Science, Technology, and Pedagogy: Exploring Secondary Science Teachers' Effective Uses of Technology

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Dedication

This dissertation is dedicated to my parents, Hatice Kendir and Halil Kendir.

Abstract

Technology has become a vital part of our professional and personal lives. Today we cannot imagine living without many technological tools such as computers. For the last two decades technology has become inseparable from several areas, such as science. However, it has not been fully integrated into the field of education. The integration of technology in teaching and learning is still challenging even though there has been a historical growth of Internet access and available technology tools in schools (U.S. Department of Education, National Center for Education Statistics, 2006). Most teachers have not incorporated technology into their teaching for various reasons such as lack of knowledge of educational technology tools and having unfavorable beliefs about the effectiveness of technology on student learning. In this study, three beginning science teachers who have achieved successful technology integration were followed to investigate how their beliefs, knowledge, and identity contribute to their uses of technology in their classroom instruction. Extensive classroom observations and interviews were conducted. The findings demonstrate that the participating teachers are all intrinsically motivated to use technology in their teaching and this motivation allows them to enjoy using technology in their instruction and keeps them engaged in technology use. These teachers use a variety of technology tools in their instruction while also allowing students to use them, and they posit a belief set in favor of technology. The major findings of the study are displayed in a model which indicates that teachers' use of technology in classroom instruction was constructed jointly by their technology, pedagogy, and content knowledge; identity; beliefs; and the resources that are available to them and that the internalization of the technology use comes from reflection. The

study has implications for teachers, teacher educators, and school administrators for successful technology integration into science classrooms.

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Chapter I: Introduction

Rationale

Over the past two decades, information and communication technologies have become inseparable from our lives. Despite its widespread infusion, technology remains poorly integrated in K-12 education. Billions of dollars have been invested in technology in K-12 schools, yet the vast majority of today's teachers do not use technology in meaningful ways in their instruction (U.S. Congress Office of Technology Assessment [OTA], 1995; U.S. Department of Education, 2003; U.S. Department of Education, National Center for Education Statistics [NCES], 2000; National Education Association [NEA], 2008).

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. Thus, the importance of integrating technology in schools has been addressed in many educational reforms such as in the "No Child Left Behind" act. The legislation states that "…schools should use technology as a tool to improve academic achievement, and that using the latest technology in the classroom should not be an end unto itself." The new U.S. administration also values technology and highly encourages teachers to use it in order to improve student learning. Science teachers are asked to apply technology to help students not only *learn* science but also *do* science (National Research Council [NRC], 2000).

Research into the use of technology in classrooms demonstrates that technology plays a critical role in student learning (Russel, Lucas, & McRobbie, 2003). Some of the large scale studies have shown the significant increase in achievement scores of students using technology as a learning tool (e.g., Lei & Zhao, 2007). Consistent findings were found in Cotton's (1992) extensive literature review regarding the improvement in student achievement through computer use. Cotton also found that computers improve student motivation to learn and attitude toward course content and school in general.

Research exploring the use of technology in science classrooms clearly indicates that the use of technology has positive influence on the wide variety of student learning outcomes including understanding of science and development of scientific reasoning skills (Dani & Koenig, 2008; Schroeder , Scott , Tolson , Huang , & Lee, 2007; Songer, 2007). In their meta-analysis research on the effects of different types of instructional strategies on student achievement, Schroeder et al. (2007) showed the positive influence of the use of instructional technologies on student learning. The authors found that the most effective teaching strategy on student learning is "enhanced context strategies" such as making the content relevant to students' everyday life experiences. As the authors suggested, real world experiences can be easily brought to students through technology since the technology facilitates authentic science activities in the classroom. For example, project-based science curricula that include learning technologies provide an opportunity for students to engage in inquiry (Hug, Krajcik, & Marx, 2005). Students design and conduct inquiry projects using various learning technologies such as handheld personal computing devices and digital measurement instruments.

There are also many types of computer-based learning environments that allow students to engage in problem solving activities pertaining to scientific reasoning through participating in inquiry projects. These learning environments such as WISE (http://wise.berkeley.edu/) includes various cognitive tools to support students' higher order thinking, hypothesis testing, and procedural and declarative knowledge development. These computer-based learning environments can assist students to regulate their learning process.

The use of learning technologies in science classrooms also increases students' attention, engagement, and interest in science (Van Lehn, Graesser, Jackson, Jordan, Olney, & Rose, 2007). Van Lehn et al. showed that computer mediated tutoring help students understand the physics concepts since the high interactivity allow students participate and learn more. Student or classroom response systems, also known as "clickers", help teachers create interactive classroom environments and increase students' interest (Deal, 2007). Moreover, research demonstrates that the use of digital microscopes in science classrooms enhance collaboration and student engagement (Dickerson & Kubasko, 2007) and enable students to actively engage in their science learning process (Bell & Bell, 2002). The commonly used technologies, science simulations, also increase students' level of engagement and understanding of abstract concepts through confronting students' own misconceptions (Cox, 2000).

Unfortunately, in spite of the substantive body of research demonstrating the efficacy of technology to enhance science learning, research has revealed that for science teachers, effective use of technology remains challenging (Yerrick & Hoving, 1999). The vast majority of science teachers either ignore the call to use technology in science teaching or they employ technology in ways that replicate traditional instructional strategies. In order to successfully use technology as an instructional tool, science teachers need to make informed decisions about what technology to use, where (in the curriculum) to use it and how to use it. There are a small number of science teachers that use technology effectively; however, the majority of science teachers that attempt to use technology become frustrated by difficulties related to implementation. Various studies report on the obstacles that impede successful technology integration (e.g., Clausen, 2007; Mumtaz, 2000). Mumtaz (2000) reviewed the literature on barriers on technology integration and provided a comprehensive list of "inhibitors" including lack of financial support, time, technical support, access, and experience with technology, and technology specialist teacher. Teachers' perceptions and personal factors and philosophical factors were also categorized as factors that might cause teachers' resistance to technology use (Mumtaz, 2000).

Brickner (1995) categorizes the obstacles to effective technology integration as *first-order barriers* and *second-order barriers*. Brickner defines first-order barriers as "extrinsic factors" which include access to technology resources, software availability and quality, planning time for technology rich lessons, and technical support. According to Brickner, second-order barriers can be defined as "intrinsic factors" that include teachers' beliefs about teaching and technology, organizational school context or culture, instructional models, and openness to integrate technology. For Brickner, first order barriers are easier to define; however, second-order barriers are more difficult to define and overcome since teachers need to restructure their belief systems about technology and also develop their own knowledge bases.

