Guzey, S. S., & Roehrig, G. H.. (2012). Integrating educational technology into the secondary science teaching. *Contemporary Issues in Technology and Teacher Education*, *12*(2), 162-183.

Integrating Educational Technology into the Secondary Science Teaching

S. Selcen Guzey and Gillian H. Roehrig
University of Minnesota

Abstract

The integration of technology in teaching is still challenging for most teachers, even though there has been a historical growth of Internet access and available educational technology tools in schools. Teachers have not incorporated technology into their teaching for various reasons, such as lack of knowledge of technology, time, and support. In this study, three beginning science teachers who successfully achieved technology integration were followed for 3 years to investigate how their beliefs, knowledge, and identity contributed to their uses of technology in their classroom instruction. The findings demonstrate that the participating teachers were all intrinsically motivated to use technology in their teaching and this motivation allowed them to enjoy using technology in their instruction and kept them engaged in technology use. The major findings of the study are displayed in a model, which indicates that the internalization of the technology use comes from reflection and that teachers' use of technology in classroom instruction is constructed jointly by their technology, pedagogy, and content knowledge; beliefs; identity; and the resources that are available to them. The study has implications for teachers and teacher educators for successful technology integration into science classrooms.

For the last two decades digital technologies have become inseparable from development and research in the science, technology, engineering, and mathematics fields. However, it has not been fully integrated into the field of education. Billions of dollars have been invested in technology to equip schools with educational technology tools, yet the vast majority of the teachers do not use technology in meaningful ways in their instruction (National Education Association [NEA], 2008; U.S. Congress Office of Technology Assessment, 1995).

The research shows that the most common use of computers in schools is in computer classes and business classes (Becker, 2000) and that, in general, most teachers use computers to perform administrative tasks such as taking attendance (Becker, 2001). Unfortunately, few teachers allow their students to use educational technology tools to solve problems, analyze data, do research on Internet, present information graphically, or participate in distance learning via Internet (U.S. Department of Education, 2003).

Research demonstrates, however, that technology plays a critical role in student learning (Russell, Lucas, & McRobbie, 2003). Large-scale studies have shown the significant increase in achievement scores of students using technology as a learning tool (e.g., Lei & Zhao, 2007). Research in science classrooms clearly indicates that the use of technology has a positive influence on a wide variety of student learning outcomes, including understanding of science concepts and the development of scientific reasoning skills (Dani & Koenig, 2008; Schroeder, Scott, Tolson, Huang, & Lee, 2007; Songer, 2007).

Furthermore, using dynamic scientific visualizations to investigate abstract science topics (e.g., meiosis), phenomena that happen quickly (e.g., chemical reactions) or change that occurs over a long time period (e.g., climate change) was found to help students develop an "integrated understanding of [complex] science topics" (Lee, Linn, Varma, & Liu, 2010, p. 81). The use of learning technologies in science classrooms has also been shown to increase students' attention, engagement, and interest in science (Van Lehn et al., 2007).

Since a substantive body of research demonstrates the efficacy of technology to enhance science learning, the importance of integrating technology in schools has been addressed in many recent educational reforms. Science teachers are asked to apply technology to help students not only learn science but also do science (National Research Council [NRC], 2000). In the science and technology-driven 21st century, the need for students with well-developed science content knowledge and critical thinking skills, as well as the knowledge and ability to use, manage, and understand technology as it relates to science learning, is greater than ever. However, effective use of technology remains challenging for science teachers (Yerrick & Hoving, 1999). The vast majority of the teachers either ignore the call to use technology in science teaching or they employ technology in ways that replicate traditional instructional strategies, such as the using PowerPoint lecture presentations. Teachers who attempt to use technology become frustrated by difficulties related to implementation (Yerrick & Hoving, 1999).

Brickner (1995) categorized the obstacles to effective technology integration as first-order barriers and second-order barriers. First-order barriers are defined as "extrinsic factors," which include access to technology resources, software availability and quality, planning time for technology rich lessons, and technical support. Whereas, second-order barriers are defined as "intrinsic factors" that include teachers' beliefs about teaching and technology, school context and culture, instructional models, and openness to integrate technology. Brickner said that second-order barriers are more difficult to define and overcome, since teachers need to restructure their belief systems about technology and also develop their knowledge base for technology integration.

Education research has paid much attention to first-order barriers that affect teachers' technology integration efforts. Most studies simply provide exhaustive lists of barriers based on survey data (e.g., Becker, 2000, Hadley & Sheingold, 1993). Missing from the literature are richly detailed profiles of teachers who have successfully achieved technology integration and overcome the barriers detailed in the literature. Examples of successful experiences in integrating technology can serve as a practical guide for teachers and provide information on second-order barriers, which are absent from the literature.

Thus, the study presented in this paper involves three beginning science teachers who frequently and successfully use various educational technology tools in their teaching while allowing their students to use technology in the classroom. The study specifically aimed to answer the following research question: How do science teachers' motivations, beliefs, and knowledge contribute to their uses of technology in their teaching?

Motivation: The Foundation for Understanding Teachers' Use of Technology

This study is largely grounded in the framework of human motivation, since motivation provides a foundation to explain human behavior (Deci, 1975). Investigating teachers' motivation reveals the factors that energize teachers to use technology, the factors (e.g., knowledge and beliefs) informing their use of technology, and ways the use of technology can be maintained or sustained.

Various theories on human motivation address different aspects of human motivation (Ford, 1992). Deci's (1975) motivation theory was specifically chosen for this study because it uses a cognitive perspective to explain how "humans process information and make choices about what behaviors to engage in" (p. 95). Furthermore, it assumes that people perform actions that are directed toward self-determined goals and that this goal selection depends on people's needs, curiosity, and interest. Finally, the theory argues that people determine behavior based on their thinking or intrinsic motivations, not because of the external rewards they might receive for the behavior.

Deci's motivation theory employs a cognitive approach to behavior and includes five stages that follow each other in sequence. The first stage involves stimulus inputs, which can come from three different sources: environment, memory, and internal. Environmental stimuli are conditions that lead the person to behave in a certain way. For example, having several technology tools available in a school may lead teachers to use them for instruction. The stimuli can also come from memory or past experiences. Finally, the stimulus may derive from internal factors such as blood sugar or hormones. Although these types of biological factors are influential on some behaviors, they are not considered as a factor for technology integration.

The second stage in Deci's model is awareness of potential satisfaction. This stage can be considered the "energy source" of activity due to awareness that completing the activity will be more satisfying than the current stage of being. At this stage, various factors may influence a person's awareness of potential satisfaction, such as emotions. In the case of technology integration, emotion plays an important role in teachers' decisions about using technology in the classroom. Fear of technology would possibly prevent a teacher from employing technology in instruction. Awareness of potential satisfaction also comes from intrinsic motivation, as people's intrinsic needs to feel competent and self-determining can lead them to behave in a certain manner.

