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ABSTRACT

Today's high school students have grown up in technology-rich environments with video games, personal computers, instant communications, and Internet access. These students are naturally more interested and involved in a technology-infused classroom. Emerging technologies change the teacher's role in the classroom. Professional teachers need to have the skills to integrate technology into their lesson plans in order to increase student learning. This paper presents a study that explored how six prospective science teachers became proficient using electronic technology to teach science. (Contains 22 references.) (YDS)

Infusing Technology to Enhance Science Lessons: Prospective Teachers as Action Researchers Learning to Teach for Conceptual Change

[M. Randall Spaid]

INFUSING TECHNOLOGY TO ENHANCE SCIENCE LESSONS: PROSPECTIVE TEACHERS AS ACTION RESEARCHERS LEARNING TO TEACH FOR CONCEPTUAL CHANGE

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High school students enter the science classroom having grown up in a technology-rich world of video games, personal computers, instant communication and Internet access. In writing about the potential of using technology in a constructivist classroom, Strommen (1995) points out that, since they are used to an environment outside of school where they control the flow and access of information, these students are naturally more interested and involved.

> Unfortunately, in many classrooms, knowledge is presented to students in a linear, didactic mode that differs dramatically from their previous experience outside the school. In contrast with the vivid images and self-directed flow of the interactive home and society, school strikes them as rigid, uninteresting, and ultimately alienating (Strommen, 1995).

With the ubiquitous presence of computers in schools, there are significant changes in the roles of the teachers using emerging technologies for instruction. The new professional teacher needs the skills to infuse technology into lesson plans in order to connect with technology-savvy children to improve their learning (Wise, 1997). Teaching prospective science teachers how to infuse their lessons with multimedia electronic technologies in a science education methods course may be a catalyst for changing the way science teachers teach high school students.

In this study at a large, public university in the southeastern United States, six prospective science teachers enrolled in a semester-long Advanced Topics in Teaching and Learning High School Science education methods course were challenged to become proficient using electronic technology to teach a science lesson. Concurrently, they practiced teaching science for conceptual change using sophisticated PowerPoint slideshows infused with video clips, animations, and hyperlinks to Internet sites. Furthermore, they had the opportunity to practice teaching their science lesson in front of actual high school science students at the university's Developmental Research School (DRS).

While others have studied how teachers learn to use technology in the classroom (e.g., Means, 1994; Strommen, 1995) and teaching for conceptual change (e.g., Chiappetta, Koballa, & Collette, 1998; Posner, Strike, Hewson, & Gertzog, 1982), this study is unique in that I had a venue in which prospective teachers could practice teaching technology-enhanced science lessons to my own tenth grade biology honors class and a general chemistry class at the DRS. In addition to having extensive experience as a science teacher, I regularly infuse my science lessons with multimedia electronic technologies, and could demonstrate my own science lessons as well as provide my university students with continuous access to tenth and eleventh grade high school science students.

Purpose for the Study

The National Council for Accreditation of Teacher Education (NCATE) is promoting reform to ensure quality in the preparation of our nation's teachers with a vision of "the new professional teacher... know[ing] how to employ educational technology effectively" (NCATE, 2000). Few, if any, teacher education programs are currently meeting all of the National Educational Technology Standards for Teachers; few prospective teachers are developing the competence to use technology as a teaching tool (Wise, 1997). The International Society for Technology in Education (ISTE) released National Educational Technology Standards for Teachers which focus on preservice teacher education and define the fundamental concepts, knowledge, skills, and attitudes for applying technology in educational settings (ISTE, 1998). According to ISTE, all prospective teachers seeking professional certification should meet these educational technology standards; ISTE further recommends that all teachers acquire competencies in basic use of computers and electronic technology for personal and professional uses as well as the application of technology for instruction.

Teacher education programs cannot predict how technology will change the teaching profession and college instructors cannot predict what knowledge, skills, and attitudes are essential for prospective teachers to perform successfully in technology-enriched K-12 classrooms. "Limited teacher training is often faulted for the low level of technology integration in the K-12 public school system" (Strudler, 1995). The majority of teacher education faculty does not model technology use to accomplish objectives in their courses, nor do they teach students how to use information technologies for instruction. For example, students are seldom asked to create lessons using technologies or practice teaching with technological tools (Strudler, 1995).