In addition to obstacles and barriers to technology integration, education research has paid much attention to factors that enable teachers to use technology in their teaching. Several researchers have explored the process of technology integration and the factors that influence teachers' decisions to incorporate technology into their teaching. OTA (1995) defined eight requirements for appropriate use of technology. These requirements are: access to technology and costs, pre-service training, in-service training, technical support, time, administrative support, vision of curricular applications, and technology suited to education goals. Several of these factors have been also emphasized in the literature on barriers to technology integration (i.e., lack of access to technology and support).

Recently, ISTE (2007) (www.iste.org) proposed thirteen essential conditions that should be met to effectively use technology in instruction. The conditions are very similar to the conditions that are defined by OTA (1995). The ISTE's conditions include a shared vision, implementation planning, consistent and adequate funding, equitable access, skilled personnel, ongoing professional development, technical support, curriculum framework, student-centered teaching, assessment and evaluation, engaged communities, support policies, and supportive external context. The three conditions, implementation planning, consistent and adequate funding, and supportive external context were not discussed as essential conditions in the previous publication of ISTE (ISTE, 2002). Implementation planning requires schools to having a plan aligned with a vision for school effectiveness and student learning. Since technology changes so quickly schools need ongoing funding to support technology infrastructure. Nationwide, local, and regional support is necessary for schools in effective implementation of technology.

The International Association for the Evaluation of Educational Achievement (IEA) conducted several comparative international studies to find the use of educational technology tools in different countries around the world and to define the factors that influence teachers' pedagogical uses of technology. The factors related to technology integration are grouped as micro-level (classroom), meso level (school and community), and macro level (state, national, and international entities) (Kozmo, 2003). According to Kozmo, the success of technology integration depends on factors at all levels. For example, effective technology implementation not only depends on the characteristics of the innovation but also on characteristics of students and teachers, school organization, and state and nation wide policies.

Statement of the Problem

Research that focuses on barriers and enablers is necessary but insufficient for providing guidelines for successful technology integration. Most research studies simply provide a long list of factors and do not pay attention on the critical relationship among the factors. To understand the interaction among the factors studies with successful technology implementers should be conducted. Missing from the literature are richly detailed *profiles* of science teachers who effectively utilize technology in their teaching, who apply technology to problem-solving and decision-making in student-centered learning environments, and who use technology to enable collaboration among students. Examples of successful experiences in integrating technology can serve as a practical guide for both pre-service and practicing teachers and provide direction on how to overcome barriers. The present study aimed to shed new light on the teacher level factors that contribute science teachers to become successful technology implementers. The critical interaction among the factors was investigated. Findings of this study will add to the research on facilitating technology integration in classrooms.

Goals and Objectives

This study was designed to explore the beliefs, knowledge, identity, and classroom practices of science teachers who are effective technology users. The primary research question that guided this study was:

- How do science teachers' beliefs, knowledge, and identity contribute to their uses of technology in their teaching?

Potential Significance of the Study

Nationwide survey studies conducted by the NCES demonstrate that 99% of all public school teachers have computers available in their schools and almost 80% of them have one to five computers in their own classrooms (U.S. Department of Education, NCES, 2000). However, approximately 18% of teachers are reported to use technology for instructional purposes more than once a week (Norris, Sullivan, & Poirot, 2003) and only 5% demonstrate meaningful use of technology in their instruction. These data demonstrate the need to explore how teachers have become successful implementers. The investigations of successful teachers' knowledge, beliefs, identity, and practices can enable us to find ways to help other teachers become successful implementers. By understanding what factors contribute to their success, we may design more effective pre- and in-service teacher education programs to better prepare other teachers to incorporate technology into their classroom practices. For example, if knowledge emerges as a key factor for effective technology use, we can redesign our teacher education programs to require teachers to take more content-specific technology courses that involve practical application.

There is no question that teachers have a substantial effect on student achievement. In the field of science, technology use has distinct advantages for student learning. Science teachers' effective use of technology allows students to improve their understanding, attitudes, and engagement (Songer, 2007). Most science teachers do not use technology effectively in their teaching and feel uncomfortable with technology. Teachers need and want to see examples or models of technology-rich classroom instruction. This study meets this need by providing portrayals of exemplary practices of science teachers who use technology effectively. In addition to providing examples of good practices, this study sheds light on the commonalities among these effective technology implementers, which may help other science teachers learn to integrate technology effectively in their classrooms.

Definitions

Identity in this study represents teacher characteristics and personality. Participating teachers' identity was investigated to find who they are as technology using teachers.

Technology is "the innovation, change, or modification of the natural environment in order to satisfy perceived human wants and needs" (ITEA, 2000, p. 242).

The effective use of technology requires teachers to a) utilize technology in their teaching to improve student learning; b) routinely include innovative ideas for using various educational technology resources in instruction; and c) allow student use of technology in carefully designed technology-rich lessons that provide students with opportunities to actively engage in their learning while collaborating with other students.

Overview of the Following Chapters

Chapter II is an overview of the relevant literature, and it provides information about the theoretical background of the study, literature on the effects of beliefs and knowledge on technology integration, and educational technology tools that are commonly used in science classrooms. Chapter III details the research methods used to carry out the study. Detailed descriptions of participant teachers, the data collection and analysis methods for this study are discussed. Chapter IV presents the individual cases for the science teachers in this study. Each case includes information about the teacher's school context, identity, beliefs and knowledge, and classroom practices. Chapter V includes a detailed within and cross-case analysis of the individual cases. The conclusion, implications, and suggestions for further research are presented in Chapter VI. Also, the main themes that emerged from the data are compared and contrasted with previous research in the final chapter.

Chapter II: Review of the Literature

This chapter includes a summary of the literature review of topics relevant to the purpose of the study. The first section of this chapter presents the conceptual framework that was used in this study. The next section explores teacher beliefs and knowledge related to technology integration. Finally, last section includes an explanation of educational technology tools that have been employed in science classrooms and meaningful use of them in the classroom instruction.

Theoretical Background

This study is concerned with how science teachers' beliefs, knowledge, and identity contribute to their uses of technology. It does not deal with teachers' rationale for integrating technology into their classrooms. In this study, it is assumed that using technology in the classroom instruction is a voluntary behavior and teachers use technology in their instruction since they are motivated to use it. People's behaviors are motivated by many factors such as emotions, beliefs, and knowledge (Ford, 1992; Pintrich & Schunk, 2001). These inclinations play important roles in making decisions on our behavior and they are influenced by external factors that either facilitate or thwart our behaviors. For example, external factors such as classroom resources and school organization influence teacher motivation and behavior.