The third stage of the model is establishing a goal or goal selection. Goal selection involves the evaluation of the various alternative behaviors. A science teacher, for example, can select from a range of instructional methods to teach Newton's laws. Newton's laws can be taught by lecturing or using student-centered, activity-oriented methods (i.e., inquiry) utilizing technology tools such as motion detectors, simulations/animations, or video capture. Choosing a teaching approach is an example of a goal selection.

Following goal selection, the person completes the goal-directed behavior, which is the fourth element of the model. People engage in specific behaviors to achieve their goals.

The final stage in the model is reward and satisfaction. Reward can be extrinsic or intrinsic. The level of reward and satisfaction feeds back into goal selection and awareness of potential satisfaction. If there is no satisfaction or if the level of satisfaction and the awareness of potential satisfaction are mismatched, the person may change the goal. This process can be associated with a teacher's use of different educational technology tools to teach a particular topic. If the impact of a specific tool on student learning does not match a teacher's prior expectations, the teacher may consider using another educational technology tool. Rewards also provide feedback to the person's intrinsic motivation, which affects the goal selection. For example, seeing the positive effect of technology on student learning may increase the teacher's motivation and lead the teacher to continue using the technology tool.

Deci's motivation theory proposes that people make choices under the influences of their environment and their "personal knowledge." Deci's notion of personal knowledge has direct parallels with beliefs and knowledge, which are also considered important sources of motivation that drive behavior (Dweck, 2002; Ford, 1992). A person's beliefs cannot be separated from the person's motivation and behavior. For example, a teacher's beliefs about using educational technology tools in the science class closely relates to the teacher's prior experiences, memories, feelings, and emotion, which are critical elements of human motivation. There is a two-way relationship between beliefs and behavior. Beliefs about a particular behavior strongly influence the approaches a person takes to the behavior. Upon completion of the behavior, the person may choose to perform the behavior again or may change beliefs about the behavior and not perform it again.

Knowledge is also associated with beliefs, motivation, and behavior. In order to demonstrate a behavior, a person needs to have relevant background knowledge regarding the anticipated behavior. Completion of a behavior may lead a person to construct new knowledge, which can be also seen as an end point of human behavior. Knowledge that the person gains through demonstrating a behavior is stored in memory, which is recycled as a stimulus input in Deci's model of motivation. Thus, motivation provides a basis for constructing new knowledge, and new knowledge may increase the motivation to repeat the behavior.

A person's behavior can be best understood in terms of the person's beliefs, motivation, and knowledge about the particular behavior. Thus, in this study, it is assumed that beliefs, knowledge, and motivation play important roles in teachers' technology-rich classroom practices. However, within the motivation field, knowledge and beliefs have not received full attention (except attribution theory); thus, there is a need to integrate these important issues into motivation theories (Eccles & Wingfield, 2002; Ford, 1992).

By focusing on teachers' knowledge of technology and beliefs about technology integration and using Deci's motivation theory as a framework, this study provides detailed information about how teachers' beliefs, knowledge, values, and goals relate to their technology-rich classroom behaviors and practices.

The Role of Beliefs in Technology Integration

Research on beliefs has a long history, but as Pajares (1992) stated, it is a messy and complex concept to study. Beliefs are cognitive constructs that can be defined as "understandings, premises, and propositions about the world" (Richardson, 1996, p. 103).

Beliefs affect the way people act or interact with their environments. "Beliefs are the best indicators of the decisions individuals make throughout their lives" (Pajares, 1992, p. 307).

In the literature, teachers' beliefs have been shown to be closely related to their classroom practices (Kagan, 1992; Nespor, 1987; Pajares, 1992; Roehrig & Luft, 2004; Wallace & Kang, 2004). Roehrig and Luft (2004) pointed out that teachers' beliefs are associated with teaching style. Specifically, the authors found that inquiry-based classroom practices were strongly influenced by teaching beliefs. In the context of technology integration, studies have also shown that teachers' beliefs about technology influence their use of technology in classroom instruction (e.g., Ertmer, 2005, Lumpe & Chambers, 2001; Windschitl & Sahl, 2002). Teachers who are the most frequent technology users hold strong constructivist beliefs (Windschitl & Sahl, 2002), as in the case of inquiry teachers discussed by Roehrig and Luft (2004).

Some studies have also explored how the use of technology can change teachers' beliefs. Levin and Wadmany (2006) found changes in teachers' beliefs and practices in their 3-year long study. Although 5 of the 6 teachers in their study expressed behaviorist beliefs at the beginning of the study, they held less behaviorist beliefs and used less direct instruction at the end of the study.

A similar substantive change in teachers' beliefs and practices was found in the Apple Classrooms of Tomorrow study (Sandholtz, Ringstaff, & Dwyer, 1997). The findings of this study showed that changing beliefs is a long and complicated process. It was found that shifts in teachers' beliefs occurred when teachers saw the effectiveness of using technology on student learning. Seeing the benefits of technology on student learning allowed teachers to transform their beliefs from teacher centered to more student centered as they implemented technology rich classroom practices.

This feedback loop between beliefs and practices is evident in Deci's (1975) model of motivation; feeling satisfaction from a selected behavior (implementation of technology enhanced instruction) provides feedback to the person's intrinsic motivation or beliefs based on the success or failure of the behavior. In the case of these studies seeing the positive effect of technology on student learning created a positive feedback loop, with beliefs or intrinsic motivation reinforcing both beliefs and practices.

The Role of Knowledge in Technology Integration

Shulman's (1986) work on teacher knowledge led many researchers to focus on pedagogical content knowledge (PCK) to understand teaching. As Shulman emphasized, having PCK makes teachers different from the content specialists. The teacher uses the most effective forms of "representations, analogies, illustrations, examples, explanations, and demonstrations" to make the content information more "comprehensible" to students while considering the "conceptions and preconceptions" that students bring to the classroom (p. 9). Shulman argued that PCK is a transformation of other types of knowledge (subject matter knowledge, pedagogical knowledge, and knowledge of context).

Among others, Mishra and Koehler (2006) described PCK specifically for use of technology tools in the classroom. The authors expanded on the concept of technological pedagogical content knowledge (TPCK; which they later changed to "technology, pedagogy, and content knowledge," or TPACK) derived from the original work of Shulman (1986). Mishra and Koehler described TPACK as a framework for teachers to integrate technology into their teaching. It is a combination of knowledge of content, knowledge of pedagogy, and knowledge of technology (Koehler & Mishra, 2008).

