests and a general lack of interest in science. A number of professional scientific societies and organizations have taken the initiative in reforming science education. The National Research Council with the assistance of the National Academy of Sciences developed the National Science Education Standards (National Research Council, 1996), which addressed standards for teaching science and science education programs. The goals addressed standards for teaching science and science education programs. Based on the standards, it was recommended that science teaching take an inquiry-based approach and be adapted to meet the interests, abilities, and experiences of students. In this case, inquiry-based referred 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 were encouraged to create an environment to enhance science understanding by encouraging students to communicate ideas with a community of learners. In addition, the standards specified the roles of colleges and universities in preparing teachers for implementing curricula that were consistent with the content standards.

In 2000 and 2001, the National Research Council provided detailed guidelines for implementing inquiry-based science and classroom assessment (National Research Council, 2000, 2001b). The council suggested that 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 stand-alone activity.

The basis of reform in science education

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 the committee's careful examinations of practical experiences.

From these reform documents, statements, and policies, four distinct characteristics can be identified as forming the basis of reformed science education:

(1) Science teaching should employ an inquiry-based approach;
(2) Assessment should attempt to ensure the quality of teaching and enhance the effectiveness of learning;
(3) Science should be integrated with other disciplines and,
(4) Applications of technology tools into science teaching and learning should be increased.

The notion of science inquiry is the major focus of reform views of science teaching and learning (National Research Council, 1996, 2000). In the National Science Education Standards (National Research Council, 1996), two elements of scientific inquiry for science learners have been emphasized: abilities to do science inquiry and understandings about scientific inquiry. Some researchers proposed that science specific technology tools, including data collection tools, simulations and modeling tools, have the potential to facilitate learners' development from simple to sophisticated forms of scientific inquiry in recent years (Windschitl, 2000; Zembal-Saul, Munford, & Friedrichsen, 2002). However, the science specific technology applications in science teaching and learning are rarely seen or appropriately used in classrooms currently, particularly in elementary level. Most research reports are limited to discussing the integration of generic technology tools such as programming languages, spreadsheet, word processor, graphic programs, and the internet in elementary science teacher education programs (Cavanaugh, 2003; Linn, 2003; Skinner & Preece, 2003). For example, at Northern Florida University, preservice teachers were trained to use the internet as an instructional tool in an elementary science methods course. They learned search techniques and methods for evaluating web resources critically. They were then required to combine web resources with science content to create instructional units (Cavanaugh, 2003). In the UK, elementary teachers used a web site dedicated to elementary science to foster students' understanding of science concepts and the use of concept-mapping software to stimulate discussion and assess students' understanding (Skinner & Preece, 2003). While these are important aspects of technology use and integration into science teaching, a more specific focus on the use of science-specific technological tools is missing and only a few teacher education programs have begun to integrate inquiry-based technology into science curriculum. For example, 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, Blumenfeld, Starr, Palincsar, Coopola, & Soloway, 1993). The Science Education Group at Penn State (Dana & Zembal-Saul, 2001; Zembal-Saul et al., 2002) also provided elementary preservice teachers with opportunities to teach science with technology and modeled the use of technology in lesson plans during the semester. These programs connect science with 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. The next section proposes a number of technology tools that have the potential to support reform efforts.

Technology tools for reforming inquiry-based science

With emerging technological innovations, the use of technology tools in inquiry-based science learning has gained growing attention. Three types of inquiry-empowering technologies include data collection tools, simulations and modeling tools, and online collaborative tools (Windschitl, 2000). These three types of technologies assist elementary students in engaging in scientific phenomenon, conducting investigations, and communicating, and developing products (Zembal-Saul et al., 2002).

Data collection tools

Data collection tools encourage students' active engagement with phenomena in a manner similar to scientists' engagement with scientific phenomena. The National Science Education Standards suggest that "a variety of technologies, such as hand tools, measuring instruments, and calculators, should be an integral component of scientific investigation. The use of computers for collection, analysis, and display of data is also part of this standard" (1996, p. 175). For example, in microcomputer-based laboratories (MBLs), students can observe graphs being produced by a microcomputer while an experiment is simultaneously being conducted. Nakhlen (1994) defined MBLs as "software which uses an electronic probe to collect information about a physical system and converts that information to a graphical system in approximately real time" (p. 368).