This study is largely grounded in the theoretical framework of *human motivation*. There are various theories on human motivation and each theory addresses different aspects of human motivation (Ford, 1992). While some of these theories describe motivation as an end product meaning desire or willingness to a particular activity, others define motivation as a cognitive process that focus on how the desired outcomes are achieved (Anderman & Wolters, 2006). The conceptual framework adopted for this study evolved out of the intrinsic motivation theory that uses the cognitive perspective to explain how "humans process information and make choices about what behaviors to engage in" (Deci, 1975, p. 95). The theory proposes that people make choices under the influences of the environment that they are in and of their "personal knowledge" meaning their feelings, thoughts, perceptions, emotions and other internal states. The cognitive processing plays an important role in deciding what to do and how to do it. In the following section, the theory is discussed and then the conceptual framework of this study is presented.

Deci (1975) argues that people engage in activities either for their own sake or for an external reward. For example, a person can engage in a behavior voluntarily (intrinsic motivation) or in order to earn money or praise (extrinsic motivation). This study does not attempt to cover all types of human motivation. It primarily focuses on the intrinsic motivation since the participants of this study use technology in their teaching voluntarily meaning without expecting any external reward. They would be intrinsically motivated since they engaged in using educational technology without expecting any rewards or praise.

According to Deci (1975), "intrinsically motivated activities are ones for which there is no apparent reward except the activity itself" (p. 23). The person enjoys doing the activity, the activity is not motivated by extrinsic needs; however, it brings internal rewards. “Intrinsically motivated behavior is motivated by one’s need for feeling competent and self-determining” (Deci, 1975, p. 62). Deci argues that there are two kinds of intrinsically motivated behaviors. The first involves seeking out situations that provides a challenge. The person uses his abilities to achieve the challenge. Consider, for example, a person is bored and decided to solve a puzzle. If he finds that the puzzle is too challenging for him, he seeks another opportunity that he can handle. The second type of intrinsically motivated behaviors involves achieving challenges that the person either face or creates to feel competent and self-determining. This type of behaviors includes reducing dissonance, incongruity, or uncertainty (Deci, 1975). An alcoholic person, for example, might quit drinking alcohol if he feels competent and determining.

Deci’s (1975) cognitive approach to motivation is primarily concerned with the choice of behavior. There are five stages in Deci’s model of the cognitive approach to behaviors. 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 many educational technology tools available in a school might lead a teacher to use them for instruction. The stimulus can also come from memory or past experiences. Consider, a teacher whose high school physics teacher employed educational technology while teaching Newton’s laws. The teacher’s memories of his past experiences as a student with technology may influence him in making his decision on whether or not to use technology while teaching Newton’s laws. Finally, the stimulus may derive from internal factors such as blood sugar, or hormones. These types of biological factors are influential on various behaviors would not be considered as a factor for technology integration.

The second stage in Deci's model is awareness of potential satisfaction. This stage might be called the "energy source" of the activity due to an awareness that completing the activity will be more satisfying than the current stage of being. At this stage, various things may influence a person's awareness of potential satisfaction such as emotions. In the case of technology integration, emotions play an important role in teachers' decision about using technology in the classroom. Fear of technology would possibly prevent a teacher from employing technology in instruction; creating behavior avoidance. A positive emotional experience might be a teacher's success in using an educational technology in the classroom. Seeing that students better understand the concept may create feeling of excitement and happiness making the teacher aware that more satisfaction is available if he uses educational technology in all his classes. Awareness of potential satisfaction also comes from intrinsic motivation as people's intrinsic need to feel competent and self-determining leads them to behave in 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 open to him, on the basis of expectations of the end states to which the behaviors would lead" (Deci, 1975, p. 106). A science teacher can select from a range of educational technology tools when teaching a particular topic, for example, Newton's laws can be taught using motion detectors, simulations/animations, or video capture. Choosing an educational tool from the list above 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 behaviors to achieve their goals. According to Deci (1975), the goal directed behavior can be changed based on changes in the person's awareness of potential satisfaction. For example, after teaching Newton's laws without using any technology tools and seeing students struggling with understanding these abstract concepts, a teacher could become aware of potential satisfaction from employing probe ware or computer simulations. This would lead the teacher to reevaluate the choices: teaching with technology vs. teaching without the technology.

The final stage in the model is reward and satisfaction. Reward can be an extrinsic reward, intrinsic reward, or changes in affect. The level of reward and satisfaction feeds back into goal selection and awareness of potential satisfaction as shown in Figure 1. If there is no satisfaction or if the satisfaction and the awareness of potential satisfaction do not match, 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 influence of a specific tool on student learning does not match what a teacher expected before using this tool, the teacher might 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 teacher's motivation and lead the teacher to continue to use the tool.

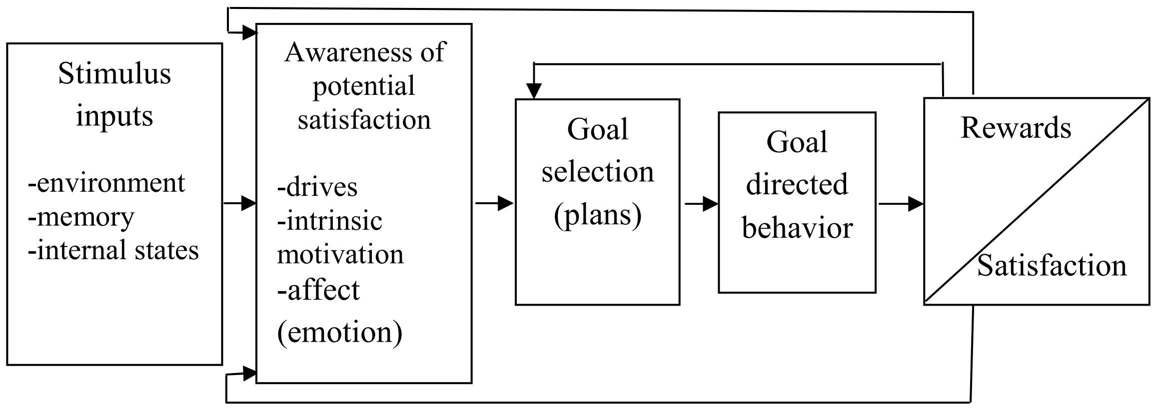

Figure 1. Deci's (1975) Cognitive approach to behavior

It is also important to note that Deci (1975) points out that the sequence of the model may be interrupted at any time when the person's expectation or the awareness of the potential satisfaction changes. In brief, the model presents a framework of human motivation. "People choose behavior which they believe will lead them to desired goals" (Deci, 1975, p. 124).

Absent from Deci's (1975) intrinsic motivation model are the role of teachers' beliefs and knowledge in the decision on how to integrate technology into instruction. The literature on teachers' knowledge and beliefs about educational technology tools will be discussed in detail later in this chapter. In the following section, I briefly discuss the need for adding beliefs and knowledge into the intrinsic motivation model and present the conceptual model for this study.