McCrory (2008) emphasized that science teachers' knowledge of science, pedagogy, students, and technology help them know "where (in the curriculum) to use technology, what technology to use, and how to teach with it" (p. 195). Niess (2005) provided a more detailed framework of TPCK, and her model had four elements: (a) a conception of what it means to teach a particular topic using technology, (b) knowledge of instructional strategies and representations to teach particular topics with technology, (c) knowledge of student understanding and learning with technology, (d) knowledge of curriculum and curricular materials that include technology. In this study, Niess' conceptualization of TPCK was used as a guide for data analysis.

Methodology

This study is qualitative in nature. An interpretive multicase study design was employed to conduct an in-depth investigation of science teachers' technology integration (Merriam, 1998). The interpretive approach was used because it provides holistic explanations for the particular phenomenon, in this case technology integration. Case study particularly suits this study, since it aims to understand the process of technology integration rather than only describing various factors that may influence science teachers' technology integration. In presenting teachers' motivations and practices, this study aims to create a model that conceptualizes how science teachers' beliefs about technology integration, TPACK, and motivation contribute to their technology enriched classroom practices.

Participants

Teacher participants included a middle school Earth science teacher (Benson), a middle school life science teacher (Matt), and a high school physics teacher (Jeremy). Participants were purposefully selected from 60 novice secondary science teachers who participated in a study during their first 3 years of teaching to explore the growth and change, if any, in their knowledge, beliefs, and classroom practices as a result of participating in different mentoring programs (Luft, 2009). Based on interview and classroom observation data, it was determined that only 3 of the 60 teachers frequently used technology tools in their instruction; hence, they were selected for the present study.

Benson, Matt, and Jeremy all participated in the same teacher preparation program. They earned their teaching license while working toward their master's degree in education. The present study took place mainly in the second semester of their third and fourth years of teaching. During the time of the study, Matt was taking courses to complete his master's degree; Benson and Jeremy had both completed their master's degrees. All study participants were White, male, and in their early 30s. To preserve anonymity, pseudonyms are used throughout this document.

Data Collection

Data sources included classroom observations, interviews, and classroom artifacts (e.g., student handouts).

Classroom observations. Each teacher was observed eight times. Rich, detailed notes were taken during the observations. Classroom observations were scheduled based on teachers' preferences, but technology integration was a required feature of the unit.

Depending on the availability of the teachers, postobservation interviews were conducted and used as a secondary data source to supplement the classroom observation data. These informal discussions focused on lesson planning and possible ways to modify the observed lessons. Post-observation interviews were digitally recorded and transcribed.

Interviews. A semistructured interview was conducted with each teacher to capture beliefs about science teaching, learning, and technology. The majority of the interview questions were adapted from the Teacher Beliefs Interview (TBI; Luft & Roehrig, 2007). The TBI questions were originally designed to capture teachers' beliefs about teaching and learning. To be able to capture teachers' beliefs about science and technology, slight changes were made to the original questions. For example, "How do your students learn science best?" was modified to "How do your students learn science best in a technology-supported learning environment?" In addition, questions that provided information about teachers' school context, lesson planning strategies, science teaching strategies, and previous experiences with technology were asked during the interviews.

Classroom Artifacts. During each classroom observation, student worksheets and laboratory handouts were collected. Those provided secondary information about teachers' lesson plans and teaching strategies. Teachers' class website content was also used as secondary data sources.

Data Analysis

In this multicase study design, an inductive approach was used for both individual and cross-case analysis. The process of "constant comparative analysis" (Strauss & Corbin, 1990) was applied to find categories and themes and to develop a model of technology integration. During the data analysis, NVivio 8.0 was used to code interview transcripts and field notes from classroom observations.

The process of constant comparative analysis involved open coding, axial coding, and selective coding. First, each concept in a teacher's document was coded as a category. As the concepts were coded, they were compared with the previous codes in the same category to find common patterns as well as differences in the data. Making comparisons, or axial coding, allowed for the development of relationships between categories. The frequency of codes and relationships was used to develop the model of technology integration. Finally, selective coding involved relating the categories and concepts to main themes, a higher level of axial coding. It is important to note that, in this study, selective coding was employed to develop the main themes and the model of technology integration. Data analysis also included cross-case analysis, which included comparing codes of each teacher participant to decide which codes should be included in the model.

Results

This study was designed to explore how teachers' motivation to use technology, beliefs about technology integration in science, and TPACK contributed to teachers' uses of technology in the classroom. The data also provided some insights about the relationships among those factors and school-based factors (e.g., school technology infrastructure and students). The major findings of this study support some findings from the existing research and also shed new light on areas that have not been fully explored. The key findings are depicted in a model (see figure 1), which will be discussed in detail following the profiles of the teachers.

Benson: The "Engager"

Benson had a BS in environmental studies. During the time of the study, he was an eighth-grade earth science teacher in a suburban public school. Additionally, he taught an elective technology course. Benson was also an Activeboard (interactive white board) lead teacher for his district; he was developing and implementing workshops to introduce a range of ways to integrate Activeboard into classroom instruction.

The school had about 900 students. Approximately 20% of the students were eligible for the free or reduced-price lunch program, and 80% of students were White. Integrating technology into teaching and learning was one of the main priorities of the school and the district. The district provided teachers various in-service training opportunities to integrate technology into their teaching. In addition, the school provided teachers a variety of technology tools to use in classroom instruction. Almost all the classrooms had an Activeboard. Teachers could check out the classroom clickers (student response systems) or laptop carts. However, according to Benson only a few of his colleagues used technology in their teaching.

Benson said that he was more "flexible" than other teachers in his school. According to him, his colleagues were "more written structured." They liked to plan detailed lesson plans; they wanted to know "how the lesson is going to work." Benson, on the other hand, liked to make decisions on the fly, and other teachers in his school did not feel comfortable doing it. Making quick decisions and prompt changes in instruction were critical to Benson to teach science with technology.

Benson's Motivation to Use Technology. Benson was a technology enthusiast. According to Benson technology played an important role in his personal and professional life. Benson said that he used technology a lot in his personal life, so it came naturally to his teaching life. Benson was fully aware of potential effects of technology on student learning. Thus, he devoted a lot of his time to learning about technology tools and finding technology applications for teaching. He acknowledged that technology integration required additional time at school and at home to complete extra tasks.

> If you are willing to try [integrating technology] you have got to put in your own time. I think good teachers put enormous amount of time outside of school with just about everything that they do...so you have to do that with technology, too.

Benson liked experimenting new technology tools. He constantly worked on finding innovative ways of using technology in his classroom, since he thought that it was "easier" to teach science with technology. He collaborated with teachers who enjoyed using technology to find what technology to use, how to use it, and new ways of using technology in science classes. Benson commented that he really liked to collaborate with those "amazing" people in the social networking sites, since he found that the collaboration encouraged him to use more technology in his classroom.