Research Questions

In studying the conceptual change in these prospective teachers and how they accommodated constructivist and reflective practices during this semester-long science methods course, I was interested in the following research questions:

- How do the prospective teachers' perceptions of using electronic multimedia technology to enhance their science lessons change throughout the semester?
- What evidence of conceptual change emerges for these prospective teachers during the semester as they revise and modify their PowerPoint slideshows?
- In what ways does instructor, peer, and high school science student feedback guide prospective teachers to modify science lessons?

It is important to note that this study explores the learning of two groups of students – the prospective teachers and the high school students at the DRS – and two categories of conceptual change – prospective teachers learning to teach science and learning to use multimedia electronic technology in the process. My primary focus was studying the prospective teachers in the science methods course.

Research Context

I had a dual role in this study as the course instructor for Advanced Topics in Teaching and Learning High School Science and as high school science teacher. The high school students who participated in this study were acclimated to seeing university students in their classrooms; prospective teachers from the College of Education intermittently observe, practice teach, and co-teach lessons at the DRS. When I told them that the prospective teachers would use PowerPoint slideshows accompanied by hands-on lab activities, my high school students were excited and enthusiastic, and promised to provide feedback about the multimedia and the lesson.

Although the prospective teachers who participated in this study had limited teaching experience and disparate competencies using computers and multimedia, all of them were science education majors, so I considered them to comprise a relatively homogeneous group. As they co-taught their science lessons with me in my classroom, I tried to minimize their concerns about student behavior and classroom management, the kinds of issues that student teachers have (Tabachnick & Zeichner, 1999).

Methodology

This study used naturalistic inquiry as the methodology (Lincoln & Guba, 1985). This allowed me to develop working hypotheses to interpret the instructional design of the prospective teachers' lessons and their pedagogy of the within the context of the methods course. For this study, a variety of qualitative methods were used "to ensure truth value, applicability, consistency, and neutrality" (Erlandson, Harris, Skipper, & Allen, 1993): multiple observations, briefing and debriefing interviews, peer assessment, member checking, and a reflective journal.

I interviewed each of the six prospective teachers at the beginning of the semester to determine their conceptions of science teaching and learning and their educational philosophy. The survey of their educational philosophies included a short description for two classroom scenarios: Mr. Gates leading a class discussion in a traditional teaching style and Ms. Wagner leading a class discussion in a more constructivist teaching style. (adapted from Ravitz, Becker, and Wong, 1998.) After reading the descriptions, the prospective teachers were asked to associate their thinking with Mr. Gates or Ms. Wagner in regard to personal preference in leading a classroom discussion, the type of class discussion they believe that high school students prefer, and the type of classroom discussion in which they believe that students learn best. We discussed the results of this survey during a regular class meeting; each prospective teacher shared personal experiences to justify his or her response.

In addition to analyzing the survey and interview data, I evaluated the pretest and posttest questions that the prospective teachers constructed using quality criteria adapted from Chiappetta, et al (1998) to determine if the questions were traditional, closed-end or constructivist, open-ended. Finally, I analyzed the initial, tentative PowerPoint slideshows created by the prospective teachers for our first briefing interviews and compared them to the revised slideshows after presentation to the science methods class students, and the final version of the slideshow that was presented to the high school students at the DRS. I evaluated the structure and sequence of the slides using the quality criteria described by Krathwohl, Bloom, & Masia (1984): receiving, responding, valuing, organization, and characterization (pp. 172-184).

While science lessons are usually designed to give students information to promote conceptual change thinking, another component is often to change or establish attitudes (Martin, 1989).

I administered a pre-test to the high school students before the prospective teachers taught their technology-enhanced lessons in my science classes. The posttests were administered at the end of the science lesson to determine if conceptual change had occurred for any high school students. In addition, I solicited immediate verbal and written feedback from the high school students about the quality and impact of the PowerPoint slideshow used during the lesson. Prospective teachers met with me before teaching the science lesson to their university classmates in the methods course. We met again after the lesson to debrief and discuss the peer comments and my observations in order to determine the appropriate revisions and modifications for improving the PowerPoint presentation. I suggested using alternative sequences of slides, and commented on the selection of images and more animation based upon my personal experiences as a science teacher. I also encouraged them to describe their feelings about the process of revision and record any difficulties or frustrations they were experiencing in their reflective journals. In order to put the prospective teacher 's slideshow in real context, I asked, Did you do what you said you would do? Was your slideshow more than just entertainment? Did you follow the guidelines of the 5-E model? The reflective journal for each prospective teacher also served as a research notebook. They regularly wrote about the progress of own action research project – their questions and interpretations of the data they collected from their peers and the high school students, their reasoning and rationale for changing their PowerPoint slideshows, and difficulties they were having.

