Technology-Integrated Project-Based Approach in Science Education: A Qualitative Study of In-Service Teachers' Learning Experiences

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Abstract

This qualitative study examines the impact of a technology-integrated project-based approach (PBA) on the learning experiences and subsequent decision-making of in-service teachers pursuing their master's degree who are enrolled in a science methods class. The authors employed in-depth interviews, journal reflections, observations, performance in class projects, and content of class projects as data sources. Through inductive data analysis the authors found that banter is a key factor in collaborative learning, that technology-integrated PBA fostered interdisciplinary connections in the science methods class, and that in-service elementary education teachers intended to integrate technology and PBA in their science classes as a result of their learning experiences in the science methods class.

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The underperformance of students in science (National Center for Education Statistics [NCES], 2006) has put science education in the United States in a state of crisis (Cognition and Technology Group at Vanderbilt, 1992). Comparing eighth to twelfth grade students against international performance paints an unflattering picture of science education in the U.S. (NCES, 2006). Investigating the reasons for this poor performance, educational researchers have identified multiple barriers to improving students' performances. These barriers include, but are not limited to, the quality of U.S. teacher education programs, the lack of science content knowledge among teachers, and the lack of professional development opportunities for teachers after completing their teacher education programs (Albion & Ertmer, 2002; Ertmer, 1999; Trowbridge, Bybee, & Powell, 2000).

Despite recent reports showing that over 90% of schools provide student access to computers with broadband connections to the Internet (Parsad & Jones, 2005; Wells & Lewis, 2006), both teachers' and students' use of technology is limited largely to low-level productivity tasks such as word processing, email, basic Internet searches, and electronic presentations (Lanahan, 2002). While the use of technology in a science classroom can exist on a continuum where minimal use might include basic Internet search and maximum use might include a fully integrated learning environment where students use application and synthesis skills, unfortunately, the examples of the fully integrated learning environment are limited. Moreover, the understanding of the term "technology-integrated" varies from teacher to teacher, school to school, and administrator to administrator. Thus, it is critical to investigate both situation- and policy-based implications of barriers and facilitators of technology-based science education curriculum in order to identify context specific challenges and solutions.

Of specific interest to the authors is the lack of utilization of technology in science classrooms in elementary school where students often form their first impressions about science. There is evidence that suggest that teachers often lack the confidence in using technology in ways that construct knowledge beyond the level of recall and that they have had poor modeling of methods classes in their training programs demonstrating how learning science can be enhanced using technology while following standardized curricular mandates (Laffey, 2004; McCannon, 2000). When teachers do receive training in technology integration in their teacher education programs, they report increased knowledge of and confidence in using technology (Overbaugh & Lu, 2008; Snider, 2003).

In-service or pre-service teachers who report increased confidence in their ability to use technology identify the value of hands-on, project-based, constructivist learning environments (Bhattacharya & Han, 2001; Halpin, 1999; Vannatta & Beyerbach, 2000; Wright & Wilson, 2007). Additionally, in-service teachers respond favorably to both teacher education programs and other professional development programs offering opportunities for collaborative, project-based approaches to integrating technology in science classrooms (Hall, Fisher, Musanti, & Halquist, 2006).

The project-based approach (PBA) is born out of the broader epistemological framework of constructivism (Piaget, 1985) which has a longstanding history in education (Airasian & Walsh, 1997; Bhattacharya & Han, 2001). PBA relies on the notion that if learners are given opportunities to construct their own meaning based out of their experiences of participating in a project with their peers, then multiple opportunities of meaningful learning occur.

By directly engaging the learner with the science (or content-related) problem, a PBA can create authentic learning experiences through which learners discover a fact, concept, or principle on their own. A systematic inquiry into the role of PBA in science instruction has revealed its value in developing scientific investigative skills among students (Krajcik, Blumenfeld, Marx, & Soloway, 2001). There is also evidence that PBA, when integrated with technology, can enhance students' performance by helping

them internalize various concepts and their applications in science (Ryser, Beeler, & McKenzie, 1995; Cognition and Technology Group at Vanderbilt, 1992).

Educational researchers have provided models and strategies and explored both the pitfalls and potential of creating a technology-integrated project-based learning environment in science classes (Blumenfield, Fishman, Krajcik, Marx, & Soloway, 2000). Nevertheless, such strategies are not widely read by teachers or commonly practiced in science education classes (Wenglinsky & Silverstein, 2006). It is difficult for teachers to stay current with educational research literature, given their daily workload and performance expectations. Consequently, the responsibility lies with teacher education and subsequent professional development programs to provide teachers with the knowledge and skills to implement new initiatives and research findings, in order to prepare qualified teachers who can facilitate students' successful performance in science.

Efforts to include systemic and sustainable integration of technology in teacher education, or to offer professional development opportunities to teacher education faculty and in-service teachers, have been found to increase educators' confidence in using pedagogically grounded technology in their classrooms (Hall et al., 2006; Overbaugh & Lu, 2008; Snider, 2003; Wright & Wilson, 2007). However, few teacher education programs currently model systemic and sustainable technology integration in science classrooms, and as a result both pre-service and in-service teachers often hesitate to use such approaches in their instruction (Ertmer, 2003; Rosaen, Hobson, & Khan, 2003). To encourage teachers to implement such approaches, it is critical to understand how learning occurs when science teachers are introduced to technology-integrated learning environments and how such environments strengthen teachers' conceptualization of their subject matter, as well as their teaching skills and openness to integrating technology.