In this study, it is assumed that beliefs play an important role in human behavior. Beliefs are cognitive constructs and can be defined as "understandings, premises, and propositions about the world" (Richardson, 1996, p. 103). Beliefs affect the way one acts or interacts with his environment. Deci (1975); however, in his model of motivation does not include the effect of beliefs on human behavior. Later motivation theories include the importance of beliefs on human motivation (e.g., Ford, 1992). Ford (1992), for example, in his Motivational System Theory, asserts that personal agency beliefs are the main component of human motivation and determine whether a person will perform the behavior. Personal agency beliefs include two types of beliefs: capability beliefs and context beliefs. While Ford defines capability beliefs as evaluative thoughts about whether one has personal capabilities to be able complete the goal, he conceptualizes context beliefs as evaluative thoughts about whether the person's context will facilitate or hinder the goal that the person wants to achieve. In this study, Ford's theory of motivation was not used since the model focuses on biological capabilities while explaining human behavior. Biological capabilities do not closely relate to technology integration. Regarding beliefs, it is known that when considering technology integration a teacher's beliefs about teaching, learning, and the effectiveness of the technology may influence his uses of technology (Windschitl & Sahl, 2002).

Deci (1975) and most other motivation theorists also do not focus on the influence of knowledge on human motivation and behavior. Instead they focus on (new) knowledge development and see it as an end point of human behavior. Ford (1992) argues that "motivation provides the foundation for learning…self-construction of new knowledge" (p. 22). While there is not a general agreement on the definition of knowledge across many disciplines (e.g., anthropology, sociology, psychology) the knowledge can be defined as "justified true belief" (Philipp, 2007, p. 259). In the case of technology integration, teachers' knowledge about educational technology plays an important role in their decisions to use a technology tool in their classroom (Mishra & Koehler, 2006). Simply put, a teacher cannot use an educational technology tool in classroom instruction without knowing about it. Developing knowledge of a technology tool can be an end product of a different goal; however, in the case of using that tool in the instruction knowing about that tool is a prerequisite.

The conceptual framework of the current study is shown in Figure 2. It represents the various aspects of the Intrinsic Motivation Theory (Deci, 1975) and the literature on technology integration that was briefly discussed in the previous chapter (see chapter I). As described above, I have added “knowledge” and “beliefs” to Deci’s model, because the model does not explicitly deal with them, and because they are necessary concepts especially when discussing technology integration as emphasized in the literature (Mishra & Koehler, 2006, Windschitl & Sahl, 2002). Since the concepts of internal states (biological motivations) are not related to the present study, I have taken them out from the model. In the case of technology integration, contextual factors such as school organization, curriculum, and students play an important role (Kozma, 2003). These and other factors included under responsive environment. Those concepts and other two concepts, student outcomes and teacher outcomes, were added to the model since the literature review on technology integration (see chapter I) warrants this. The conceptual framework was used as a working model for the current study during research design and data collection. It does not specifically map out the necessary relationships among some concepts. During the data analysis stage, a more complex and detailed framework was created building on this initial conceptual framework (see chapter V).

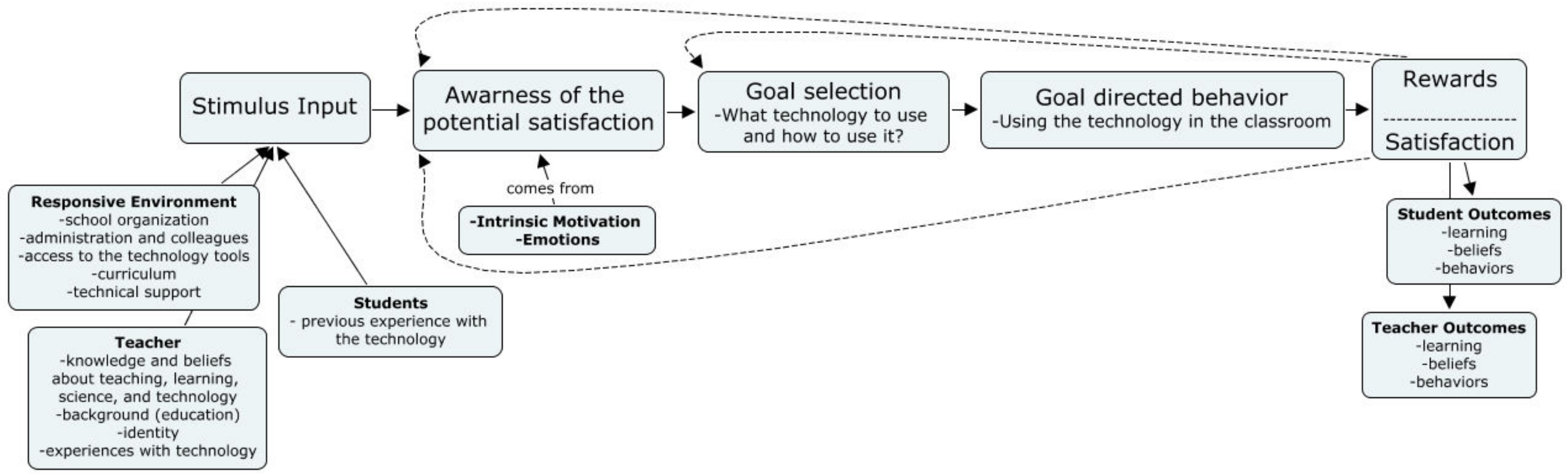

Figure 2. Conceptual framework of the study

The Role of Beliefs in Technology Integration

Research on beliefs has a long history. However, as Pajares (1992) stated it is a "messy" and complex concept to study. The discussion among the definition of beliefs, attitudes, knowledge has still been going on. Some researchers use the terms attitudes and beliefs interchangeably, others argue that beliefs and knowledge are separate constructs, and others identify beliefs and knowledge are inseparable. Based on their descriptions, researchers have built quantitative or qualitative measurement tools to assess teachers' knowledge, beliefs, and attitudes. In this study, attitudes and beliefs are considered as two different constructs that are components of belief systems. Knowledge is also a component of belief systems and generally knowledge and beliefs are intertwined.

Pajares (1992) stated that "beliefs are the best indicators of the decisions individual make throughout their lives" (p. 307). Nespor (1987) stated that beliefs have four features: existential presumption, alternativity, affective and evaluative aspects, and episodic structure. According to Nespor, beliefs relied on previous presumption, include representations of alternative realities that are different than the present reality, rely on affective and evaluative components, and episodically stored while organized based on personal experiences and events. Nespor pointed out that belief systems include "propositions, concepts, [and] arguments" (p. 321) and they are not fully bounded systems.