After each prospective teacher taught a revised lesson at the DRS, we met to discuss the high school students' feedback, my observations, and their self-reflections. At this point of the semester, I used a regular class meeting to engage them in the analysis of data they had collected for their action research projects. Finally, at the end of the semester, I conducted an exit interview with each prospective teacher to discuss the reflection journals and action research projects.

We met as a class for ninety minutes twice each week. During our class meetings, the prospective teachers reconstructed their memories of their high school science classes as we discussed group work, "cookbook" science labs, drill-and-practice seatwork, instructional videos, teacher demonstrations, computer simulations, using probeware for data collection, developing a rationale for teaching Science, Technology and Society units; and engaging students in science fair research projects. In addition, we examined what they learned in previous methods classes and during their previous classroom observations of experienced science teachers. As appropriate, I regularly shared actual stories about my own science classes for analysis and discussion.

The Prospective Teachers' Action Research Questions

In integral component of this science methods course is engaging the prospective science teachers their own action research studies. During a science methods class, early in the semester, we discussed how to do action research (Dick, 1997). I guided them as a group to devise and refine their own research questions to explore their own teaching and learning about the effective use of electronic technologies in the secondary classroom. Their research questions included

- How do I use multimedia effectively to motivate students to pay attention during a science lesson?
- How does an animation or video clip help science students correct their misconceptions about natural phenomena?

- In what ways do girls and boys respond to PowerPoint slideshows and multimedia when I am teaching a science lesson?
- What difference does a complex PowerPoint slideshow make for high school students to learn science concepts?*(sic)*
- What kinds of "bells-and-whistles" must be included in a PowerPoint slideshow to get high school students engaged during my science lesson?

To illustrate how different assumptions lead to fundamentally different conceptions of the use of technology for teaching science lessons, this paper provides a new perspective toward teaching prospective teachers how to infuse their science lessons with electronic technology. This paper also describes how some prospective teachers think about how science students learning and how those beliefs influence their lesson planning. In each case, the prospective teacher's pedagogical philosophy becomes the guiding focus of this study.

Data and Observations

Results of the Survey Questions at the Beginning of the Study

- *Which type of class discussion are you more comfortable having in class*? All of the prospective teachers believed that they could successfully lead a class discussion like Ms. Wagner's. Most of them described a high school class taught by a teacher whom they considered exemplary and constructivist.
- *Which type of discussion do you think most students prefer to have?* Abygail and Tiffany believe that students prefer more traditional discussions like Mr. Gates'. Samantha, Christina, and Mike chose the type of discussion that Ms. Wagner was leading because they believe that teachers should be flexible even when the class is off the original topic. Jimmy explained that he chose undecided because he has no teaching experience.

- *From which type of class discussion do you think students learn more science?* Jimmy and Christina could not decide, ostensibly because they have no teaching experience. Their classmates believe that students learn more in a constructivist classroom like Ms. Wagner's but they could not justify their answers.

These data are tentatively analyzed as resulting from naïve assumptions about science teaching and learning as well as from a lack of familiarity with the tenets of constructivism (Bybee, 1997). Although these students had previously taken a methods class in which constructivism was modeled and promoted, perhaps these students have had few previous experiences in a constructivist science classroom during their secondary schooling and college classes. There was insufficient data collected in this study to explore this further; however, it provides a reference point from which to determine if any conceptual change has occurred during the semester-long course.

According to Posner, et al (1982), conceptual change occurs when students become dissatisfied with their present ideas or beliefs about a phenomenon they have observed, when they accept evidence that another explanation makes more sense, and when they believe that this new explanation is useful in order to learn more about the concept or idea. These prospective teachers were unfamiliar with this conceptual change terminology. Jimmy wrote in his journal:

> I began to get a little worried. I was not just teaching students some cake lesson out of a book, but I was actually gonna have to change some preconceived ideas that students might have. Learning that I would be using conceptual change as a technique changed my thought process completely. I would have to actually put some thought into this. . . .my ideas about teaching the lesson had changed. . . .(Excerpted from Jimmy's journal, beginning of semester.)