The purpose of this exploratory study is to identify the role(s) of a technology-integrated, project-based approach in a science methods course as perceived by in-service elementary school teachers. Two research questions guide this exploratory study:

1. How do in-service teachers describe new insights learned as a result of participating in technology-integrated, project-based activities?

2. In what ways does a technology-integrated, project-based approach contribute to the in-service teachers' intentions of teaching science with technology in their future practices?

A third research question the authors wish to explore investigates the long-term effects of technology-integrated PBA on in-service teachers' classroom approaches, by examining the ways in which they use technology in their science classrooms. However, that question is beyond the scope of the current investigation.

Theoretical Framework

Grounded in PBA, this study investigates the value of PBA in a learner-centered, constructivist classroom environment in increasing in-service teachers' comfort with technology integration. PBA is reported (Bransford & Stein, 1993) to yield a product or performance that demonstrates learners' ability to apply new concepts in complex, meaningful ways. PBA offers learners an experimental, interactive, investigative, and cooperative form of learning (Schwab, 1964; Willis & Mehlinger, 1996). By incorporating personal experiences and social interaction with peers in the learning process, PBA allows learners to connect, reflect on, interrogate, and integrate new information into their pre-existing knowledge. The instructor's role is mainly that of a facilitator who fosters a learner-centered environment to create autonomous learners (Marx, Blumenfield, Krajcik, & Soloway, 1997). Thus, learners become skilled at developing evidence-based arguments by discovering facts, concepts, and principles in their informal interactions with each other, such that learners can act as mentors to one another.

An integral part of PBA involves collaborative learning, in which peers work together and serve as mentors for one another through formal and informal conversations. Informal conversations leading to the internalization of concepts in PBA reveal the importance of providing a non-threatening learning environment in which peers provide models of training for each other. Several studies support the value of such training in enhancing teaching and learning (Glazer, 2004; Snyder, Farrell, & Baker, 2000).

The informal academic training aspect of PBA supports the idea that students who have mastered instructional skills can act as mentors and teach those who are struggling by using modeling, coaching, and scaffolding until the mentee demonstrate an understanding similar to that of the mentors. When peers demonstrate expertise for each other, they model successful engagement and confidence in subject matter for those who are underperforming. The mentors can model the target skill or task, then ask the mentees to emulate the task or the skill with the their guidance, coaching, and scaffolding. The more comfortable the mentees become with the task or skill, the less the mentor provides guidance or scaffolding.

PBA can be divided into three phases: planning, creating, and processing (Katz & Chard, 2000). Each phase requires collaborative learning and cognitive apprenticeship. However, although the three phases may be described separately, it is important to understand that the experience of project-based learning is an iterative one. Learners do not move in a unidirectional, linear progression from the planning, creating to processing phase. Instead, they may move back and forth from one phase to another based on the ways they construct knowledge.

In the planning phase, learners collaboratively choose a project, set goals and identify necessary resources. The second phase, creating, involves collecting data and other relevant information for the project. During this phase, learners might choose to revise their topic based on feasibility, access to resources, etc. In processing, the third phase of project-based learning, learners reflect on their own projects, assess how well

they have accomplished the goals set during the planning phase, and revise any goals if they need to.

Additionally, during the final phase, learners share their product and/or performance with other members of the class and reflect on the learning process and the product through dialogue and feedback. Because PBA has the potential to improve students' knowledge and performance, it can also reinforce the in-service teacher of her/his teaching strategies and ability to create successful learning environments (Trowbridge et al., 2000).

While strong evidence-based arguments support the value of project-based methods in all areas of instruction, such methods may not be appropriate in cases where learners lack the requisite intellectual ability, social skills, or attitudes to participate effectively in such projects. However, these learners may be inducted into the method after they have developed the necessary skills. Moreover, the method may be less effective if introduced at the beginning of a term, when learners are less likely to know one another and the teacher may not have sufficient knowledge of each student's predispositions, strengths, and weaknesses.

Research Methodology

This study sought to identify the role of a technology-integrated, project-based approach in a science methods course as perceived by in-service elementary school teachers. Because this study was exploratory, an open-ended systematic inquiry was used to identify participants' perceptions of their learning experiences and how those experiences will inform their future instructional practices. The data sources included observations of participants' activities in the science methods course, participants' reflections about their learning experiences throughout the semester the science methods course, and analysis of documents such as journals, assignments, lesson plans, and in-depth open-ended interviews with participants about insights learned as a result of their participation in a science methods course which was driven by technology-integrated PBA. Hence, qualitative methods were most suited to this study. Qualitative research provides an in-depth understanding of people's experiences in a specific environment. This method of inquiry allows stories to be told in context and compiles evidence drawn from several methods of data collection (Patton, 2002a).

Qualitative research methods may be used to describe processes, relationships, settings and situations, and people's actions (Peshkin, 1993). Thus, in order to develop an in-depth understanding of the in-service teachers' learning experiences, the research design was informed by interpretivism. Interpretivism is a theoretical framework used in qualitative inquiry that focuses on the ways in which participants make meaning of their experiences, actions, and performances by interpreting their interactions with people and the world around them (Crotty, 1998).

According to Max Weber (cited in Crotty, 1998, p. 67), an early theorist of this framework, interpretivism does not seek causality. Instead, interpretivism seeks to understand how people make meaning. Another tenet of interpretivism is that as humans

create meaning, they also re-interpret meaning based on their interactions with others. In other words, the interpretivist approach "looks for culturally derived and historically situated interpretations of the social life-world" (Crotty, 1998, p. 67).