In the literature, teachers' beliefs have been shown to be closely related to their classroom practices (Kagan, 1992; Nespor, 1987; Pajares, 1992; Prawat, 1992). Kagan (1992) pointed out that teachers' beliefs are associated with teaching style. For example, in a study with ten chemistry teachers, Roehrig and Luft (2004) investigated teachers' beliefs as a factor that influences their inquiry-based teaching practices. The authors found that teachers who implemented inquiry-based practices held some constructivist beliefs, whereas teachers who used traditional classroom practices were found to have more teacher-centered beliefs. This study shows the connection between beliefs and practices. On the other hand, in a longitudinal study with 166 beginning science teachers, Simmon, Emory, Carter, Coker, Finnegan, Crockett et al. (1999) found that even though teachers possessed some student-centered beliefs their classroom practices they tended toward teacher-centered strategies. Clearly beliefs are only one factor that influences teachers' classroom practices. It should also be noted that in many studies, such as Roehrig and Luft (2004), an intervention was used to influence both beliefs and practices so comparisons across studies should take care of the context of the study.

Kagan (1992) defined teachers' beliefs as stable and resistant to change. This is particularly true in the case of experienced teachers. Luft (2001) conducted a study to find the effects of an inquiry focused in-service program on both beginning and experienced secondary science teachers' beliefs and practices. During the 18-month program, six beginning teachers and eight experienced teachers participated in various inquiry activities. Classroom observations and interviews were conducted to collect data. The analysis of the data showed that the program changed beginning teachers' beliefs more than their practices; however, it changed only the practices of experienced teachers. Since experienced teachers have established belief systems it was challenging to change their 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). Czerniak, Lumpe, Haney, and Beck (1999) investigated how K-12 teachers' beliefs impacted their intent to use educational technology. The authors applied the Theory of Planned Behavior (Ajzen & Madden, 1986) to develop a questionnaire to examine science teachers' attitudes, subjective norm, and perceived behavioral control. According to the theory, attitudes, subjective norm, and perceived behavioral control influence a person's intent to engage in a behavior and these three elements are influenced by a person's beliefs. About 250 teachers filled out the questionnaire. The authors found that most teachers expressed that the use of technology in the classroom enhance student learning, increase student motivation and interest in science, allow students to gain up-to-date science knowledge, and provide various instructional strategies to meet all students' needs. Teachers also believed that integrating technology into teaching was both "desirable and needed" (p. 76). However, only half of the teachers reported using technology in their instruction. Teachers stated that there were not enough support structures (e.g., available tools, on-going professional development, and time) available to help them achieve technology integration. Regression analyses that were run to find the relationship between teachers' beliefs and practices showed that teachers' intentions influenced their implementation of educational technology use in the classroom. Furthermore, the authors found that perceived behavioral control and subjective norm provides strong influences on the intent to implement educational technology while attitude toward behavior did not have a significant influence on intention.

Windschitl and Sahl (2002) also conducted a study to show that teachers' use of educational technology was influenced by their beliefs. Teachers' beliefs about students, good teaching, and the role of the technology on student learning were found to mediate the way that teachers integrate technology into classroom instruction. The condition of having access to the technology was found to be "neither a necessary nor a sufficient condition to affect pedagogy" (p. 201) which was also suggested by Czerniak et al. (1999) study. The authors worked with three teachers in a school that started a laptop program. Each teacher and student in the school was required to have a laptop computer. After teachers and students received their computers, the authors started to observe teachers' practices and interviewed them to catch their beliefs. They followed the teachers for two years. Of the three teachers, two of them were found to change their practices toward more constructivist practices. The third teacher did not become more constructivist in her practices since she did not have dissatisfaction with her teacher-centered practices; thus, devalued the effects of technology on student learning.

Some studies have explored how the use of technology can change teachers' beliefs. Levin and Wadmany (2006) conducted a three-year long study with six teachers to measure the change in teachers' practices and beliefs about teaching, learning, and technology when they attempt to integrate technology into their teaching. The researchers provided technological equipment and ongoing support for the teachers. Findings showed that during the three-year period changes occurred in all six teachers' beliefs and practices. While five of the six teachers expressed behaviorist beliefs at the beginning of the study, at the end of the study they hold less behaviorist beliefs. They were found to use less direct instruction after the study. A similar substantive change in teachers' beliefs and practices were found in Apple Classrooms of Tomorrow (ACOT) study (Sandholtz, Ringstaff, & Dwyer, 1997). The findings of ACOT study showed that changing beliefs is a long and complicated process. It was found that shift in ACOT 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 practices from teacher-centered to more student-centered and technology rich classroom practices. Considering Deci's (1975) model of motivation, rewards provide feedback to the person's intrinsic motivation which affects the goal selection. Thus, seeing the positive effect of technology on student learning may lead the teacher to use the tool.

Other studies found teachers' beliefs to be a barrier to integrating technology into classroom instruction. Brickner (1995) categorized beliefs as second order barriers meaning intrinsic factors that affect teachers' technology integration efforts (External factors are the first order barriers). Ertmer, Addison, Ross, and Woods (1999) designed a study following Brickner's categorization of first and second order barriers. The authors found that teachers respond to the first order barriers based on their beliefs about effective classroom practices. Having unfavorable beliefs about technology seems to be a reason why many teachers are struggle with integrating technology into the classroom instruction.

The Role of Knowledge in Technology Integration

In his groundbreaking article on teacher knowledge, Lee Shulman (1986) argued that there are seven knowledge bases that teachers need to have in order to teach their content area effectively. These knowledge bases are: content knowledge, general pedagogical knowledge, curriculum knowledge, pedagogical content knowledge, knowledge of learners and their characteristics, knowledge of educational contexts, and knowledge of educational ends, purposes, and values and their philosophical and historical grounds. For Shulman, among all of these knowledge bases, pedagogical content knowledge plays the most important role.

> [Pedagogical content knowledge] represents the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented and adapted to the diverse interests and abilities of learners, and presented for instruction (Shulman, 1986, p. 8).

As Shulman emphasized having pedagogical content knowledge 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 the students while considering the "conceptions and preconceptions" that students bring to the classroom (1986, p. 9). Shulman argues that PCK is a transformation of other types of knowledge (subject matter knowledge, pedagogical knowledge, and knowledge of context).

Following Shuman's work, Grossman (1990) provided a more detailed model of PCK in her book, *Making of a Teacher.* The author suggests that there are four components of PCK: knowledge and beliefs about the purposes and goals for teaching a subject, knowledge about students' understanding, conceptions, and misconceptions of particular topics, knowledge about curriculum, and knowledge about instructional strategies (see Figure 3). The first component – knowledge and beliefs about the purposes for teaching – represents teachers' goals for teaching their subject area. In the case of science teaching, a science teacher's goal might help students to improve their science literacy or the goal might be to help students to make connections between school science and their everyday life experiences. The second component – knowledge about students' understanding, conceptions, and misconceptions – reflects teachers' understanding of students' learning about a particular topic. Teachers need to know what students already know, what misconceptions they bring, and what might be hard for them to understand. The third component –curricula knowledge – includes knowledge about the curriculum materials. For example, science teachers should know which activities and materials should be used in teaching a particular topic. This component also includes teachers' knowledge about what students have already learned in previous years – vertical curriculum (Grossman, 1990). Finally, the fourth component – knowledge about instructional strategies and representations – includes teachers' use of appropriate experiments, explanations, activities that are effective to teach a particular topic. The following diagram shows Grossman's conceptualization of PCK and factors that influence on nature and development of PCK. According to Grossman, previous experiences as students, subject matter knowledge, teacher education, previous teaching experiences, and school context have impact on teachers' PCK.