<u>Analysis of the PowerPoint Slideshows</u>

Krathwohl, et al (1984) suggest that instructional designers must address student needs in the affective domain as well as the cognitive domain. When the prospective teachers analyzed their PowerPoint slideshows during our first briefing interview, each slide was inspected to determine its value for engagement, exploration, explanation, elaboration, and evaluation. All of the prospective teachers indicated that they wanted to find better images, animations, and video clips. Most of them decided to delete some slides that did not provoke inquiry and many of them rearranged their lessons and changed the order of their slides. Jimmy wrote about his thinking:

> After I learned that I had to focus on the concept, my PowerPoint outline changed. Instead of listing the definitions we would be going over, I set it up in a way that the students would have to answer the questions I asked, and then a slide would come up clarifying what they had just answered. This made my lesson more of an inquiry lesson. Before it was just straightforward. (Excerpted from Jimmy's journal, mid-semester.)

After each prospective teacher presented a mini-lesson to the science methods class, the audience of peers was asked for a written assessment of the slideshow and we discussed the lesson as a group. After class, each presenter met with me to debrief the lesson and consider the peer comments. Some of them were sheepish about their "performance; however, all of them valued the feedback and decided to revise their slideshows. Although she did not admit this during our debriefing, Kristy wrote in her journal that she had carefully designed her lesson to impress her classmates and now had to revise it for the high school students:

> I wanted to look so good . . .. I think I didn't want anyone to say that teaching was not something I could do well. It has already become such a part of my personal identity. The [high school] students were not the people who I wanted to please; it was those others who want the same dream. (Excerpted from Kristy's journal, mid-semester.)

<u>Constructive Criticism from the Peer Assessments</u>

The peer critiques about the PowerPoint slideshows were forthright, pragmatic, and constructive. Comments included: rearrange the order of slides, emphasize the importance of a video clip or animation, select larger graphics, change font size and colors, incorporate text builds and slide transitions to maintain instructional momentum and sustain student interest.

The prospective teachers made final revisions to their slideshows and constructed a pre-test before presenting their lessons to my high school science students–they were confident that their slideshows would engage the students in inquiry. All of the prospective teachers in this study anticipated that their PowerPoint slideshow would stimulate higher level thinking by the high school students, pique their interest in the topic, and create disequilibrium in their thinking

Constructive Comments from the High School Students

In the high school science classroom, four of the prospective teachers discovered that most of the twenty-nine students in the class were anxious to engage in the lab activity that accompanied their PowerPoint presentation. Two of the prospective teachers were disappointed that the high school students were not more responsive during the slideshow portion of the science lesson, although the results of the post-test indicated that the students had learned the concept the were teaching. When the prospective teachers conducted a review at the end of their lessons, most of them were delighted that the high school students could answer questions about what they had learned. Some of the high school students admitted that they misunderstood the concept of surface tension and density, and had changed their minds after seeing the PowerPoint examples and doing the lab activity. When the prospective teachers analyzed the pretests and posttests, they confirmed that most of the high school students answered the posttest questions that required higher level thinking correctly.

When the prospective teachers and I debriefed after their lessons and evaluated the students' comments in view of the effectiveness of their PowerPoint slideshows, we considered the impact of the video clip, whether the sequence of slides was logical, and the effectiveness of the images, animations, and hyperlinks. Not only did these prospective science teachers receive input from their instructor and their peers in the science methods class, there was a target audience of high school stakeholders with the savvy to provide an additional perspective regarding effective use of technology when teaching a science lesson.

Many of the high school students wrote that the video clip was entertaining and helped them learn the concept; several were uninterested in the images, they only wanted notes for the posttest. Suggestions to improve the slideshow included adding graphics, using custom animations, changing layouts or colors. A few recommended additional movies and sounds so that the slideshow wasn't so boring. All of the prospective teachers believed that the comments were valuable. One of them wrote in his journal:

> The lesson went well: the video I [showed] of the astronaut on the moon seemed effective, but upon receipt of the feedback, the class was bored by it.... The aim was too low, and most of the class hated wasting their time. Fixing this lesson would mostly consist of me better using the PowerPoint. I used graphics only to illustrate a point. Instead, I could have used the pictures to set up an example, which is something I never thought of until after the presentation. (Excerpted from Mike 's journal, end of semester.)