Underlying this approach is the belief that we as individuals do not simply drift through life as passive objects of socialization. Instead, we actively engage in constructing our social world, thus creating our own social reality (Crotty, 1998, p. 74). Since interpretivism is aligned with the constructivist theory of learning, we chose this framework for our research design. Interpretivism relies on inductive approaches to data collection and analysis. Qualitative studies informed by inductive approaches rely on working "up" from the data (Patton, 2002a) to identify patterns and themes within and across all data sources. Therefore, this study utilizes a multi-method approach to data collection in order to systematically analyze data for codes, categories, and themes that represent the participants' experiences, activities, and perceptions.

Context and Study Design

The University of Chalksville[1] is a teaching university in the southeastern U.S. with a college of education that offers both undergraduate and graduate teaching degrees. Both pre-service and in-service teachers attend the University of Chalksville for teaching certification and to enhance their professional qualifications. The participants in this study were volunteers chosen through purposeful selection (Patton, 2002b). The criteria for selecting participants were twofold. Volunteers had to be in-service teachers in Chalksville; and complete a science methods course at the University of Chalksville as part of their master's degree prior to participating in the study[2]. While all the participants had taken methods classes as part of their undergraduate training, their training varied in terms of its focus on mastery of content, teaching strategies, and technology literacy. The master's program at the University of Chalksville offers in-service teachers a required science methods course to help them gain mastery of content and increase their confidence in using technology in their science classes.

The authors selected 70 participants over the course of four semesters who taught between grades one to six. Twenty-three teachers participated during summer 2004, 17 in fall 2004, 22 in summer 2005, and eight in fall 2005. The participants provided demographic data as well as information about their experience with technology, knowledge of project-based approaches, and previous participation in professional development experiences. Table 1 represents the demographic distribution of the participants across all semesters.

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[1] A pseudonym

[2] To avoid putting pressure on the students to participate in this study, the study was not introduced to the students until they had completed the science methods class.

Table 1
Demographic survey of participants

N=70	Total # of students	Experience with PBA	No experience with PBA
Highest degree held by students			
a. B.S.	52	4	48
b. M.S.	13	2	11
c. Post-Graduate Diploma	5	0	5
Students' years of teaching experience			
a. 1-3 years	41	4	37
b. 4-6 years	26	2	24
c. More than 6 years	3	0	3
Number of technology-integrated science lessons taught by students			
a. Internet surfing only	37	0	37
b. Use of Word, Excel, Graph, and Internet	30	5	25
c. Use of Image Probe, MS Office, and Internet	3	1	2
Attendance at science workshops for professional development			
a. Once a year	47	5	42
b. Once in two years	9	1	8
c. Once in three or more years	14	0	14

At the beginning of each semester, as part of their course requirements students were asked to write reflective essays about their experiences in teaching science, their familiarity with a project-based approach, and the teaching practices they intended to implement as a result of the class. During the semester, students were expected to document their learning experiences through reflective journaling. The students were

introduced to various technologies to help them design mini-research projects investigating the effects of pollution on a local bayou and their implications for local culture. The mini-research project included developing a research purpose and questions, conducting data collection and analysis using the technologies introduced in class, and presenting their findings as a group to the entire class using appropriate technologies.

The technologies the students used included Image Probe software to test properties of bayou water samples including salinity; ph; and the levels of nitrate, phosphate, and dissolved oxygen. The students were encouraged to take photos with a digital camera as part of their data collection and to import these into a PowerPoint presentation to be delivered at the end of the semester. To aid the students in conceptualizing the data, they were introduced to Inspiration software that helped them develop concept maps to connect their ideas and make sense of the data they gathered.

Finally, students learned how to enter their data into Excel spreadsheets, perform descriptive statistical functions, and represent information graphically. At the end of the course, students were expected to complete their reflective journaling by documenting how their participation in this science methods class affected their confidence in teaching science with technology grounded in PBA. As part of the research design, we wanted students to feel comfortable using these technologies as we facilitated a constructivist learning environment. Our subsequent inquiry into the students' experiences directly aligned with the purpose of the study.

The second author of this paper, a qualitative researcher, acted as the primary methodologist for this study. She invited 14 students for open-ended, in-depth interviews after the conclusion of the course. These students were selected from among those who volunteered to participate based on a range of representative variables, including the semester in which the student took the science education class (marked 01- 04), initial comfort with technology based on their journal reflections, years of teaching experience, and previous attendance at professional workshops. We used the maximum variation sampling strategy (Patton, 2002) to obtain an in-depth understanding of diverse perspectives. Table 2 demonstrates the maximum variation sampling selection of participants.

Table 2
Demographic survey of in-depth interview study participants

N=14	Semester	Initial comfort with technology	Years of teaching practice	Attendance at professional workshops
Participant 1	01	Uncomfortable	3	Once a year
Participant 2	01	Comfortable	5	Once a year
Participant 3	02	Expert	3	Once a year
Participant 4	02	Uncomfortable	3	Once a year
Participant 5	03	Uncomfortable	3	Once in two years
Participant 6	03	Comfortable	3	Once a year
Participant 7	04	Comfortable	4	Once a year
Participant 8	04	Uncomfortable	3	Once a year
Participant 9	01	Expert	5	Once a year
Participant 10	03	Uncomfortable	4	Once in three years
Participant 11	02	Comfortable	3	Once in two years
Participant 12	04	Uncomfortable	1	Once a year
Participant 13	04	Uncomfortable	5	Once in three years
Participant 14	02	Uncomfortable	3	Once a year

At the end of every interview, both researchers compared the data, identified gaps in understanding the participants' accounts, and formulated follow-up questions for the participants. Finally, the methodologist followed up with the participants after data analysis to verify the accuracy of the findings. The collection of interviews, observations, the researchers' journal data, and the students' pre- and post-reflective essays generated in excess of 200 pages of raw data.