Benson's Beliefs About Technology Integration in Science. Benson believed that his role as a teacher in the classroom was an "engager." He defined an engager as "somebody who has a lot of specialized knowledge and who has a lot to share, but it is not necessarily dispensing that, but it is trying to get students involved." Benson further explained that his role was not necessarily "an entertainer, but going beyond that." It is his responsibility to "clearly define the fun stuff versus what students need to do." He stated that students learn science when they are actively involved in their learning.

According to Benson, many topics that he taught were very abstract; thus, students needed visuals to be able to fully understand those topics.

Also, as he commented, he was a “visual” learner, and he believed that students learn better when they “see” what they are studying. Benson believed that “pictures can tell more than words.” He stated that with earth science “visual representations are important more than other representations.” As such, he believed that visual applications such as simulations and animations play an important role in student learning.

According to Benson, the application of educational technology tools made classroom instruction more student centered and learning more meaningful while promoting student collaboration and inquiry. For example, while talking about the Activeboard, Benson said, “It is very engaging....You just draw a simple line on the board, and all the kids went, ‘Wow!’ So the engagement factor is huge.” Benson explained that his motivation increased when he saw that his students found science fun and interesting when they used technology.

Benson’s TPACK. Benson explained that he liked experimenting with new technology tools. He felt comfortable using various educational technology tools, such as the Activeboard, that became an invisible part of his teaching. He had an impressive repertoire of digital images, videos, podcasts, graphs, simulations and animations, virtual labs, and online assessments, and he used them on a daily basis in his teaching. Benson constantly added online resources to support his curriculum. He said that using a variety of visual representations was critical in improving his instruction but also in developing students’ science content knowledge.

In addition to the Activeboard, Benson regularly used clickers. He utilized clickers to assess students’ prior knowledge and misconceptions and to evaluate student understanding and learning of a topic. To monitor student learning Benson also employed online quizzes and tests. Furthermore, students utilized technology tools to create class project reports or presentations, which allowed Benson to evaluate both science learning and technology skills. In turn, Benson could select and modify technology tools used for class projects based on student learning.

Benson facilitated classroom activities in which students actively engaged in their learning. To encourage student involvement he developed lessons that were interesting for students and that required their use of technology. For example, during the time of the study, Benson’s students were asked to join online discussions on the class website and completed several classroom projects using Google applications (e.g., Google docs and Google presentation.), iMovie, and VoiceThread.

As an example, students completed a group project on volcanoes. In this observed activity, Benson introduced the topic by showing students engaging simulations and pictures of volcanoes and opening up an interactive discussion on the topic. Then, he asked his students to get in groups to choose a topic about volcanoes that they were interested in investigating further. The project took several days. Students did research on the Internet and used Google presentation software to make their presentations. They also uploaded their presentations to the class Ning environment to continue discussions on their research findings after the final day of the project.

Benson said he had implemented the classroom project on volcanoes using iMovie several times in the past. However, his reflections on what students learned, how they interacted, and how technology tools influenced student learning allowed him to evaluate the project.

Benson found that the iMovie project was "too technical" for students, meaning that students focused mainly on the transitions and sound effects of their iMovies, not the science part of the project. Benson then decided to do the same project with Google presentation.

Matt: The "Coach"

Matt had a BS in oceanography. He taught eighth-grade life science in a prestigious private school that provided various materials and equipment for teachers. Classroom laptops, Activeboard, Vernier probeware, microscopes, and clickers were just some of the materials readily available to teachers. In the school the average class size was 16 students. The school served approximately 400 students with 90% of the student population categorized as White. According to Matt, his colleagues were motivated to integrate technology and students felt comfortable using technology tools.

Matt's Motivation to Use Technology. Instead of sticking with a single lesson format, Matt preferred to experiment continually with new ways of teaching science to improve his teaching and to help students understand science better. He liked exploring new technology tools or teaching strategies in his teaching. According to Matt, one thing that allowed him to experiment with different technology tools in his teaching was that he had "comfort or familiarity with the technology." He never panicked if an educational technology tool did not work as intended during instruction, he would calmly fix it and continue the lesson.

Matt constantly searched for opportunities to improve his knowledge and skills about technology tools. He attended professional development programs that were specifically designed for teachers to learn to integrate technology into their teaching. Matt said that each year he improved and was able to implement strategies that he could not do the year before. The more he integrated technology tools in his teaching, the more he "enjoyed" teaching science with technology. He reported that using technology in his instruction was "natural" for him; he started to become "dependent" on the technology tools that he used in the classroom.

Matt's Beliefs About Technology Integration in Science. Matt believed that technology integration was an important aspect of his teaching philosophy:

> My personal teaching philosophy is very constructivist. I think students should be creating their own knowledge and my use of technology definitely supports that and gives them a lot of opportunities to work on things independently.

Matt said that his role as a teacher was "fundamentally a sort of a coach" and a "guide." He saw his role as "coaching students through their ideas and helping them to learn and supporting their learning." Matt believed that students learn best when they are "active" and "intellectually engaged" in the classroom activities. Several times during the interview he expressed that he tried to use hands-on activities in his teaching as much as possible. Matt stated that employing technology helped students learning science.

One of the things that really helps student learning is that the technology focuses more on the students often times than on the teachers....It makes students more personally responsible for their knowledge or their understanding of that objective and really invites them to be more actively engaged.

Matt also reported that allowing students to use technology helped him to understand if learning was occurring in the classroom. According to him, when students used technology in the classroom they were more responsible for their learning. Furthermore, Matt said that when his students used technology he experienced less classroom management issues than normal. He also reported that technology increased his productivity in various tasks, such as grading and recordkeeping. Simply asking students to upload their assignments in his Moodle course website helped him get more organized and provide feedback to students more efficiently. Seeing that using the technology in instruction benefited both him and his students increased his efforts to use technology in his teaching.

Matt's TPACK. Matt knew how to use a variety of educational technology tools; he was able to select technology tools for certain purposes, and he used them regularly in this teaching. He provided various opportunities for students to use technology in the classroom, since he believed that technology tools allowed students to develop a conceptual understanding of science. Matt followed a school-adopted curriculum that included only guided inquiry activities, which let him readily implement student-centered activities. Matt selected appropriate technology tools to include in his curriculum to improve the activities. When choosing the technology tools Matt first looked at the goals and objectives of a classroom activity and then tried to tailor the technology tool that would best achieve that goal.

Matt also used technology tools to monitor and evaluate student learning throughout the curriculum. For example, he set up online discussions/forums on the class website to track student learning. According to Matt, his students better understood a topic when they had a chance to explain it to him, teach it to each other, or discuss it with each other.