Results of the Survey Questions at the End of the Study

During the exit interviews at the end of the semester, I queried each prospective teacher with the same questions about discussions in Mr. Gates' and Ms. Wagner's classes to determine if their beliefs about the roles of teachers and students in science classes had changed. Each of them had experienced the role of a teacher leading a class discussion in an actual science classroom and I wanted to know if they viewed constructivist practices differently now. I was looking for evidence of conceptual change in their thinking. As we discussed epistemology and pedagogy, some of the prospective teachers stated that they believed a constructivist approach to teaching science should result in increased student learning. The vignettes and results of the beginning and ending surveys are found below and in Table 1.

Mr. Gates was teaching his biology class in an animated way, asking simple questions that the students could answer quickly based on the demonstration they had seen the day before and the homework reading assignment. After this review, Mr. Gates presented the class pre-lab material, again using simple questions to keep students attentive and listening to what she said.

Ms. Wagner' class was also having a discussion related to the demonstration and homework reading assignment, but many of the questions came from the students instead of the teacher. Though Ms. Wagner would clarify students' questions and suggest where they could find relevant information, she didn't really answer most of the questions herself.

Table 1

Comparison of Beginning of Semester Survey and Exit Interview

	Definitely Mr. Gates'	Tend towards Ms. Gates'	Can't decide	Tend towards Ms. Wagner's	Definitely Ms. Wagner's
BEGINNING OF SEMESTER a. *Which type of class discussion are you more comfortable having in class?*				A, S, J, R, C, M	
EXIT INTERVIEW a. *Which type of class discussion are you more comfortable having in class?*					C, S, J, M
BEGINNING OF SEMESTER b. *Which type of discussion do you think most students prefer to have?*	A, R	J		S, C	M
EXIT INTERVIEW b. *Which type of discussion do you think most students prefer to have?*	A	R		C	J, S, M
BEGINNING OF SEMESTER c. *From which type of class discussion do you think students learn more science?*			J, C	R, S	A, M
EXIT INTERVIEW c. *From which type of class discussion do you think students learn more science?*	A	R		C	J, S, M

A=Abygail, S=Samantha, J=Jimmy, R=Kristy, C=Christina, M=Mike

Although they carefully followed the 5-E model to construct a PowerPoint slideshow to teach a science lesson for conceptual change, Abygail and Rebecca had not completely changed their conception of teaching and learning–their responses to the first question indicate that they are more comfortable leading a traditional discussion than a constructivist classroom. Both of them indicated that they also believe students prefer the traditional classroom discussion and will learn more in this setting. Abygail explained in her journal:

> I really wasn't aware that on the average high school students are very basic. They need things pointed out to them. They need to be told exactly what to do. Now, either I was a very bright, independent student in high school or I don't remember being that elementary. (Excerpted from Abygail's journal, end of semester.)

Abygail did not receive as many positive comments from the high school student about her PowerPoint slideshow and science lesson that her classmates did. Perhaps Abygail's response to the question was defensive because she felt she had no "real" control of the class; or, perhaps she simply reverted to teaching the way she was taught. She was concerned about students who were not paying attention to her. She chided them, "Hey! Pay attention to me" and "You have to write this down if you want to pass the posttest, so quit talking." Abygail wrote about this situation in her journal:

> On the left side of me there were a couple of students that were not paying attention at all or just plain non-participatory. I had a hard time dealing with [them] because it was not my classroom officially. (Excerpted from Abygail's journal, end of semester.)

At the beginning of the semester, Jimmy was undecided about how science students think and learn. He asked if the PowerPoint was supposed to be entertaining to capture the students' interest. When I reminded him about his question at the end of the semester, he stated that, now that he was more familiar with constructivist teaching and learning, he knew that the PowerPoint was supposed to be much more than entertainment, "but it could engage the student if it was interesting enough."

Samantha, Jimmy, Mike, and Christina indicated that they would be comfortable in a discussion like Ms. Wagner's, but I am not certain that all four of them have a clear and deep understanding of the roles of the teacher and students in a constructivist classroom after interviewing them and reading their journals. Samantha wrote:

> I liked being the "teacher" and knowing that students look up to me for answers and direction. I think having experience teaching baton twirling, and knowing how to take an authoritative role, gave me the confidence to be the one in charge. I never really was to hesitant about being in front of the class, I just didn't want to make a mistake, or not know enough information. (Excerpted from Samantha's journal, end of semester.)