In microcomputer-based laboratories, students are shown to develop science concepts, collect and analyze real time data, and visualize data much more quickly (Royuk & Brooks, 2003; Russel, Lucas, & McRobbie, 2003; Trumper & Gelbman, 2001). As mentioned earlier, the ability to graph and collect data is one of the integral practices of scientists in the course of their investigations. The microcomputer-based laboratories enable students to conduct difficult or previously impossible investigations (Bannasch, 2001). In addition, the microcomputer-based laboratories purport to strengthen students' science graphing process and problem solving skills because of the capability of simultaneously collecting and graphing data. One example is probes, a microcomputer-based tool that can detect temperature, voltage, light intensity, sound, distance, dissolved oxygen and so on. Probes are now available for various hand-held devices, such as the Palm, through ImagiWorks, and the PASPORT System, through PASCO, thus increasing the possibility for dissemination and use in schools.

Simulations tools

Simulations combine video, pictures, computer graphics, text and interactivity to present students with phenomena that otherwise would be inaccessible, too hazardous, too time-consuming, or too expensive to observe. Using simulations, students can manipulate variables that would otherwise be 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. Simulations allow students to ask "What if" questions, make predictions, and test out their ideas (Windschitl, 2000).

Online collaborative tools

Spitulnik, Stratford, Krajcik, & Soloway (1998) suggested that "teachers need to provide environments which support students' inquiry, collaborating, and communicating" (p. 6). Such environments can help students to generate scientific understandings, which can be built up through email, threaded discussions, and chat rooms and other online communication tools.

In recent years, several projects have made substantive efforts to create collaborative environments for students to get access to second-hand data and participate in discussions with people in the U.S and from around the world (Bombaugh, Sparrow, & Mal, 2003; Butler, &MacGregor, 2003; Howland & Becker, 2002). For example, the Global Learning and Observations to Benefit the Environment (GLOBE) Program (www.globe.gov), initiated by former 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 participate in threaded discussions about a variety of topics and investigations with scientists. GLOBE also supports students in data collection and analysis. After data collection, students report their data through the Internet and 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.
In the preceding sections, this article discussed science education reform and the technology tools that have the potential to realize the goals of science education reform. In the next section we discuss the current challenges of preservice science teacher education in the area of technology integration.

Challenges of elementary preservice science teacher education

In this section, we discuss a number of problems in technology integration in teacher education programs that are equally evident for elementary science teacher education programs. A number of national reports (International Society for Technology in Education, 2002, 2005) have indicated that although teachers have more resources through technology, some of them have not received sufficient training in the effective use of technology. Most elementary preservice teachers in different content areas and disciplines know little about the effective use of technology and are not confident in using technology when they teach (Nonis & O'Bannon, 2002; US Congress, 1995). They also lack an understanding of their role in implementing lessons with technology. Whetstone and Carr-Chellman (2001) conducted a survey, which revealed that elementary preservice teachers did not appear to see the importance of their roles in integrating technology in classrooms.

In order to address these issues, research has shown that teacher education programs need to engage in substantive efforts to prepare preservice teachers for teaching with technology. Successful integration of technology in teacher education programs should provide preservice teachers with opportunities to use technology to advance content area learning (Bull, Willis, & Bell, 2000), and promote authentic learning experiences (Brush, Igoe, Brinkerhoff, Glazewski, Ku, & Smith, 2000).

Specifically, colleges and universities should be aware of their ability to address elementary preservice teachers' competence in teaching with technology. Teacher education programs should consider all aspects of teacher education and have the ability to provide adequate opportunities for preservice teachers to apply what they have learned. Hargrave and Hsu (2000) presented results of a survey of instructional technology courses in preservice teacher education programs and concluded that more emphasis was placed on integrating instructional technology into the curriculum than on using technology for teacher productivity or personal use. However, most universities and colleges offered only one three-credit instructional technology course to prepare preservice teachers to teach with technology. In their survey study of investigating important factors in predicting preservice teachers' professional uses of technology with K-12 students in the classroom, Dexter and Riedel (2003) found that setting high expectations for designing and delivering instruction using technology was effective in getting preservice teachers to use technology during clinical experiences. Yet, the results also indicated that preservice teachers wanted to have more access to technology and support and feedback from cooperating teachers and university faculty during field experiences.

Systemic plan

In light of challenges of elementary science education programs, this article suggests a research-based systemic plan to sustain the technology integration change process. The previous sections identified the reasons for elementary preservice teachers being ill-prepared to teach science with technology, including poor design of college-level courses and lack of integration of instructional technology courses into field experience. A systemic plan to address these shortcomings considers three major components: people, process activities, and systems to ensure successful technology integration.