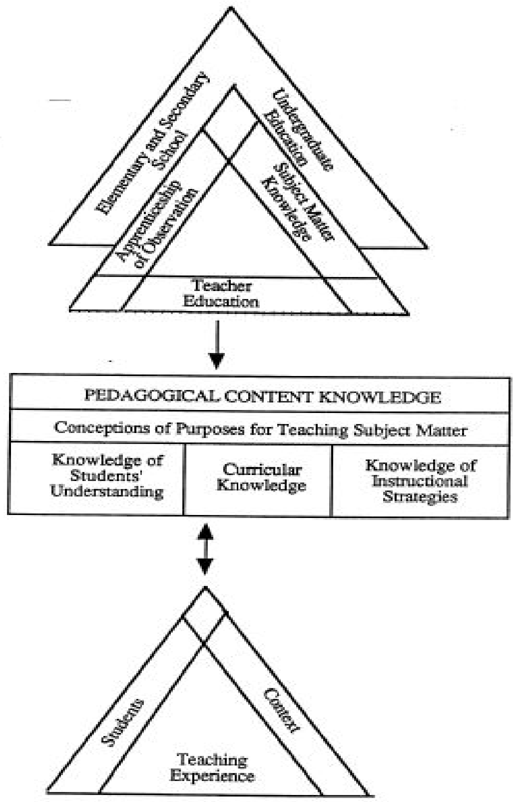

Figure 3. Grossman's (1990) conceptualization of PCK

Following Grossman's conceptualization of PCK, Magnusson, Krajcik, and Borko (1999) further conceptualized PCK for science teachers. The authors argue that PCK includes both knowledge and beliefs and it is a transformation of subject matter knowledge and beliefs, knowledge and beliefs about context, and pedagogical knowledge and beliefs. In their definition of PCK, Magnusson et al. (1999) included the following components: (1) orientations toward science teaching, (2) knowledge and beliefs about science curriculum, (3) knowledge and beliefs about student understanding of specific science topics, (4) knowledge and beliefs about assessment in science, and (5) knowledge and beliefs about instructional strategies for teaching science. Orientations toward science teaching component have a central role in the model. This category of PCK influence on other components of PCK and it is also influenced by them. “An orientation represents a general way of viewing or conceptualizing science teaching” (Magnusson et al., 1999, p. 97). This component of PCK guides teachers in giving decisions about instruction. Magnusson et al. identified nine different orientations toward science teaching: (1) process, (2) academic rigor, (3) didactic, (4) conceptual change, (5) activity driven, (6) discovery, (7) project-based science, (8) inquiry, and (9) guided inquiry. A teacher with inquiry orientation teaches a science topic different than a teacher with didactic orientation.

Another component that Magnusson et al. (1999) included in their conceptualization of PCK is the knowledge and beliefs about assessment in science. This category of PCK refers to teachers’ knowledge and beliefs about what to assess and what methods to use to assess student learning. This component of PCK does not occur in Grossman’s or Shulman’s model of PCK. Tamir (1988) originally proposed this knowledge base as a component of PCK while he named PCK as “subject matter specific pedagogical knowledge.” In addition to knowledge of assessment or evaluation, in his model, Tamir also included the following components: students, curriculum, and instruction. Each component includes two elements: knowledge (knowing that) and skills (knowing how). While knowledge refers to “propositional knowledge”, skills refer to “procedural knowledge” (Tamir, 1988, p. 100). For example, a teacher needs to have knowledge about student misconceptions about a particular science topic, he also needs to have skills to catch or diagnose where students might have difficulties in understanding a particular science topic.

Carlesen (1999) also reframed PCK for science teachers; in his model of PCK he includes understanding of students' common misconceptions, specific science curricula, topic-specific instructional strategies, and purposes for science teaching. Comparing to the other researchers (e.g., Magnusson et al., 1999), Carlesen paid more attention to the component "understanding of student misconceptions" in his model of PCK. Like others (e.g., Grossman, 1990) he points out that contextual factors have a critical role in developing PCK.

In the last 20 years, since Shulman (1986) coined the term PCK, educational researchers conceptualized PCK in different ways while all attempted to show the influence of PCK on teacher practices. They identified PCK from different perspectives. Most researchers follow Shulman's argument which is PCK is a blending or transformation of other knowledge bases and design their studies based on this assumption (e.g., Grossman, 1990). Others, on the other hand, characterized PCK by taking apart its components and then simply sum up those to define PCK of a teacher (Lee & Luft, 2008). It is important to note that, simply having the knowledge bases does not lead a teacher to transform that knowledge into practice. Abell (2008) suggests that quality of PCK is more important than quantity of PCK.

Gess-Newsome (1999) proposed two models of PCK that might explain Abell's (2008) point of quality of PCK vs. quantity of PCK. She suggests that there are two models of PCK: the integrative and transformative model. The author uses an analogy to explain the models: a mixture versus a compound. In the integrative model, the teacher integrates three knowledge bases, subject-matter, pedagogy, and context, and they exist as separate knowledge domains or elements in a mixture. In the transformative model, the teacher transforms the three knowledge bases into a unique form. This can be described as forming a compound from original ingredients. Thus, in transformative model, the three knowledge bases combined and form PCK. In the transformative model of PCK, the teacher blends all the components of PCK and transforms this new knowledge into practice.

Since several studies have shown that most beginning teachers do not have adequate PCK (Lee, Brown, Luft, and Roehrig, 2007), one might think that integrative model is more appropriate for beginning teachers while the transformative model of PCK represents experienced teachers' PCK. However, having years of teaching experience does not always an indicator of having transformative model of PCK or well-developed PCK (Guzey, 2007). Lee and Luft (2008) investigated the PCK of four veteran science teachers who had more than 10 years of teaching experience and more than three years of mentoring experience. The analysis of PCK of experienced science teachers showed that there are seven components of PCK: science, goals, students, curriculum organization, assessment, teaching, and resources. The authors propose these components as elements of PCK since all teachers have them while they were found to conceptualize PCK differently. However, having all these components does not always refer that the teacher can employ all these individual parts and transfer them into his teaching. As many authors (e.g., Shulman, 1986) argued PCK is blending of all the individual components which represent Gess-Newsome's transformative model of PCK. Magnusson et al. (1999) argue that there is a complex relationship among the components of PCK and "lack of coherence between the components can be problematic in … [forming and] using the PCK" (p. 115).