Data Analysis

To effectively manage the volume of data, the researchers used QSR NVivo[TM], a qualitative data management software program, to systematically chunk the data into smaller analytical pieces in order to code and categorize the data for thematic analysis. Interpretive data analysis in qualitative methods is always iterative and involves working up from small, manageable sections of data to create codes and categories that lead to identifying generalizable themes across all data sources (LeCompte & Preissle, 1993; Miles & Huberman, 1994). Coding in qualitative studies involves labeling chunks of data by identifying salient ideas contained in that section of the data. The NVivo software also allowed the researchers to write analytical memos, search for and retrieve large volumes of data almost instantaneously, and interrogate the patterns in all data sources using various combinations of Boolean searches (e.g., and/or searches, proximity searches).

We employed an open coding technique, which is "the analytic process through which concepts are identified and their properties and dimensions are discovered in data" (Strauss & Corbin, 1990, p. 101). This process involves naming concepts, developing categories, and attributing appropriate contexts in which such labeling is given meaning. Once all data sources were coded, we took like codes and grouped them together. We then looked at the like codes and began to identify broader labels to encompass them by asking, "What is going on here?" These broader labels are called "categories" in qualitative research. The researchers recorded their analysis, thoughts, interpretations, questions, and directions for further data collection through memo writing in order to gain an in-depth understanding of the data.

Once categories were developed, the researchers began to look across all categories and try to answer the research questions by discovering relationships between key patterns in the data. Table 3 represents the connections made between codes and categories in order to determine one of the overall themes in this study.

Table 3
Example of development of a theme

Codes	Frequency of codes	Categories identified	Development of theme
Impacts on water quality using Image Probe	61	Topical research with technology	Technology-integrated learning environment fostered interdisciplinary connections.
Home to animals, people, trees, fish	60	Identify impact on ecosystem	
Connect science and social science with technology	59	Connect multiple subjects and integrate technology	
People's lives affected, bayou culture	49	Impact on local culture	
Sustainability of environmental resource	37	Wildlife preservation	
Maintain ecosystem	31	Identify impact on ecosystem	
Impact of littering	27	Impact on local culture	
Wildlife preserve	19	Wildlife preservation	

The researchers further sought to uncover conceptual relationships across various data sources. Figure 1 demonstrates the conceptual process of discovering relationships between patterns in the data.
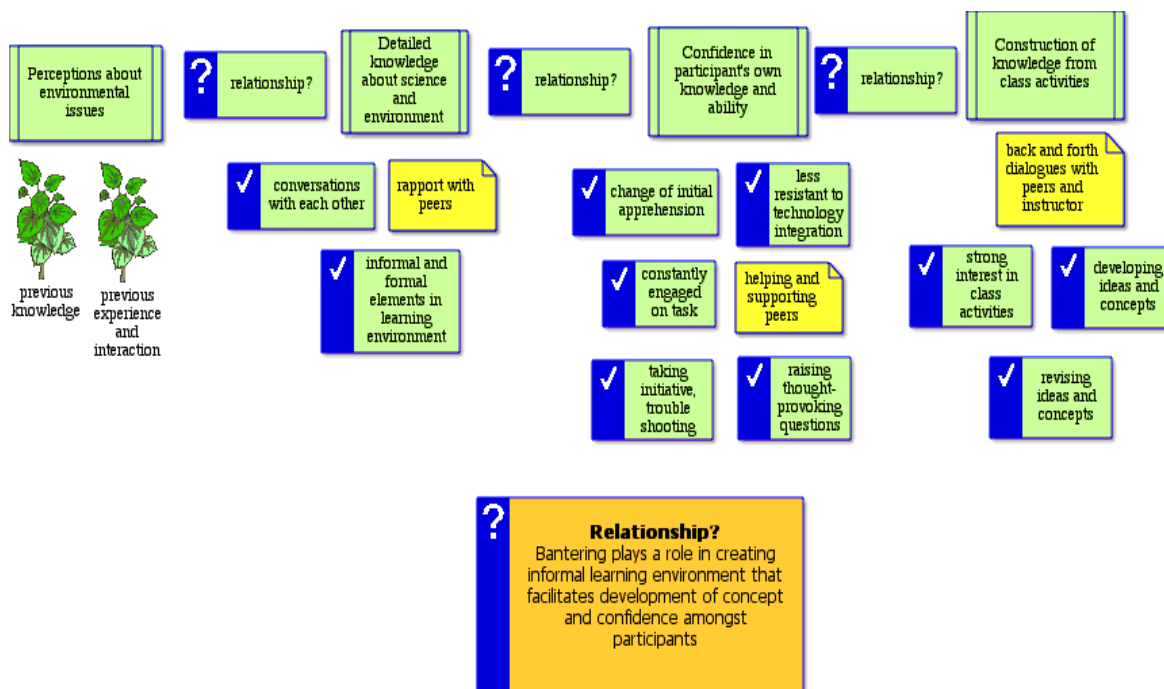

Figure 1. Discovering relationships in data patterns

Through multiple dialogues between the researcher and the participants, and by documenting relationships between the categories developed from all data sources and patterns in the data, the researchers identified three key themes. These themes occurred across all categories in the data and related to the research questions about participants' learning experiences and their intentions for future teaching practices.