People

1. Recruit key persons to form a leadership team.

The first way to sustain technology integration is to form a leadership team by recruiting a minimal number of key faculty members or school teachers who possess expertise in elementary science education and share different experiences in technology integration. The faculty members fulfill certain types of functions, each focusing on design, administration, and establishing liaisons. Specifically, one leader focuses on the re-conceptualization of the curriculum changes, monitors the progress in the implementation stage, and revises the curriculum either by informal feedback or conducting research. One leader acts like a facilitator to facilitate the changes by empowering other teachers to be receptive to changes within school by providing professional development. The other leader is responsible for outreach to the school community and securing necessary resources in the form of funding and human capital. It is suggested that these three major responsibilities be shared among the leadership team, consisting of faculty members, principals, school teachers, or school administrators.

An example of leadership team is illustrated in the case of a team of university faculty in a science education program that sustained successful technology integration at the university level (Hsu, 2004). In this case, the key leadership team consisted of three faculty members, who had certain types of experience and adopted specific roles. The three faculty members fulfilled specific types of functions, each focusing on design, administration, and establishing liaisons. For example, one faculty member adopted the role of lead researcher in the context of technology integration because of her past research and teaching interest in technology integration in elementary science education. She, thus, conducted research with graduate students within the context of technology integration and based on the findings, she became responsible for refining course design and revising the technology integration process. The second faculty member assumed the role of coordinator with the university and the software companies because of the length of his tenure at the department and his knowledge of how and where to negotiate and secure resources. He, thus, ensured that the faculty members and graduate assistants participated in professional development workshops and obtained technological support from software companies. He also negotiated with administration to secure classrooms to set up technology tools and resources. The third faculty member, a former science teacher in a local school district, adopted the role of liaison between the science education program and various local school districts. She became responsible for providing adequate hardware, software and conceptual understanding of technology integration when these resources or support were unavailable in schools for integration into lessons by elementary preservice science teachers. Although these three leaders were responsible for different aspects, they held meetings and talked to each other to ensure that they were on the same track. This division of roles and responsibilities, in the light of individual abilities and interests, was a strong support for the technology integration process.

A study of 13 Chicago elementary schools in an urban setting indicated another form of a school leadership team (Spillane, Diamond, Walker, Halverson, & Jita, 2001). The leadership team consisted of the principal, the science coordinator, and the assistant to the coordinator. The principal appointed a particular classroom teacher as a science coordinator. Collaborating with an assistant funded by the school, the science coordinator took advantage of the annual science fair and worked with other science teachers across all grade levels to integrate more inquiry-based science instruction and develop performance assessment rubrics to assess students' projects. 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, to empower change in science education. The leadership team showed a division among the functions of design, administration, and liaisons although some of the functions might overlap. Another example of a leadership team was identified in one elementary school in North Carolina (Franklin, 1993; Nesbit, DiBiase, Miller, & Wallace, 2001).

The joint effort of the leadership team members is a powerful force in sustaining change because leadership team members can deal with different aspects in the technology integration change process and thus contribute their expertise.

2. Encourage the formation of a learning community.

A learning community is essential in sharing ownership of the innovation and involving other members in a variety of activities. The formation of a learning community is important for several reasons: to generate a sense of shared ownership among program participants as well as to foster a lifelong learning experience for the stakeholders.

One suggestion to form a learning community is to involve stakeholders in conducting action research. In Hsu's (2004) study, the learning community consisted of a faculty member and four graduate students who were either course instructors or were interested in technology integration in elementary science. They conducted research within the context of technology integration in the elementary science methods course and field experience classrooms to examine practice critically. In the process, they developed a conceptual model for guiding technology integration in a science methods course. They also examined and evaluated the organization and content of the course assignments such as web-based portfolios to better assist elementary preservice science teachers in reflecting on their technology integration experience critically. Accordingly, the framework for guiding the web-based portfolio assignment underwent several revisions based on the group's research for a period spanning six years from 1997 to 2003 (Hsu, 2004; Avraamidou & Zembal-Saul, 2002). The formation of the learning community helped the participants have shared ownership of the technology integration process, leading to a deeper commitment to the change process.