<u>Results of the Action Research Projects</u>

The action research projects seemed to help these prospective teachers to identify and reflect on their underlying assumptions about what science teaching and learning is and the potential for using electronic technologies to enhance their lessons. I did not require a formal report oat the end of the semester because I was more concerned that they would spend more time in and out of the science methods classroom to reflect on their experiences in the DRS science classroom. Their journals indicate that they were learning to engage in reflective practice. Below are some comments from the their journals:

> It's different to try to read and understand what it is like to teach, but to actually do it is so much more beneficial. You can find your flaws, and fix them. I went into this class feeling a little overwhelmed, but I left feeling more confident and assured of teaching. I did not realize how much technology can enhance teaching. (Excerpted from Samantha's journal, end of semester.)

> This class not only taught me the technology that goes along with teaching but also gave me confidence in my ability to teach with technology. (Excerpted from Jimmy's journal, end of semester.)

> This class actually made me feel like a teacher. For the first time in my college career, I was thinking like a teacher. Now when I make lessons or look at web sites, I ask myself how they would be valuable to my students and me. (Excerpted from Abygail's journal, end of semester.)

> Even though I only taught one lesson, I learned so much about how to think, what my students are thinking. . . . I wish there were more courses like this one throughout the education program, because it really opens your eyes to the real world of teaching, and not just hearing about it from a professor who hasn't been in a high school classroom for twenty years. (Excerpted from Christina's journal, end of semester.)

Discussion

Calderhead (1983) suggested that prospective teachers have no schemata for pace, level of intellectuality, affect, and work orientation of high school students since they lack the complex knowledge that experienced teachers have. During the science lessons, I recognized a myriad of student behaviors which indicated that student learning was taking place– eye contact, note-taking, courtesy, enthusiasm, verbal responses to teacher questions, and engagement in the lab activity. Although most of the prospective teachers asked questions at the beginning of their lessons to discover the high school students' prior knowledge about the topic, only a few were able to use their knowledge of their students' thinking to plan their teaching. When we discussed the feedback from the high school students during the science class, each prospective teacher explored his or her own action research questions, asking, Do these DRS students simply "know the drill," answering teacher questions dutifully and following the visuals on the slideshow passively? Did any students other than visually oriented students benefit from this lesson? Were the students only marginally interested in the video clips and animations?

During my debriefing interviews with the prospective teachers, I tried to describe what kinds of learning I understood to be going on in the classroom and why the high school students did not respond to the PowerPoint slideshow with much enthusiasm. A colleague of mine at the DRS added this explanation for the comments by the high school students:

> These high school students are not all-visual learners–they may need to hear it, may need to do it, or touch it– but they all seem to be *oriented* to visual stimuli. They have been acculturated by television and video games; they are a video generation. They are savvy [as an audience]when it comes to PowerPoint because they know how to construct them and they sniff at inferior work. [W]hen you cross over to using PowerPoint for a lesson, it had *better* be more than a high tech blackboard. Want credibility with students? If you cannot do it [PowerPoint] well, do not bother doing it at all. (Mrs. Walters, English teacher, personal communication, end of semester, italics added.)

What is unique about this study? Since I was the science education methods instructor and I also teach at the DRS, (1) I linked a science methods course and a "real" science class for the prospective teachers, (2) I was able to enlist a group of actual high school science students to comment on each prospective teacher's lessons, (3) as the regular science teacher, I knew which of the high school students would provide useful comments and could screen out the less useful responses from those students who were uninterested in participating in the study. Although most of the twenty-nine science students in the DRS classroom comprised a pool of interested and experienced informants, capable of articulating their comments, statements that were clearly counterproductive were discarded (e.g., "it [the slideshow] was really pathetic.")