For the purposes of consistency between researchers and alignment with the methodological literature (Bogdan & Biklen, 2003; Miles & Huberman, 1994; Strauss & Corbin, 1998), the criteria for a theme had three requirements: First, the theme had to provide an answer to the question, "What is going on here?" Second, the ideas subsumed in the theme had to be repeated by the participants several times in their banter, conversations, and journal reflections. Third, a theme also had to appear in multiple data sources. Once the themes were identified, they were further verified with five scholars who are similarly situated in relation to the researchers, both substantively and methodologically. This verification enabled us to establish academic rigor, trustworthiness, and the strength of logical analysis of codes, categories, and their inductive development into themes.

Results and Discussion

Given the qualitative nature of the data analysis, discussion is presented in embedded form within the Results section as part of the thematic description and interpretation of data. This approach aligns with that of other qualitative researchers in many fields, including science education (Sadler, Amirshokoohi, Kazempour, & Allspaw, 2006).

The researchers asked two broad research questions:

1.   How do in-service teachers describe new insights learned as a result of participating in technology-integrated, project-based activities?

2.   In what ways did the technology-integrated, project-based science methods course influence   the   in-service teachers' confidence in their ability and intention to integrate technology in their own future practice?

The three themes we identified after conducting inductive data analysis respond to these two questions. The three key themes include: (1) in-service teachers identify banter as a key factor in creating a collaborative, non-threatening learning environment; (2) technology-integrated PBA enables in-service teachers to forge interdisciplinary connections; (3) in-service teachers reported strong intentions to implement hands-on learning in their classrooms as a direct result of the science methods class, the PBA, and their mastery of technology-integrated science projects. In the following section, we elaborate on these themes with excerpts from such data sources as in-depth interviews, observations, and journal reflections.

Banter Created a Collaborative and Non-Threatening Learning Environment

In designing the study, we did not anticipate that banter would play the key role that it did. For the purpose of this study, we situate banter as informal good-humored conversations with a playful, teasing tone between students. We were aware of the value of collaborative learning and identified the relevant literature, as evidenced earlier in the paper. To our surprise, however, one of the key forms of communication between students was banter and friendly competitions set up among themselves to compare mastery of technology and content. Banter became a way for students to teach mastery of technology and content to each other and foster successful collaborative learning in groups.

Since the learning environment demanded that the participants design their own research study focusing on a relevant scientific topic using technology, the participants constructed various inquiry approaches to demonstrate mastery. The process of demonstrating mastery was facilitated with banter among peers. Due to the open-ended nature of the mini-research projects, participants were encouraged to explore, discover, and share their findings with each other. Consequently, the participants were excited and curious to learn about the technology (Image Probes and digital cameras) and to determine how they could use it in their mini-research projects. This excitement resulted in banter as participants explored various functions of the technology and assisted each

other in its use. The participants used banter to share anxieties about using technology, joke with each other to create a safe learning environment, and assist each other topically and methodologically at various stages of their mini-research projects.

For example, during the initial stages of participation in class assignments, students used banter as a way to create a safe environment to share their anxieties. Michelle stated, "I am not sure how I am going to handle all the technology that I have to use in this class. I am a technology idiot. Kyla, if I fail it's all on you girl. You need to get me through this." This kind of bantering allowed students to feel safe to express their lack of knowledge in one area and seek help from their peers.

Moreover, when the students were successful in using technology to collect research data, they started bantering about how easy it was to learn a new skill as evidenced by Tammy's remarks, "This is not as hard as you think, Beth. I didn't know anything about this before but in to time you will be a tech expert." Such banter created open spaces for mentoring between students where they guided each other and provided encouragement. When discussing the substantive aspect of learning science in a collaborative group setting, Jamie stated, "Hey, I didn't think I could get excited about this project. But y'all in the group were getting so excited that I thought I would miss out if I didn't take interest. This was fun!" Banter between group members created a heightened enthusiasm and interest in the subject matter, which facilitated collaboration amongst group members. Additionally, when students became successful in understanding the concepts in the assigned tasks, they used banter amongst each other to provide encouragement and foster a safe collaborative learning environment. Kyla stated, "Nah, don't worry. It's not that bad. I didn't think I could do my own science research project either. Hang with our group. I think we are doing some of the same stuff." Such supportive banter continued to keep students on task and work collaboratively even though the students might have felt anxious or overwhelmed at the thought of learning new technology as they mastered their subject matter.

As the students began their mini-research projects, they expressed anxiety about the use of technology and uncertainty about the sufficiency of their scientific knowledge to successfully design and implement a research project. The initial demographic data in Table 1 also informed the researchers of most students' lack of exposure to technology and PBA. Therefore, the learning environment was purposely created to foster multiple social learning opportunities. Since the students did not know each other prior to attending the class, sharing their anxieties became a way for students to interact with and support each other.