The second activity for a learning community is to form study groups. Study groups read articles or books together, discuss the implications of ideas and engage in reflective dialogues, which lead to better instructional practice. For example, in addition to conducting research, the faculty member and the graduate students met weekly to discuss the readings assigned from the previous week (Hsu, 2004). During the meeting, they exchanged their ideas about obstacles encountered by their elementary preservice science teachers when they integrated technology into their field experience classrooms. Through these discussions, the study group participants were able to gain insight into specific problems and solve them by consulting each other in a short period of time. Reflective dialogues in the study group provided a basis for the changes of the design of curriculum in the following semester. The formation of the learning community sends a message to the participants that learning as a group can be much more powerful in sustaining the technology integration change process than learning individually.

In the FIRST (Fund for the Improvement and Reform of Schools and Teaching) project initiated in North Carolina, teacher leaders and the other teachers used various activities to form a learning community to introduce inquiry-based science instruction (Nesbit et al., 2001). The teacher leaders co-taught lessons with other teachers in the school, which encouraged exchange of expertise between the teacher leaders and other teachers. The leaders also led other teachers to reflect on the challenges faced in the implementation of inquiry-based science instruction and solved the problems together. Teachers who showed resistance were invited to regular meetings to share their expertise; this involvement resulted in reduced resistance because of a growing understanding of the process and positive feedback from the teacher leaders. The teacher leaders also designed workshops where trainee teachers participated in role-playing to increase their confidence in delivering inquiry-based science lessons. In this case, the formation of the learning community creates a group learning environment, resulting in the reduced resistance from the stakeholders.

At Ganado Primary School in Ganado, Arizona, the principal and teacher leaders built their learning community by involving teachers and staff in discussion about curriculum and instructional practices on a regular basis and by making time for collegial sharing (Cosner & Peterson, 2003). Other ways of building a learning community in schools include distributing weekly staff newsletters highlighting efforts of teachers who adopted innovative instructional strategies and communicating the expectations and vision with the teachers and staff.

It is suggested that careful planning of these activities, including conducting action research, forming study groups, engaging in reflective dialogues, modeling teaching, collaborating on solving problems, and involving in regular discussions of instructional practices, bolsters the formation of a learning community in order to sustain technology integration.

Process activities

A variety of process activities are needed to ensure that the technology integration change process is able to sustain over time. Process activities include pilot-testing of technology tools and adopting web-based portfolios to scaffold teacher development.

3. Pilot-testing the use of technology tools.

Prior to any large-scale technology integration, it is important to pilot test the use of technology tools with a small group of end users and stakeholders within the authentic learning environment and collect as much feedback as possible from the users. It is also critical to allow some time to reflect on the feedback and to avoid rushing into the implementation of technology integration. Hsu's (2004) research indicated that a key faculty member in the change process piloted different technology projects with a small group of elementary preservice teachers for two years before implementing the technology tools with the entire group of 180 elementary preservice teachers.

Including stakeholders such as course instructors, students, and researchers (Hsu, 2004) in pilot testing can provide very important information. In the specific context of technology integration in an elementary science education program, for example, course instructors were able to describe their feelings about the technology tools and their appropriate integration into class and curriculum. Course instructors also provided assessment data that supported the utility of technology tools in enhancing learning; they could identify students' technical and conceptual problems and suggest ways to improve student learning. Students could describe whether they learned better by using technology tools and whether the technology tools were easy to operate. Researchers could assess the project holistically in terms of technology integration and curriculum conceptualization, and suggest appropriate design refinements. Such testing provided empirical support regarding the efficacy of the proposed instruction in the elementary science methods course. Although pilot-testing appears to be a common procedure to help instructional designers make informed decision of the use of technology in organizations (White & Branch, 2001), it became an essential task to bring about the sustenance of the technology integration change process in this particular context.

Pilot-testing appears to be a critical process activity in the technology integration change process. Although resistance might occur, it is imperative to take time to pilot-testing the technology tools with a small group of end users within the authentic learning environments.

4. Using practice and reflective activities to scaffold teacher development.

One important method for supporting pre-service teachers learning of technology-based science is the integration of reflection as part of the process. According to Lin, Hmelo, Kinzer, and Secules (1999), reflective thinking involves "actively monitoring, evaluating, and modifying one's thinking and comparing it to both the expert's models and peers" (p. 43). It is critical for preservice teachers to draw connection between the coursework, practice in clinical experience, and national standards. In addition, they need to adapt their knowledge and skills, cope the issues in their clinical experience classrooms and develop their repertoire of integrating technology to enhance teaching and learning. All of these skills require highly complex reflective thinking process. Therefore, it is essential to provide support and scaffolds to assist preservice teachers in developing reflective and critical thinking about these tasks in teacher education programs. While many options can support reflection, one popular form is a portfolio that integrates practice and reflection meaningfully.