Through evaluating and reflecting on student responses, Matt found that he needed to provide the discussion questions to push for more thoughtful and meaningful conversations among students. He also decided to ask his students to comment on at least one of their classmate's responses in addition to responding to the questions. Matt said that the satisfaction he felt after seeing the engaging and thoughtful discussions encouraged him to keep using online discussions in his teaching.

As an example, one of the technology-rich activities that Matt liked and implemented each year was a water quality activity. In this activity, students conducted experiments to find the water quality of a local creek. Using probeware students collected data to measure pH, temperature, and dissolved oxygen and carbon dioxide levels in the creek. Students then wrote research reports and made PowerPoint presentations to share their findings.

Jeremy: The "Facilitator"

Jeremy was a ninth-grade physical science teacher. During the time of the study, Jeremy taught in two school settings. He first taught in a public school where various technology tools were available for the teachers and then moved to a charter school with limited availability of technology tools. Jeremy's first school was the largest high school in the state with a population of about 3,160 students. According to Jeremy, the school district was "financially one of the well-off districts in the state." The school had some socioeconomic diversity but not as much as a typical suburban high school had. Approximately, 84% of the students were White.

The school environment in his second school was very different from his first school. The school served students from grades 9-12, and the population of the school was around 100 students. It had a diverse student ethnicity. Attendance, dropout, and behavior problems were the challenges Jeremy faced in this school. He was the only science teacher in the school. Regarding the technology tools, he said that compared to his previous school this charter school had “virtually nothing.” He reported, “I was actually very surprised when I came to this school to learn we actually had a couple of projectors.” While he was teaching in the charter school, Jeremy worked hard to create solutions, such as borrowing educational technology tools or collaborating with university educators who brought technology tools into Jeremy’s classroom.

Jeremy’s Motivation to Use Technology. Jeremy loved learning and teaching physics; in other words, physics was his passion. Jeremy said he liked to know “how things work,” and that was one of the strongest reasons for becoming a physics teacher. Technology was Jeremy’s second passion and according to him “science and technology cannot be separated.” He felt satisfaction with using technology in his first school, which encouraged him continue to use technology in his instruction. His second school had negative effects on his technology integration efforts, but he reported that his motivation led him to find ways to keep using technology in his instruction.

Although Jeremy knew about a variety of technology tools to which he was introduced in his teacher education program, he was willing to learn more about applications of educational technology tools. Thus, he participated in professional development workshops on technology integration and continued to take graduate level coursework to learn more about technology tools. Through collaboration with other science teachers he also learned innovative ways to integrate technology into his teaching. Jeremy devoted an extensive amount of time and effort to learning the use of educational technology tools. He taught himself various technology applications on his own time to grow both professionally and personally. According to Jeremy, his experimentation with new technology tools motivated him to integrate technology in his teaching.

Jeremy’s Beliefs About Technology Integration in Science. Jeremy believed that “to learn science students should enjoy science.” For Jeremy, using hands-on activities and visual applications were very important, since they enabled learning to become fun and interesting. Jeremy described his role as a teacher as a “facilitator” who “gives students new things to talk about, new things to discuss if they are getting off track, new things to try out in experiments.” He also said it was his role to ask questions to students to address their misconceptions and to involve them in science.

Jeremy believed that using technology in the classroom had many advantages. He pointed out that “in the simulation world, students can play around with things normally they would not be able to do in real life.” He then gave an example:

> You can hook up like a hundred batteries in series [and] in just a short amount [of a time] things start on fire. It is very exciting! In real life it is very dangerous. In a simulation, you can do all you want. Students love it!

Jeremy also said that some equipment used to conduct physics experiments is expensive. Not all science teachers can afford to buy such equipment, but they do not need to buy it if they use simulations or virtual laboratories.

Jeremy’s TPACK. Jeremy said that technology tools increase student engagement and interest in science. Thus, it was critical for him to learn about technology tools and implement them into his instruction. He reported that visual representations were a big part of his teaching, since it was challenging for students to learn some abstract physics concepts such as electricity. The following excerpt exemplifies Jeremy's conception of learning science with technology:

> The simulations allow you to show things visually like electron charges moving from place to place, which they really do, but you are never going to be able to see them in the real world since they are so small. If you can actually show these electron charges, students [can more quickly gain] access to the concepts about what is really going on at this fundamental level that you cannot see in real life, but it is really there.

Jeremy reported that when he integrated visual representations in his instruction his students could conceptually understand these abstract physics concepts. Thus, he included a variety of visual representations in his curriculum. He was also aware of many high-quality online resources (e.g., University of Colorado at Boulder PhET Interactive Simulations website at http://phet.colorado.edu), and he selected visual representations, simulations, or virtual labs from those resources based on his students' needs.

In addition to using visuals in his teaching, Jeremy used laboratory probeware. For example, in observed lessons on velocity and speed, Jeremy's students followed a guided inquiry lab activity, in which they collected speed and velocity data using motion detectors. Students set up a ramp and released their car to measure velocity and distance. They then graphed their results. Jeremy had implemented this activity several times in the past. His reflections on the outcomes of this technology-rich classroom practice on student learning showed that these activities engaged students and helped them understand speed and velocity.

Development and Discussion of a Model for Technology Integration

The cross-case analysis revealed few differences (i.e., specific technology tools that were used and classroom activities) across the cases; the similarities outweighed the differences. Thus, the similarities among the cases allowed us to develop a single model of technology integration (Figure 1) that focused on teachers' motivation to use technology, beliefs about technology integration in science, and TPACK. Various aspects of Deci's (1975) model were supported by the findings of the study and, therefore, it forms the basis of our technology integration model. Some parts in Deci's model, such as emotions, did not emerge from the data. On the other hand, several new concepts such as reflection were added based on the codes developed during cross-case analysis. In the model, the bold arrows represent strong interactions (strength was defined based on the frequency of the codes).

Motivation

Motivation plays a critical role in the model. Intrinsic motivation was found to facilitate teachers' use of technology in their teaching, to increase their interest in using educational technology, to develop their knowledge of and beliefs about technology tools, and to choose appropriate technology tools to use in their instruction. All three teachers in this study said that they used technology because they found it intrinsically rewarding. Many times during the interviews the teachers stated their enjoyment in using educational technology tools.