Effective science teachers should develop PCK for all the topics that they teach. The review of the literature shows that most researchers who investigate PCK mostly prefer to study topic specific PCK of teachers (e.g., Magnusson et al., 1999). For example, in a study, Henze, van Driel, and Verloop (2008) investigated nine experienced science teachers' development of PCK of a specific topic – Models of the solar system and the universe. The authors included four elements of PCK: knowledge about instructional strategies; knowledge about students' understanding; knowledge about assessment of students; and knowledge about goals and objectives of the topic in the curriculum. The authors argued that teachers have two types of PCK of "Model of the solar system and the universe" based on what knowledge base teachers possessed. In Type A PCK, teachers have PCK knowledge that focus on model content. This group of teachers used models to explain their content and assess student understanding on models. In Type B PCK, teachers have PCK knowledge that focus on model content, model production, and thinking about the nature of models. This group of teachers more focused on the student motivation to understand the models and student thinking and interpretation of models. It seems differences in Type A and Type B can be an explanation for teachers' different instructional strategies. However, since this study is heavily focus on models, replication of this study in different topics may seem to be necessary. Investigating teachers topic specific PCK can provide insight into relationship between teachers' instructional practices and topic specific PCK; however, making generalizations or putting teachers into categories based on their one topic specific PCK seems ineffective.

Several studies also have investigated the influence of other knowledge bases on the nature and development of PCK (Gess-Newsome, 1999). Most of these studies focus on the influence of content or subject-matter knowledge since Shulman (1986) suggested the central role of them on nature of PCK. Rollnick, Bennett, Rhemtula, Dharsey, and Ndlovu (2008) investigated the influence of subject matter knowledge on PCK through conducting two case studies with four chemistry teachers. In the first case study, two teachers taught about mole and in the other case study two teachers taught chemical equilibrium. All four teachers were interviewed before and after they were observed and classroom artifacts were collected. Through analyzing the data, the authors built a model of PCK. They argued that PCK is an "amalgamation" of subject matter knowledge with other knowledge domains (knowledge of students and general pedagogical knowledge) and representations, curricular saliency, assessment, and topic specific instructional strategies are the "visible features" of PCK in the classroom (p. 1880). Thus, subject matter knowledge plays a very important role in using effective representations, choosing useful instructional strategies and assessment techniques, and giving effective decisions about how a particular topic can be placed in the curriculum (Gess-Newsome, 1999).

This review of research on PCK suggests that in most studies, researchers have investigated the components of the PCK and failed to have agreed on the components on those knowledge bases and the complex relationship among the components. Since Shulman's conceptualization of PCK, researchers have conducted many studies to further explore the components and development of PCK. Over the 20 years, various studies have conducted with pre-service and in-service teachers. In her review of research on PCK, Abell (2007) concluded that the research on PCK is "less cohesive" than research on other teacher knowledge domains. The author also emphasized the lack of agreement on the components of the PCK and criticized the misapplication of researchers' own conceptualizations onto their research.

The review of research also shows that while some researchers (e.g., Grossman, 1990) see beliefs as an important component of teacher knowledge domains, others (e.g., Tamir, 1988) do not consider beliefs as an element of teacher domain. "Teachers' beliefs about teaching and learning are related to how they think about teaching, how they learn from their experiences, and how they conduct themselves in classrooms (Grossman, Wilson, & Shulman, 1989). Grossman and Magnusson et al. (1999) indicates that PCK of science teachers includes both knowledge and beliefs.

Technology, Pedagogy, and Content Knowledge (TPACK)

The concept of technology, pedagogy and content knowledge (TPACK) (previously known as technological pedagogical content knowledge, TPCK) (Mishra & Koehler, 2006) has recently emerged in the education literature. Researchers in the area of educational technology have conducted various studies to understand the nature and development of TPACK. Mishra and Koehler conceptualized TPACK as a framework for teachers to integrate technology into their teaching. They argue that TPACK builds on Shulman's conceptualization of PCK. According to the authors, TPACK is a combination of knowledge of content, pedagogy, and knowledge of technology (Koehler & Mishra, 2008) (see figure 4).

> …TPACK is the basis of effective teaching with technology and requires an understanding of the representation of concepts using technologies; pedagogies; pedagogical techniques that use technologies in constructive ways to teach content; knowledge of what makes concepts difficult or easy to learn and how technology can help redress some of the problems that students face; knowledge of students' prior knowledge and theories of epistemology; and knowledge of how technologies can be used to build on existing knowledge and to develop new epistemologies and old ones (p. 18).

Koehler and Mishra (2008) point out that there is a complex relationship among the components of TPACK and emphasize that teachers need to establish a dynamic equilibrium between each component.

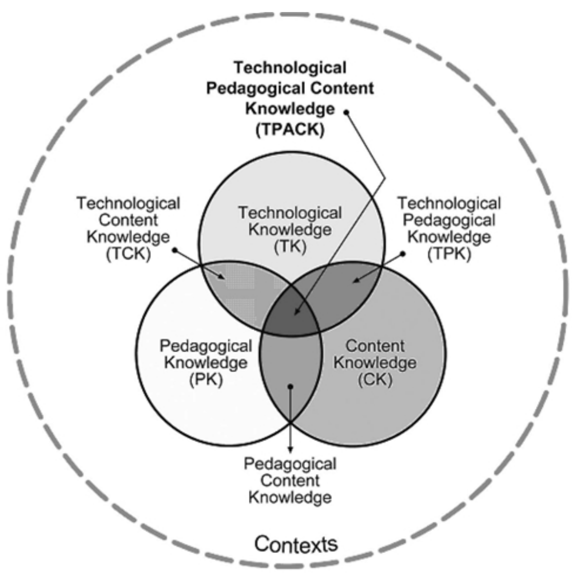

Figure 4. Koehler & Mishra's (2008) TPACK framework

Considering science teachers' TPACK, 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). There are various technologies available for teachers to use in their teaching. The tools included probe ware, calculators, laptop computers, Web 2.0 (More specific information about these tools will be presented in the next section of this chapter). For science teachers, it is critical to choose the appropriate tool to teach particular science content. McCrory states that all the four knowledge bases emphasized above work together when a teacher uses technology in classroom instruction.