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 being useful for preservice teachers in a variety of ways. First, portfolio development is a powerful tool to engage teachers 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 preservice teachers' ability to connect theories and practices (Morris & Buckland, 2000).

The portfolio has been represented in different media over time. Because of photocopying costs and storage problems, hypermedia portfolios gradually replaced paper-based portfolios. Web-based portfolio, as one type of hypermedia portfolio, 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). 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 conclusion was reached by Glasson and McKenzie (1999) in examining the development of multimedia portfolios for enhancing learning and assessment in an elementary 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 preservice teachers as they developed curriculum and taught children at a local school and in the classroom" (p. 337).

Land and Zembal-Saul (2002) investigated the influence of scaffolds in the Progress Portfolio, a generalized tool for articulation and reflection, on preservice teachers' construction of scientific arguments within the context of an innovative science course that aimed at providing preservice teachers with experiences learning science using inquiry empowering technologies. The results indicated that the computer-based scaffolding supported articulation and reflection of evidence-based explanations. The preservice teachers showed increasing sophistication in their explanations, and the prompts within the Progress Portfolio seemed to stimulate preservice teachers to become more precise in their explanations, to offer justification, and to connect evidence with claims. They also suggested further research on varied scaffolding methods incorporated into computer-supported learning environments to facilitate reflective thinking.

In the specific case of Hsu's (2004) study, web-based portfolios were used to scaffold elementary preservice science teachers' development in a science methods course. Two faculty leaders conducted a study about the progress of these teachers in developing web-based portfolios that included evidence and evidence-based justification to reflect on their experience in integrating technology into their science teaching within one semester in an elementary science methods course. The findings indicated that web-based portfolio development can support preservice teachers' metacognition by making connections between evidence and justification explicit, and allowing them to express themselves creatively and save changes over time. Most importantly, the findings indicated that web-based portfolio development could engage students in meaningful reflection in technology integration in science teaching since these preservice teachers appeared to select more convincing evidence and provided stronger justification as the semester progressed.

A hierarchy of Systems

Identifying the function of different levels of the educational systems allows adoption of approaches that can strengthen synergy among different levels. In addition, foreknowledge of these levels allows one to address problems that may arise from these systems before and during the technology integration change process. In general, one can focus on the university level, the local community level, state level, and the broader public.

5. Increase the involvement of the local community.

At the local community level, it is essential to involve local school district teachers and students through the change process. Example activities include involving local school community in university-held events and delegating liaisons to regularly coordinate activities involving local community and local school district personnel. During the early stages of the technology integration change process at a northeastern university, Hsu (2004) found that in the first few years, barriers to technology integration included a lack of technology resources in school and lack of support from mentor teachers. Due to these deficiencies, elementary preservice teachers were unable to implement lessons with technology in their field experience classrooms. However, in the later stages of technology integration, Hsu (2004) indicated that inviting local elementary school students and teachers to visit the university appeared to be a successful intervention in sustaining the technology integration change process. During such visits, elementary preservice teachers practiced teaching lessons with technology with a small group of students and thereby gained opportunities to experience the effect of technology integration on science learning. These visits also provided in-service teachers with opportunities to observe how inquiry-based science lessons were taught using technology.

White (2001) suggested the importance of reaching out to different interest groups in the community that may contribute to the enhancement in the areas of science and technology. These groups include the private sector, government, educational institutions, and the science and technology community. Taylor and Wochenske (2001) identified a number of strategies for a long-term business-school partnership that has enhanced science education reform efforts in the San Diego school districts for the past ten years. These strategies included holding annual science fair, inviting local scientists, university faculty and graduate students to schools, and engaging in-service science teachers in discussion with the science research community in after-school seminars.

Professional development schools (PDS) are another method of establishing close relationships between university-based researchers and school-based educators. Grove, Strudler, and Odell (2004) suggested that it is critical to establish school district-university partnerships to assist student teachers in integrating technology in field experiences by implementing frequent professional development sessions. Mentor teachers helped novice teachers to build knowledge about how to teach in reform-minded ways with technology and how to mentor student teachers to teach in ways consistent with science reform standards. Mentor teachers were introduced to new practices and research in integrating technology with curriculum-based, student-centered activities by university faculty, which exposed them to new models for teaching and learning and learn to encourage novice teachers to teach in similar ways through modeling, practicing, and analyzing teaching together. Collaboration between school teachers and university faculty appears to be critical in sustaining the technology integration change process.