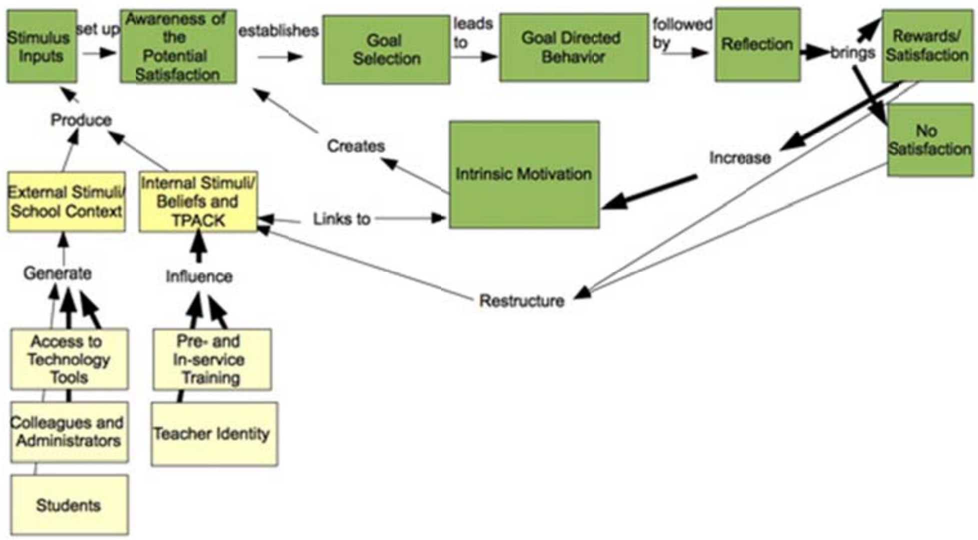

Figure 1. A conceptual model of successful technology integration.

Motivation drives teachers' technology-enhanced practices. All three teachers used technology in their instruction without expecting any rewards from their colleagues or administrators. Using technology in the classroom was their choice. Hadley and Sheingold's (1993) nationwide survey of technology using teachers also found that teacher motivation was a vital factor for teachers to accomplish technology integration. Teachers in this study who integrated technology successfully into their teaching had high motivation in and commitment to using technology for instruction.

Beliefs About Technology Integration in Science

All three teachers possessed constructivist, student-centered beliefs regarding teaching and learning. The teachers' awareness of the importance of student-centered instruction promoted inquiry and student learning using technology, unlike other studies reporting that the predominant use of technology was for administrative purposes (Becker, 2001). Teachers in this study saw digital technologies as necessary and important tools to enhance student learning and to improve their instruction. As in previous studies (Ertmer, 1999; Ertmer et al., 1999; Honey & Moeller, 1990; Levin & Wadmany, 2006; Windschitl & Sahl, 2002), teachers' beliefs about technology were found to be strong indicators of teachers' uses of technology in the classroom.

Teachers' beliefs about the effectiveness of technology on student learning was found to be closely related to teachers' previous experiences with technology and their personality. In particular, the positive experiences of using technology in their teacher education program helped these three teachers see the effects of technology on their own learning and develop a vision of what technology integration should look like in real classrooms. Their personal willingness to learn technology tools also contributed to their beliefs about technology integration.

TPACK

As noted earlier, Niess' conceptualization of technological pedagogical content knowledge was used as a guide to analyze teachers' knowledge. The four domains of TPACK were found to work collaboratively. These domains function as a part of a whole in influencing teachers' decision about technology integration.

Teachers recognized the interplay of science and technology and transformed their ideas into their teaching. For these teachers, technology tools were invaluable in terms of making science more engaging for students and presenting science concepts better to students. Their knowledge of instructional strategies and representations were reflected in their classroom practices. They mostly applied hands-on science activities and inquiry-based activities and used a variety of representations. Teachers in this study commonly used visual representations.

Their knowledge about student learning was another critical factor for their technology integration. They all believed that students learn by doing. Reflective of this knowledge about student learning, all of the teachers planned for their students to use technology to assist in the development of content knowledge. Finally, teachers' knowledge about curriculum materials, particularly educational technology tools, were mirrored in their use of various technologies in their teaching. They knew a wide range of technology tools to teach their content area and they continually updated their knowledge and technology skills.

Teachers applied their TPACK to decide what technology tools to use and when and how to use them to promote student learning. Well-developed TPACK was found to be necessary for successful technology integration. This finding was also supported by previous research (Guzey & Roehrig, 2009; Koehler & Mishra 2008; McCrory, 2008; Niess, 2005). Teachers must draw upon their knowledge about teaching, learning, science, and technology to select appropriate educational technology tools to teach particular topics to their specific group of students.

Other Components of the Technology Integration Model

Findings of this study supported the assertion that Deci's model of human motivation and behavior can be used to explain technology integration in science classrooms. Although originally this study aimed to analyze teachers' motivations, beliefs, and knowledge, the findings indicated that factors such as school-related elements influenced all three factors; thus, they are also important predictors for technology integration.

External Stimuli

External stimuli influenced teachers' technology integration in their science classrooms. Three categories form external stimuli: available resources, students, and colleagues and administration. Access to educational technology tools influenced teachers' decisions about what technology to use and how to use it. The school context was found to have an important influence on teachers' technology-rich practices. Teachers seemed to implement their technology-supported instruction more easily when they had ready access to the tools; however, not having access to technology was no excuse for not using technology.

Students' experiences with technology were also a factor in teachers' decisions. Based on students' needs the teachers decided what they needed to do with technology. Although most of the students were technology savvy, teachers emphasized that they also had non-tech-savvy students in their classrooms; thus, they had to differentiate their teaching.

Colleagues and administrators were also critical in teachers' technology integration efforts. Collaborating with colleagues to design technology-rich lesson plans and having administrators who shared the same vision with teachers fostered smooth technology integration. The teachers in this study emphasized several times how supportive their administrators were in helping to incorporate technology into their instruction. Seeing that their philosophy of teaching matched with their administrator's philosophy was very "encouraging" in the decision to use technology in their teaching.

As also described in previous studies, the school's vision for technology use, the school technology infrastructure, and students' experiences with technology and student outcomes were found to impact teachers' technology integration efforts (Brickner, 1995; Sandholtz, Ringstaff, & Dwyer, 1997; Zhao, Pugh, Sheldon, & Byers, 2002). However, regarding the school infrastructure, having available technology tools did not necessarily lead teachers to use technology or to apply constructivist instruction. This finding supports the claim that teachers need to have motivation and favorable beliefs about technology and constructivist instruction in order to integrate technology successfully into instruction.

Awareness of Potential Satisfaction

The awareness of potential satisfaction explains the desire to include technology in instruction. Teachers' beliefs about technology integration in science and TPACK produce this component of the model. Teachers in this study believed in the effective influence of technology on student learning. They all expressed that technology was engaging, increasing student interest in science and motivation to learn science. Believing in the effectiveness of technology in student learning and being aware of the positive effects of using technology on students heavily influenced teachers' decisions about technology integration.