For example, many students were anxious about using the Image Probe. The Image Probe technology was integrated in the course to allow students to obtain immediate feedback on subjects like the ph level and salinity of the water in their local environment. The immediate information retrieval prompted students to discuss their previous understanding, formulate a new understanding, and conceptualize how such findings could play a role in the mini-research project they designed. However, because the Image Probe was a new technology to many students, they were reluctant to play with the technology initially. As the semester went on, some students became comfortable

using the Image Probe and began to tease and goad their peers to use the technology. These students became experts to those who were apprehensive about the technology. The experts began to playfully tease other students to goad them into trying out the technology as they played the role of a mentor. Once, mentees became familiar with Image Probe, they often expressed excitement with phrases like, "I got it!" or "Is that it?" as they screamed or ran around with the Image Probe. Such actions contributed to further banter and created a safe learning environment.

Due to the informal nature of the banter, students were able to draw on each other as resources when they encountered problems learning the technology or understanding a scientific concept. Through analysis of observation notes, post-course interviews, and post-course reflections, it became clear that banter with peers helped create a collaborative learning environment that contributed to understanding both the subject matter and the use of technology. Banter also provided encouragement and camaraderie, leading the students to take ownership of their learning process through meaningful engagement with content.

The role of banter in shaping students' learning experiences was especially evident in the post-course reflection essays. These essays were filled with rich descriptions of peer interactions, banter with other students, and informal conversations with the instructor. Beth wrote in her reflection:

> I never realized that using technology could be as fun. Although I was afraid at first, Jenine showed me how to use technology. What a simple way to learn and teach. I am so glad that I remained open to technology because now I can see how I can use it in my classroom. We have a bayou right in front of our school and I didn't even realize that I can use it as a learning tool and integrate technology. If my students can help each other the same way we did then I can see that this would be a very helpful activity for my students. Going through this class, and watching my classmates use technology so well made me think that I can do it too.

Allowing banter among the students became an instructional strategy that often produced a disorganized and disorderly learning environment. Rather than disrupting the learning process, however, according to the researcher's observation notes this loosely structured, student-directed learning environment instead enabled meaningful construction of knowledge for students. For example one excerpt from the researcher's observation journal denotes:

> Kyla and Beth kept snatching the Image Probe out of each other's hands. Kyla kept running around trying to teach everyone how to use the Image Probe. The other students were joking around and laughing at Kyla's energy and enthusiasm. Mike said that she was like the Energizer bunny. Every time she went to a group to show them what she learned about the Image Probe, she got them excited. Students would scream out loud for being able to master something with which they were initially struggling. By the middle of the class, people were busy running around, joking with each other, showing each other how to use the Probe,

and then testing and trying out the Probe, creating what would have looked like a chaos to an outsider. But once students learned how to use the technology, there was no stopping them. They wanted to explore how they could use it to answer their research questions.

Thus banter, while creating a disorderly learning environment, contributed to meaningful educational experiences by allowing students to explore their investigative skills, support each other, and create an environment that was flexible and responsive to the students' learning needs and preferences.

Interdisciplinary Connections Were Facilitated through Technology-Integrated PBA

The learning environment in this science methods class was pedagogically integrated with various technologies including Image Probe, digital cameras, PowerPoint, Inspiration, and Excel spreadsheets. While most students were initially unfamiliar with the technology, they developed a working knowledge of all the technology as they worked collaboratively with their peers. Moreover, some of the technology, like Image Probe, provided immediate feedback, which aided in data collection about the water quality. Such immediate feedback assisted the students in making multiple connections, as they were able to integrate issues of water quality with both science and social science topics.

Immediate feedback on water quality also eased students' initial apprehension about using unfamiliar technology, allowing them to focus on making meaning from the information they collected. Impressed with her own ability to test for information and understanding the implications of her learning experience, Katie stated:

> The research done at the bayou was so helpful. I now have a better understanding of our ecosystem [and] connection[s] between temperature, salinity, ph which made [an] impact on aquatic animals. I went into this project not sure of what to expect and without the science background. I felt lost in left field at first, but then as I became accustomed to the procedures I got into it. The research aspect was very interesting, and I did enjoy going to the bayou and testing for results. The image probes were an excellent idea. I thought, Those equipments are for real scientists; I am an elementary teacher. Why do I need to learn this? Now I am feeling I need a little more time to investigate other areas also. I am not at all intimidated by technology anymore. The research was a very interesting hands-on experiment that I felt students could utilize to learn much about our surrounding environment.

Despite her initial anxiety, Katie was ultimately able to use the technology to collect and test information and make connections to other areas of knowledge. Her initial fears dissipated once she became used to the procedures, and she began to concentrate on what the data meant, not just for the purpose of her mini-research project but also for future projects that could be conducted using a similar approach. Katie's increased comfort and confidence mirrored the experiences of her peers, all of whom were engaged in their tasks and continued to help each other in problem-solving as they

learned various applications of technology in research. Thus, a group that began the course with limited exposure to a technology-integrated, pedagogically grounded learning environment became their own agents of change through bantering and social learning opportunities.

Using digital cameras to document the research site and uploading the pictures into PowerPoint allowed students to think critically about both the alignment of the pictures with their research questions and the conclusions they sought at the end of their mini-research projects. Moreover, once students learned to upload pictures into PowerPoint they became more adept at manipulating the pictures in various parts of their presentations. These PowerPoint presentations assisted students in connecting topical issues such ecosystem management, the impact of pollution on local culture, wildlife preservation, and policy implications at local and state levels.