The prospective science teachers in this science course critiqued and evaluated each other's lessons to determine if they followed the steps for conceptual change. They began to recognize how student experience and expectations about electronic technology affects lesson planning and demonstrated some conceptual change in their pedagogical views. All of the prospective teachers constructed their PowerPoint slideshows using the 5-E teaching model. When they revised the slideshow, they systematically searched for the more effective visuals and redesigned slides to engage the high school students in higher level thinking instead of utilizing the slideshow as a sophisticated overhead projector to provide definitions and information for note-taking. Even the pre- and posttest questions were carefully constructed to provide the evidence they needed to determine if the students had changed their conception because of the lesson.

As the instructor of this methods course, I guided the prospective teachers as they made many of the revisions. I continually challenged them to reflect on their thinking about how students learn and how they would learn to teach science. Perhaps total conceptual change is too great an expectation within the limited time apportioned to methods classes (Gess-Newsome, 1999a). Prospective teachers need to become aware of their own implicit conceptions about teaching and learning science in regard to the understandings and actions in teaching – they teach the way they themselves learn best.

The prospective teachers in this study initially believed that teaching is telling and learning is gathering information. Years of apprenticeship of observation and of watching the public behaviors of teaching have led them to believe that they understand what is required of teaching (Lortie, 1975). Their first PowerPoint slideshows were mostly definitions and information. Teacher educators, on the other hand, may view teaching and learning quite differently: "Four time-honored conceptions of teaching are recognized: teaching as cultural transmission, skills training, fostering natural development, and promoting conceptual change" (Scardamalia & Bereiter, 1989). If methods instructors can help prospective teachers identify the appropriate points for integrating technology into their pedagogical practice, there is a greater potential to support deeper, more reflective, self-directed student learning.

Recommendations

Since technological advancements are affecting the way we teach and learn in high school science classrooms, teacher education programs for must integrate technology early in the sequence of courses leading to professional certification for science teachers. Furthermore, science education methods instructors must model how to use electronic technologies in the teaching and learning process if prospective teachers are to adopt a fearless attitude in the use of technology. “The idea is not only to teach them how to use the hardware and software, but how to integrate it seamlessly into the curriculum. Otherwise, it doesn’t work..." (Siegel, 1994). Science education methods instructors must provide authentic opportunities for prospective science teachers to practice teaching technology-enhanced lessons long before the semester traditionally scheduled for a classroom internship. To be most effective, these pre-internship experiences should take place in a public school setting which includes the target audience of high school students, and the prospective teachers should be engaged in their own reflective studies. One of the prospective teachers in this study wrote that he was able to concentrate on his lesson in my classroom despite my presence:

> I was never intimidated by his [the teacher’s] presence in the classroom. It made me a little bit more confident knowing that he was there to help me in case I needed it. I knew that I was the one teaching the lesson, so it was strictly up to me to get my points across to the class. (Excerpted from Samantha's journal, end of semester. Pseudonyms are used throughout this paper.)

The journals of the prospective teachers in this study seem to indicate that my extensive experience as a science teacher, my familiarity using electronic technologies for teaching science lessons, the availability of my secondary science classroom for practice teaching, and easy access to student feedback appear to have benefited them during this science methods course. One of the prospective teachers wrote that these classes helped her start thinking like a teacher:

> It was very helpful to have an experienced teacher there to ask me open-ended questions that got me thinking. I finally have to think like a teacher and his questions allow me to do that. (Excerpted from Christina's journal, mid-semester.)

As educational researchers explore collaborative relationships between science education methods instructors and local high school science teachers, I hope that more evidence will indicate that practice teaching in a "real" science classroom full of "real" high school science students provides more realistic experiences for prospective teachers than the methods course classroom on a college campus. When technologically-savvy students and experienced teachers team up in the tutelage of prospective science teachers, there is potential for equipping new teachers with the skills requisite for successful and rewarding careers.

Many students in our high school classrooms have multidimensional experience with interactive media outside of the school and they may be more techno-literate than their science teachers. The prospective teachers in this study learned about infusing technology to teach science lessons for conceptual change. Some of them showed signs of their own conceptual change toward teaching and learning science as evidenced by their deliberate, iterative modifications to their PowerPoint slideshows–they wanted to impact student learning and believed that a technology-enhanced tool would be effective. Although they demonstrated a limited understanding of the 5-E model of teaching for conceptual change, the prospective teachers were enthusiastic about their teaching experience in the high school classroom. College students in methods calsses such as this one may need to undergo conceptual change with respect to their notions of teaching, learning, the nature of science, and/or the nature of knowledge (Gunstone & Northfield, 1992). As he planned his lesson, one of the prospective teachers wrote in his journal:

> I realized that just learning a bunch of terms is not conceptual change. I switched my mode of thinking to a broader concept. I was asked the question, What is the one thing that you want the students to leave there knowing? This made me realize that terms and definitions are great, but do students actually learn? If there is no main concept to go along with the terms and definitions, then what good are they? (Excerpted from Jimmy's journal, beginning of semester.)