Goal Selection

Teachers carefully chose the appropriate teaching strategies and instructional methods to present a particular science concept in the classroom. All three teachers used instructional methods that allowed them to create learner-centered, activity-driven learning environments. The teachers integrated technology into their teaching and the following technology tools were found to be utilized by all three teachers: Activeboard, a variety of multimedia tools such as simulations/animations and digital images, and online forums. Selecting appropriate tools depended on various factors (e.g., content area and knowledge of the educational technology tool).

Goal Directed Behavior

In the model, the goal directed behavior includes both teacher and student practices. Various student and teacher practices were observed in classroom observations. Student practices included collecting and analyzing data, joining online discussions, performing virtual labs, searching content information on the Internet, and designing class projects. Teacher practices, like student practices, varied. Teachers used the technology tools to present content information, share class material, assess student learning, or determine students' prior knowledge and misconceptions.

Reflection

Reflection did not occur in Deci's (1975) cognitive model of behavior. Reflection includes evaluating the lesson, thinking about what went well or wrong, and considering possible ways for modifications. Evaluating student outcomes such as achievement and motivation and personal outcomes such as knowledge, beliefs, and motivation allowed teachers to assess their technology-rich classroom. The postobservation interviews showed that teachers drew conclusions every day from their classroom practices. Through reflection on what and how students learn, how technology tools influenced students' learning, and how the lesson might be modified, the teachers actively evaluated their teaching. In the interviews, the teachers explained possible ways to modify their lessons based on their evaluations of their teaching and student learning.

This study suggests that sustained technology integration involved continuous reflection on classroom practices. Through reflection, teachers in this study saw the effectiveness of particular educational technology tools on their students' learning. They modified their strategies, if necessary, after reflecting on their classroom practices. This process allowed them to sustain technology use in the classroom. The importance of reflection in technology-rich teaching has also been emphasized in previous literature (Ertmer, 1999).

Rewards and Satisfaction/Dissatisfaction

Feeling satisfaction after completing an intrinsically motivated behavior allowed the teachers to set up further goals. Rewards can be intrinsic or extrinsic. However, the teachers in this study used technology in their teaching without expecting any external rewards. Feeling satisfaction or dissatisfaction might cause a readjustment of the beliefs on teaching, learning, and technology tools. Since beliefs links to knowledge, there exists a feedback loop in the model.

Conclusion

The findings of this study support a model, created through modifications of Deci's (1975) cognitive approach to behavior, and shed new light on teachers' technology integration efforts. The model developed from these findings provides a deep understanding of the teacher-level factors, the complex relationship among these factors, and the effects of school-level factors. The model demonstrates that intrinsic motivation in conjunction with beliefs and knowledge drives teachers to use educational technology tools in their teaching. Furthermore, the model shows that reflection is critical for sustained technology use.

Limitations

There are several limitations of the study. The first limitation of this study is the nature of the sample. There are three participant teachers in this study. Because of the small sample size, the results of this study may not be generalizable but the complex relationship among teacher beliefs, knowledge, and practices is transferable. Furthermore, it is important to note that all of participants of the study are male. As noted earlier, the participant teachers were selected from a pool of 60 science teachers. Since none of the female teachers in this pool were found to achieve technology integration, they were not invited to participate in the study.

Additionally, we were not able to conduct postobservation interviews with the three teachers after each classroom observation. Jeremy and Benson did not always have enough time to talk to us after the classroom observations since their next class period started in 5 minutes. On the other hand, Matt had a prep time after the class that we observed, so we conducted all the postobservation interviews with Matt. However, we pursued in-depth information pertaining to Jeremy and Benson's observed classes in the semistructured interviews.

Implications and Future Research

The presence of professional collaboration seems to be crucial to digital technology integration. Collaboration with other teachers helped teacher participants to decrease the amount of time that they needed to spend in designing technology enriched lesson plans. It also seems important that teachers needed to attend professional development opportunities to learn innovative lesson plans and to update their knowledge of technology. Finally, teacher education programs influenced teachers' adoption of educational technology in their teaching. Teachers in this study were required to take a science-specific technology course where they learned about the use of particular technology tools in science classrooms and pedagogical issues related to technology integration into teaching and learning.

Requiring teachers to take subject-specific technology courses in their teacher education program would be beneficial. In these courses, teachers might also see the effectiveness of the use of technology on learning; they might decrease their fear of technology and increase their motivation to apply them in their teaching. It is important to provide teachers with opportunities to explore and practice with various technology tools in those technology courses.

The findings and implications of this research lead to some questions that need to be answered in further investigations. A necessary step would be to conduct a comparative study between teachers who have achieved technology integration and teachers who could not. A comparison study might reveal further connections among teachers' motivation, beliefs, and knowledge and how they influence their technology integration efforts. Another study would be to examine teachers who teach the same science subject. This new study may shed new light on the pedagogical practices of teachers who teach the same science subjects and use technology.

References

Becker, H. J. (2000). Findings from the teaching, learning, and computing survey. *Education Policy Analysis Archives, 8*(51). Retrieved from http://epaa.asu.edu/ojs/article/viewFile/442/565

Becker, H. J. (2001, April 21). *How are teachers using computers in instruction?* Paper presented at the annual meeting of the American Educational Researchers Association. Retrieved from the Center for Research on Information Technology and Organizations website: http://www.crito.uci.edu/tlc/findings/conferences-pdf/how_are_teachers_using.pdf

Brickner, D. (1995). *The effects of first and second order barriers to change on the degree and nature of computer usage of secondary mathematics teachers: A case study*. Unpublished doctoral dissertation, Purdue University, West Lafayette, IN.

Dani, D., & Koenig, K. (2008). Technology and reform-based education. *Theory into Practice, 47*(3), 204-211.

Deci, E. (1975). *Intrinsic motivation*. New York, NY: Plenum Press.

Dweck, C. S. (2002). Beliefs that make smart people dumb. In R.J. Sternberg (Ed.). *Why smart people can be so stupid* (pp. 24-41). New Haven. CT: Yale University Press.

Eccles, J., & Wingfield, A. (2002). Motivational beliefs, values, and goals. *Annual Review Psychology*, 53, 109-132.

Ertmer, P. (1999). Addressing first- and second-order barriers to change: Strategies for technology integration. *Education Technology Research and Development*, *47*(4), 47-61.

Ertmer, P. (2005). Teacher pedagogical beliefs: The frontier in our quest for technology integration? *Educational Technology Research and Development*, *53*(4), 41-56.

Ertmer, P., Paul, A., Lane, M., Ross, E., & Woods, D. (1999). Examining teachers' beliefs about the role of technology in the elementary classrooms. *Journal of Research in Computing in Education*, *32*(1), 54-71.

Ford, M. (1992). *Motivating humans: Goals, emotions, and personal agency beliefs*. Newbury Park, CA: Sage Publication.