Echoing the experiences of many of his peers, Steve reports:

First I thought that taking pictures was a really cool aspect of this project. I took the digital camera and took many nice pictures. They were pretty pictures of the bayou and I was really proud of myself when I was able to upload them all to my computer to be used for our PowerPoint presentation later. I also learned how to crop pictures so that I can get exactly what I wanted. But as the course continued, I began to think that the cool pictures weren't the best pictures for the kind of evidence I needed to justify my conclusions. I went back and began to take more topically focused pictures and was very happy at the way the project came together.

The act of taking pictures and uploading them to a computer added another level of comfort in the students' use of technology. Knowing that the pictures required alignment with the content presented, students were able to evaluate the merit of their arguments by focusing their efforts on evidence-based data. Their ability to think critically was particularly sharpened by discriminating between pictures that would count as evidence or support an argument and pictures that were "cool" or "nice" but of less persuasive value.

After using various technologies students delivered a final PowerPoint presentation at the end of the course. The purpose of this assignment was for the students to triangulate multiple data sources and reach evidence-based conclusions. The presentations were rich in information with many visual examples, including pictures, concept maps, graphs, and image probe data that were meaningfully connected to the conclusions. The students reported that watching other people's presentations reinforced their own learning and helped them make further interdisciplinary connections. Jamal reported on the value of the final presentations:

I do not live near [the] bayou, so I hardly ever think about what is going on there. Well, after our research, other presentations by groups, my interest in the conditions of [the] bayou suddenly changed and I was able to see the bayou as the site of study for multiple subjects.

While Jamal was able to make both personal and topical connections as a result of his own participation and by watching other presentations, Chantal valued the way all the information learned throughout the class was integrated into the final presentations. She observed:

> As for the final presentation, I thought the PowerPoint project was an excellent way to bring everything learned together. Not only did I learn about science, but I felt more confident about working with numbers. I thought even young students (4th grade and up) could benefit from this form of presentation, and they would enjoy the use of technology as well. I also learned how studying water quality in our bayou was more than science. It was about the lives of people who lived by the bayou. This was truly interesting to me, because I could apply (lessons learned here) to my social studies class (in order) to learn about our surroundings and (to learn) so many other topics.

Through final presentations grounded in technology-integrated investigative experiences around a local bayou, Chantal was able to gain an integrated understanding of science, social science, and math as she made connections through her experience in the project-based learning environment.

The technology-integrated, project-based approach allowed students to make meaningful connections between multiple subject areas as they became familiar with applying technology and grew to understand the implications of the information they collected. Students were able to identify the salient issues around the local bayou culture and witness the ways in which various types of data were collected, analyzed, and presented in response to the research questions presented by their mini-research projects. Once their anxieties about using technology were alleviated, students were able to make meaning from the data they collected and improve their investigative skills to support their understanding of the subject. Consequently, students were able not only to respond to their own research questions but also to extend their thinking to multiple disciplines and envision how they might foster those connections in their future teaching practices.

Intentions for Future Practice Involving Technology-Integrated PBA for Science Classes

One purpose of creating a technology-integrated, project-based approach to learning was to create exploratory learning environments that would increase in-service teachers' confidence in using technology. Having participated in such a learning environment themselves, the researchers' expectation was that the teachers' confidence in using technology in their own classrooms would increase. As we analyzed the reflection essays at the conclusion of the course and further probed the in-depth interviews, we found that all 14 of the teachers found the hands-on experiences beneficial and reported being surprised by the ease of using the technology. They identified multiple applications they wished to use in their own classrooms and expressed how engaged they felt their students would be once they experienced meaningful connections to the curriculum.

Sheila, a fourth-grade elementary school teacher, was apprehensive at first about using a technology-integrated learning environment for her students. However, after

completing the course she stated, "Even my young students (4th grade and up) could benefit from technology-integrated presentation. I know they are more tech savvy than I am and will think I am a pretty cool teacher to let them play." Kyla, a social science teacher, stated, "I could apply what I learned here to my social studies class to the learning of our surroundings. This, I definitely can bring into my classroom." It was encouraging to see that while technology played a role in enhancing the in-service teachers' learning experiences, their intentions for future teaching were grounded in teaching effectiveness and not in imagining technology as a panacea.

Responding to the value of hands-on learning, in-service teachers expressed their intention to immerse students in the natural environment so they could develop investigative skills. In response to growing concerns about effective classroom management strategies, Katie remarked, "Getting the students immersed in investigation in natural surroundings with technology will make my headaches for classroom management go away." Not only have these teachers found ways to create meaningful experiences for their students, they have also identified classroom management and teaching strategies as potential advantages of hands-on, technology-based learning.

While all 14 in-service teachers interviewed expressed appreciation for the ease of technology use in hands-on learning, six of them also articulated a need to receive further training to develop better teaching strategies that would allow them to cover the curriculum while integrating investigative learning with technology through project-based experiences. Steve stated, "While I know this will take my teaching to a new level, I am not quite sure about the ways I would develop some of these teaching strategies into my lesson plan and still cover all my material." Melanie, an elementary school teacher, likewise expressed:

> I have no problem with project-based approach. My class is open to this, but I need to learn how to work it into my ways of teaching. I have always been the leader and let the students follow, however through the knowledge learned in this class I can expand my teaching to new levels but I wish that there were more people in my school who could be role models for me. But I know that I will be able to better my teaching strategies through the use of the lessons learned in this class.