In spite of the fact that the short duration of the study limited the impact of their action research, it appears that these prospective teachers also learned new reflective skills. The interview data and reflective journals indicate that the authentic classroom experience enhanced this constructivist-based science methods course; they also suggest that constructivist-based instruction, which includes the use of multimedia, helped these prospective science teachers develop positive attitudes toward computer-related technologies. Future researchers may examine parts of this instruction model in detail to identify specific items or procedures that contribute to enhancement of prospective teacher education. Thus, the significance of the study has practical and theoretical implications for teaching secondary science methods courses based on a constructivist approach.

Limitations of the Study

There are a number of issues that emerged during the data collection, analysis, write-up, a and presentation of this study. Some of the issues are related to my expectations as a methods course instructor during the short duration of the study– my expectation that these prospective teachers could concurrently learn about how to teach an inquiry lesson for conceptual change and learn how to conduct their action research projects. Another issue arose regarding the data sources, such as whether the peer assessments and high school student comments are credible and unbiased. I also must speculate – what effect did my own educational philosophy, pedagogy, and epistemology have on the participants? Were they constrained to construct and teach lessons using my teaching style? How did my presence in the classroom, ostensibly to manage student behavior, impact their student teaching? Two of the prospective teachers were preoccupied with my presence, one wrote that she would have corrected two of my high school students who were talking during her lesson, but she did not want to usurp my authority. The other was concerned that I was judging her performance and claimed it distracted her. If these issues affected the teaching of the lesson, it may have affected the high school students' assessments and feedback.

One of the prospective teachers wrote that she wanted to impress her classmates when she taught her practice lesson in the methods classroom. I do not know if she will invest as much time preparing inquiry lessons and infusing technology during her student teaching. I was startled that she was less concerned with impressing me or the high school students and I suspect that she had less conceptual change throughout the semester compared to the other methods class students. Perhaps she regressed to a more traditional model of teaching because it was more familiar. She described herself in class as successful "and more comfortable" during high school and college taking traditional courses. She was somewhat skeptical that students will benefit in a constructivist classroom. Hence, I am not sure how to get at her thinking without additional interviews. I do not know if she is receptive she did not provide rich data in her journal.

Since this study lasted only one semester, there did not appear to be sufficient time for conceptual change to occur in the prospective teachers. Furthermore, they only visited my high school classroom once or twice–three of them indicated in their journals that they wanted more practice time in the "real" classroom. I encouraged them to use the 5–E learning cycle steps; however, two of them told me during the exit interview that they could not change the lesson "on-the-fly" after finding out what prior knowledge the high school students had. I told them I believe that experienced teachers have a tacit understanding of classroom dynamics that comes with practice. Four of the prospective teachers wrote that, after teaching the lesson, they understood why I emphasized building rapport with high school students and why I espoused designing lessons that address the affective domain.

Perhaps I attempted to cover too much in one semester: learning to use new electronic technologies, exploring curriculum materials and embracing too many new concepts about how to teach science in a secondary classroom. Learning to teach inquiry lessons is difficult enough, I directed these prospective teachers to teach inquiry science lessons for conceptual change. Jimmy's journal entry describe the conundrum for him until he realized that this teaching strategy goes way beyond giving definitions and talking about a phenomenon. The action research was new to all of the students in this methods course, but at least one of them, Abygail, wants to continue the journaling and self reflection when she student teaches.

During the semester, I modeled teaching behaviors to the methods class that I consider to be effective; however, I emphasized that each of them would need years of practice planning lessons, teaching "real" students, assessing their learning, and reflecting on the outcome. Perhaps participating in the study will begin the process for them. A follow-up study of their student teaching experiences might indicate that some of the course objectives in this methods course were reached and embraced by these prospective teachers. I hope these prospective teachers evolve into reflective science teachers who regularly infuse their inquiry lessons with multimedia in a determined effort to teach for conceptual change.

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