Guzey, S. S., & Roehrig, G. H. (2009). Teaching science with technology: Case studies of science teachers' development of technology, pedagogy, and content knowledge. *Contemporary Issues in Technology and Teacher Education*, *9*(1). Retrieved from http://www.citejournal.org/vol9/iss1/science/article1.cfm

Hadley, M., & Sheingold, K. (1993). Commonalities and distinctive patterns in teachers' integration of computers. *American Journal of Education*, *101*, 261-315.

Honey, M., & Moeller, B. (1990). *Teachers' beliefs and technology integration: Different values, different understandings* (Technical Report No 6). New York, NY: Center for Technology in Education.

Kagan, D. (1992). Implication of research on teacher belief. *Educational Psychologist*, *27*(1), 65-90.

Koehler, M., & Mishra, P. (2008). Introducing TPCK. In The AACTE Committee on Innovation and Technology (Eds.), *Handbook of technological pedagogical content knowledge (TPCK) for educators*, (pp. 3-31). New York, NY: Routledge.

Lee, H.-S., Linn, M.C., Varma, K., & Liu, O.L. (2010). How does technology-enhanced inquiry science units impact classroom learning? *Journal of Research in Science Teaching*, *47*(1), 71–90.

Lei, J., & Zhao, Y. (2007). Technology uses and student achievement: A longitudinal study. *Computers and Education*, *49*, 284-296.

Levin, T., & Wadmany, R. (2006). Teachers' beliefs and practices in technology-based classrooms: A developmental view. *Journal of Research on Technology in Education*, *39*(2), 157-181.

Luft, J. (2009). Beginning secondary science teachers in different induction programmes: The first year of teaching. *International Journal of Science Education*, *31*(17), 2355-2384.

Luft, J., & Roehrig, G. H. (2007). Capturing science teachers' epistemological beliefs: The development of the teacher beliefs interview. *Electronic Journal of Science Education, 11*(2), 38-63.

Lumpe, A., & Chambers, E. (2001). Assessing teachers' context beliefs about technology utilization. *Journal of Research on Technology in Education*, *34*(1), 93-107.

McCrory, R. (2008). Science, technology, and teaching: The topic-specific challenges of TPCK in science. In The AACTE Committee on Innovation and Technology (Eds.), *Handbook of technological pedagogical content knowledge (TPCK) for educators* (pp. 193-206). New York NY: Routledge.

Merriam, S. (1998). *Qualitative research and case study applications in education*. San Francisco, CA: Jossey-Bass.

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for integrating technology in teacher knowledge. *Teachers College Record*, *108*(6), 1017-1054.

National Education Association. (2008). *Access, adequacy, and equity in education technology: Results of a survey of America's teachers and support professionals on technology in public schools and classrooms.* Retrieved from the Edutopia website: http://www.edutopia.org/files/existing/pdfs/NEA-Access,Adequacy,andEquityinEdTech.pdf

National Research Council. (2000). *Inquiry and the National Science Education Standards*. Washington, DC: National Academy Press.

Nespor, J. (1987) The role of beliefs in the practice of teaching. *Journal of Curriculum Studies*, *19*(4), 317-328.

Niess, M. L. (2005) Preparing teachers to teach science and mathematics with technology: Developing a technology pedagogical content knowledge. *Teaching and Teacher Education*, *21*, 509-523.

Pajares, M. F. (1992). Teachers' beliefs and educational research: Cleaning up a messy construct. *Review of Educational Research*, *62*(3), 307-332.

Richardson, V. (1996). The role of attitudes and beliefs in learning to teach. In J. Sikula (Ed.), *The handbook of research in teacher education* (2nd ed.; pp. 102-119). New York, NY: Macmillan.

Roehrig, G. H., & Luft, J. A. (2004) Inquiry teaching in high school chemistry classrooms: The role of knowledge and beliefs. *Journal of Chemical Education*, *81*, 1510-1516.

Russell, D. W., Lucas, K. B., & McRobbie, C. J. (2003). The role of the microcomputer-based laboratory display in supporting the construction of new understandings in kinematics. *Research in Science Education*, *33(*2), 217-243.

Sandholtz, J., Ringstaff, C., & Dwyer, D. C. (1997). *Teaching with technology: Creating student-centered classrooms*. New York, NY: Teachers College Press.

Schroeder , C., Scott, T., Tolson , H., Huang , T., & Lee, Y. (2007). A meta-analysis of national research: Effects of teaching strategies on student achievement in science in the United States. *Journal of Research in Science Teaching*, *44*(10), 1436-1460.

Sheingold, K., & Hadley, M. (1990). *Accomplished teachers: Integrating computers into classroom practice*. New York, NY: Center for Technology in Education, Bank Street College of Education.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, *15*(2), 4-14.

Songer, N. B. (2007). Digital resources versus cognitive tools: A discussion of learning science with technology. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 471-493). Mahwah, NJ: Lawrence Erlbaum.

Strauss, A., & Corbin, J. (1990). *Basics of qualitative research: Grounded theory procedures and techniques*. Thousands Oak, CA: Sage Publications.

U.S. Congress Office of Technology Assessment. (1995). *Teachers and technology: Making the connection*. Retrieved from the Princeton University website: http://www.princeton.edu/~ota/disk1/1995/9541/9541.PDF

U.S. Department of Education. (2003) *Federal funding for educational technology and how it is used in the classroom: A summary of findings from the integrated studies of educational technology*. Retrieved from http://www.ed.gov/rschstat/eval/tech/iset/summary2003.pdf

Van Lehn, K., Graesser, A. C., Jackson, G. T., Jordan, P., Olney, A., & Rose, C. P. (2007). When are tutorial dialogues more effective than reading? *Cognitive Science*, *30*, 3-62.

Wallace, C., & Kang, N-H. (2004). An investigation of experienced secondary science teachers' beliefs about inquiry: An examination of competing belief sets. *Journal of Research in Science Teaching*, *41*(9), 936-960.

Windshitl, M., & Sahl, K. (2002). Tracing teachers' use of technology in a laptop computer school: The interplay of teacher beliefs, social dynamics, and institutional culture. *American Educational Research Journal*, *39*(1), 165-205.

Yerrick, R., & Hoving, T. (1999). Obstacles confronting technology initiatives as seen through the experience of science teachers: A comparative study of science teachers' beliefs, planning, and practice. *Journal of Science Education and Technology*, *8*(4), 291-307.

Zhao, Y., Pugh, K., Sheldon, S., & Byers, J. (2002). Conditions for classroom technology innovations. *Teachers College Record*, *104*(3), 482-515.

Author Note:

S. Selcen Guzey
STEM Education Center
University of Minnesota
320 H LES
1954 Buford Ave
St. Paul, MN 55108, USA
Phone: 612-626-2132
Fax: 612-626-0993
Email: kendi003@umn.edu