Jamie, a middle-school teacher, discussed the confidence he now feels in using technology, but expressed some skepticism about its practical application in his class due to the amount of material he is expected to cover. He stated:

> I really enjoyed the technology use in this class and thoroughly loved the exploratory aspect of my learning. I would love to use some of these ideas in my classroom but I am not sure how I will be able to cover all the material and continue to remain explorative in my instruction. I will be able to use some of the techniques that I learned in the class but I am afraid that without having someone to talk to at my school about ways to cover the curriculum and still remain current in my teaching strategies I might not be able to accomplish all that I wish to do with my class.

Although in-service teachers discussed various uses of the technology-integrated, project- based approach for their individual classes, they expressed concern about the absence of role models in their schools to guide them in furthering their specific instructional strategies. While the in-service teachers described an increase in their confidence in using technologies, they also feared that without support from colleagues and administrators, and with the pressure of completing all the curriculum mandates, they would be limited in transferring what they had learned in the science methods class to their own classrooms. Nevertheless, the in-service teachers' increased confidence in using technology made them concentrate on designing content to create pedagogically grounded and meaningful instruction that would keep their students engaged and immersed in applied learning experiences.

Conclusion and Implications

This research explored the role(s) a technology-integrated, project-based approach plays in a science education class in shaping the experiences of in-service teachers and their intentions for future instructional practices. We were able to answer our research questions by discovering that in-service teachers gained confidence in using technology-integrated instruction as they became comfortable using several types of technology, and thus were able to concentrate on the content of the class instead of focusing on the nuances of the technology. Using authentic learning experiences through a project-based approach allowed in-service teachers to make connections to a variety of topic areas in science and social science, thereby identifying multiple ways they could use such an approach in their own classrooms. However, while all the in-service teachers identified numerous potential uses of the technology-integrated, project-based approach in their classrooms, many expressed a concern that lack of time, the absence of effective instructional models, and the pressures of standardized testing and curriculum mandates might pose obstacles to implementing innovative, investigative, and exploratory teaching practices.

The implications of this work are multifaceted, highlighting not only the value of a technology-integrated, project-based learning environment but also the need for support at multiple levels, including both K-12 and higher education. Because there is an urgent need to improve teachers' skills in using technology in their classrooms, care must be taken to ensure that the use of technology is pedagogically grounded in authentic experiences in which learners engage meaningfully with the subject of study, instead of becoming mired in the details of using technology. Technology employed in a learning environment should be relatively easy to use, so students can gain confidence in their ability to utilize the technology while focusing their thinking on the material under investigation. The confidence gained through engaging in learning experiences in a technology-rich, socially interactive environment allows learners to identify various possibilities for problem-solving.

Moreover, because students were able to forge interdisciplinary connections between science, social science, and math, they were able to expand their understanding of science beyond textbooks, and results obtained in laboratories, to everyday examples. Through the discovery of these interdisciplinary connections and their increased

confidence in using and integrating technology in their classrooms, pre-service and in-service teachers were able to identify multiple possibilities for their future teaching practices.

In light of the progress demonstrated by teachers in this study, more teacher education classes should model technology-integrated, engaged learning environments so pre-service and in-service teachers have a wider range of options from which to choose when developing their own teaching strategies. Furthermore, such technology-infused learning environments would offer in-service teachers multiple possibilities for grounding instruction pedagogically instead of simply adding new technology to the classroom without any connection to learning theories, resulting in isolated and possibly ineffective efforts to incorporate technological literacy into teaching practices. With a range of options and exemplars modeled in teacher education courses, in-service teachers will be able to critically evaluate the appropriateness of instructional strategies in their own teaching environments based on the resources, funding, and support available.

Finally, support for creating and maintaining technology-integrated, project-based learning environments needs to come from all administrative levels. Such support should include, but not be limited to, modeling lesson plans, identifying successful instructional strategies, designing quality instructional aids, and providing funding for necessary resources so that teachers who wish to employ innovative approaches may continue to meet curricular mandates. With teachers' current workload, it is not possible for them to reinvent their teaching unless they are provided with exemplars and necessary resources. To this end, before teachers are asked to adopt a new pedagogy and reinvent their instructional strategies a team approach must be firmly in place. This approach must engage all stakeholders (i.e., administrators, practitioners, university faculty, and students in teacher education programs) in creating and evaluating the effectiveness of innovative learning environments, and identifying all possible resources and support needed for successful implementation.

Because this is an exploratory study, we cannot generalize these findings to other settings. However, our study is situated within the current literature, in which calls for technology-integrated science education are pervasive. Findings from this study might be transferable in part to other similarly positioned teacher education programs. Moreover, this study may provide ideas for creating teacher education programs that are responsive to NCLB initiatives and support teachers in preparing to meet such initiatives. Furthermore, educational researchers, instructional designers, and technologists can work collaboratively with teachers, teacher education programs, and school administrators to identify specific needs and to appropriately address those needs in teacher education programs. Ultimately the investment of time and resources will be well worth the costs, as the performance of students and teachers within a school will only be as strong as the training and support provided.

It is unfair to expect our students and our teachers to be global competitors in science education without adequate training and resources. Because this is a critical issue facing many science educators and teacher education programs across the country, more open-ended conversations and research need to occur to identify possibilities to break

through challenges like prior training, lack of exposure to pedagogy-based technology-integrated science education curriculum and instruction, and lack of ongoing support and resources. However, it is undeniable that without developing an in-depth understanding about challenges facing science education, and developing local and national solutions, students in the U.S. will continue to perform poorly in science.

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