6. Actively identifying funding opportunities and standards from the state department of education.

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. In the specific case of Hsu's (2004) investigation of change in elementary science education, state standards greatly influenced the technology integration process. State academic standards in science informed the selection of topics for long-term projects every semester and the choice of technology tools. As an example, instructors designed units of lessons on watershed management to respond to the new standards of environmental ecology from the state department of education.

In light of the economic hardship of state departments of education, a number of methods to secure external funding need to be identified. Cooper and Bull (1997) indicated that funding appeared to be an essential factor in technology integration because technology software and hardware need to be updated every year. They suggested that deans and other leaders, individually or collectively, should educate university presidents, provosts, state boards of education or professional practices boards and state legislatures on the importance of adequate technology resources. Bauer (2001) specified four major funding sources, including foundation funding, corporation grants, individual giving, and federal and state grants. Among these resources, federal and state grants place the greatest impact on technology resources in educational settings. Thus, it is critical to recognize the importance of funding in technology integration, to identify where the funds can be granted, and to identify means to obtain the funds to sustain technology integration.

7. Identify means to collaborate with and gain recognition from national professional organizations and software vendors.

At the national level, it is essential to identify means to gain recognition from accreditation agencies, to attend national contests or reviews and meetings of professional organizations, and to disseminate experience by authoring articles in journals, and to develop partnerships with educational software companies for appropriate support. Hsu (2004) identified that positive attention from an accreditation agency was critical in sustaining technology integrations. The faculty members and course instructors within the science education program gained confidence and momentum in technology integration because of recognition by National Council for Accreditation of Teacher Education (NCATE), an accreditation organization. Published journal articles and conference papers drew the attention and interest of people working in similar areas of research, which reinforced the accomplishments of faculty members' and course instructors' efforts in technology integration. Thus, in educational settings, rewards can accrue in a number of ways and it is not necessary to use money as a form of reward.

Software companies can provide technical assistance and buy-in. They can also offer professional development workshops for the potential users and learners. Cooper and Bull (1997) suggested the establishment of partnerships between the educational programs and vendors of educational software to ensure that students receive appropriate exposure to software. They 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. In Hsu's (2004) study, software companies were very supportive of the science education program and provided additional tools and professional training for the faculty members and course instructors. The companies also worked diligently to develop compatible technologies and more elementary-friendly tools based on faculty members' and course instructors' feedback. You (2001) provided a number of practical suggestions for developing school-business partnerships that promote educational reform in science and technology. These suggestions include aiming for a long-term relationship, getting top-level commitment, deciding on goals, looking for partnership opportunities that fit in school's situation, being flexible, building on little success and publicizing your efforts, and assigning a staff person or outreach coordinator to develop partnerships.

As discussed in the previous sections, the technology integration change process can involve different levels of systems. It is essential to identify the impacts that different systems might have and to exercise strategies to reinforce strengths of and tackle possible resistance from these systems.

Conclusion

Although we suggest a research-based systemic plan for integrating technology in elementary science education, a number of areas remain to be answered. First, a leadership team has proved as a powerful force in sustaining technology integration in elementary science education. However, it is important to further study methods for recruiting key persons with expertise in science education and keeping them involved in the technology integration change process. It is also important to identify and clarify mechanisms that allow for sharing responsibilities in a leadership team.

Second, a learning community can be very powerful in sustaining the technology integration change process in elementary science education. However, we need to identify how to designate experts with vision to serve as catalysts for forming and leading the learning community. Additionally, research and practice must explore the design of a variety of significant, motivating, and relevant activities in which to engage stakeholders. Also, for busy teachers, it is important to identify methods to motivate them to engage regularly in aforementioned activities.

Third, the technology integration change process cannot be sustained if support from different systems is insufficient. We identified a number of systems that have influence on technology integration. It is important for the change agents to recognize the resources and inhibitors within the systems and accordingly assign different weights while evaluating the success of the implementation plan in different contexts.

This article provided the background of reform in science education in the United States in recent years. This article also addressed major types of technology tools that are responsive to reform efforts. In addition, this article indicated the challenges of elementary preservice teacher education and justified why the technology integration change process is worthy of further examination. Change takes time and efforts; not all change can be sustained. Thus, a systemic perspective was provided for educational researchers, practitioners, and policymakers involved in the change process to plan for successful technology integration in their contexts.

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