Regarding the development of TPACK, practicing the use of old and new educational technology tools and context plays an important role. According to McCrory (2008) TPACK is developed "as a response to specific students and contexts (p. 203). In a study with pre-service mathematics and science teachers, Niess (2005) focused on the development of teachers' TPACK. Teachers participated in a year-long graduate level teacher preparation program that focused on technology integration. In the program teachers learned about various technologies, pedagogical issues related to these technologies, and strategies to teaching with those technologies. From 22 teachers, while 14 of them were found to develop their TPACK, the remaining was found not to have well-developed TPACK at the end of the program. Niess suggested that the previous experiences with technology, conception of teaching and learning science with technology, knowledge of instructional strategies and curricular materials, knowledge of student learning, and cooperating teacher's knowledge and beliefs about technology have impact on teachers' development of TPACK.

Guzey and Roehrig (2009) also investigated science teachers' development of TPACK. Thirteen secondary science teachers participated in a year-long professional development program on technology integration. In a two-week long summer workshop, teachers learned about several technology tools such as probe ware and CMap tools. During the subsequent school year, they participated in an online learning environment. Four teachers were purposefully selected to track their development of TPACK. The program was found to have positive impacts to varying degrees on teachers' development of TPACK. In addition, contextual factors and teachers' pedagogical reasoning were found to affect teachers' ability to enact in their classrooms what they learned in the program.

In reviewing the literature on TPACK it is clear that there are only a few studies conducted on nature and development of secondary science teachers' TPACK. As in the case of PCK, there has not been an agreement among the researchers on the elements of TPACK. While Mishra and Koehler (2006) and McCrory (2008) mostly focus on the interplay of TPACK with other knowledge bases, they do not specifically separate TPACK into parts. Niess (2005), on the other hand, employed Grossman's conceptualization of PCK to frame TPACK. Her model of TPACK has four elements: 1) a conception of what it means to teach a particular topic using technology, 2) knowledge of instructional strategies and representations to teach particular topics with technology, 3) knowledge of student understanding and learning with technology, 4) knowledge of curriculum and curricular materials that include technology. In this study, Niess's conceptualization of TPACK will be used; however, Grossman's (1990) and Magnusson et al.'s (1999) addition of beliefs to the model of PCK will be applied as knowledge and beliefs are generally inseparable concepts when considering classroom practice.

In the final section of this chapter, I explore the educational technology tools that are commonly used in science classrooms and meaningful ways of using those tools in classroom instruction.

Research-based Use of Technology in the Science Classroom

Computers, probe ware, data collection and analysis software, multimedia/hypermedia, and interactive white boards are educational technology tools that are commonly used in science classrooms. These tools can help students actively engage in the process of acquisition of scientific knowledge and development of the nature of science and inquiry when teachers use them appropriately in classroom instruction.

In 1998, Becker (2001) conducted a nationwide survey of 4100 teachers to find how teachers use educational technology in their classrooms. Only 1/6 of the science teachers reported that their students use computers weekly bases in class time–more than 20 occasions in about 30-week class. While some of these teachers were grouped as constructivist teachers, those who allowed students to use technology to collect and analyze data, write research reports, and present their findings; others were grouped as transmission teachers who relied on traditional practices, only allowing students to complete drill-and-practice activities with the technology.

Unfortunately, teachers were found to mostly use computers for administrative tasks and to support their teacher-directed practices (Becker & Ravitz, 2001). The use of computers to take attendance or using power-point presentations to deliver content knowledge is still very common among teachers. Teachers tend to use educational technology to facilitate their teacher-centered practices where students are treated as passive learners. Using educational technology as a supplement in traditional, didactic instruction does not help students to learn new information meaningfully. The impact of technology on student learning depends on the ways the technology is being integrated into the classroom instruction. According to Jonassen, Howland, Moore, & Marra (2003), classroom instruction should include five characteristics of learning: active, constructive, authentic, intentional, and cooperative. Jonassen et al. (2003) defined these characteristics as attributes of meaningful learning and stated that “learning activities that represent a combination of these characteristics result in even more meaningful learning than the individual characteristics would in isolation” (p. 9). In science classrooms, inquiry-based teaching support meaningful learning. In an inquiry activity students actively engage in their learning while constructing knowledge or making meaning through interacting with others in authentic activities. While inquiry takes many forms in science classrooms, inquiry occurs when students engage in scientifically-oriented questions, collect and analyze data, formulate explanations, connect explanations to existing science knowledge, and communicate with others to justify explanations (NRC, 2000).

Students can use various educational technologies in an inquiry-based instruction. When educational technology tools are used appropriately and effectively in inquiry, students can perform investigations as scientists do in the real world, actively engage in their knowledge construction, and improve their thinking and problem solving skills. For example, Hug, Krajcik, and Marx (2005) investigated student learning and engagement in a middle school project-based science curriculum that included learning technologies. During the eight-week long curriculum, students conducted investigations to answer the following research question: “Can good friends make me sick?” Students used various technology tools such as Artemis (an online web-based learning environment) and Thinking Tags (a digital manipulative). While Artemis allowed students to conduct research on diseases, students investigated the concepts of immunity, incubation time, and source of the disease using the Thinking Tag. The authors found that the Thinking Tags and Artemis provided opportunities for students to ask scientific questions, design simple experiments, collect and analyze data, and share their findings. Students were found to engage in meaningful ways with the science content through the use of these tools.

Songer and Lee (2002) investigated six urban science teachers’ implementation of a technology-rich inquiry program on the topic of weather. Each teacher implemented the 8-week middle school weather curriculum and pre-post data was collected on students’ knowledge of the science content and inquiry. The authors found that teacher’s instruction and use of the technology tools were related to differences in student test results. While some teachers were able to enact all the activities effectively others could not implement them since they faced with challenges such as inadequate computer lab space and lack of time to enact inquiry. The findings showed that learning results are depended heavily on teachers’ practices and use of the technology tools included in the curriculum

In the following paragraphs, I describe several specific educational technology tools that are supportive active learning in science as inquiry classrooms.

Probe ware

Through the use of probe ware (also known as lab probes), students in science classrooms can collect "real-time" data and display them in graph form simultaneously. Probe ware includes a probe, an interface, a microprocessor (e.g., Palm, graphing calculator, and computer) and data analysis software. Probes measure physical quantities (e.g., temperature, motion, pressure, Ph) in a physical system and change these quantities into electrical quantities to allow the interface to transfer the information into microprocessor. Data analysis software displays the data in graphical form. Real-time data graphing provides students with immediate feedback and develops students' data interpretation skills (Friedrichsen, Zembal-Saul, Munford, & Tsur, 2001; Mokros & Tinker, 1987).

In the last decade, a wide variety of probe ware has become available in science classrooms (e.g., Vernier and Pasco). In addition to real-time data graphing feature, the latest versions of probe ware have the capability of digital video analysis. This new advance allows students to capture video and make digital video analysis. Particularly, in physics classes the use of video analysis help students increase their understanding of the complex science concepts such as Newton's Laws and kinematics (Bryan, 2006).

Simulations

Science teachers commonly use simulations and animations in their classrooms (Lehman, 1994). Computer simulations allow students to visualize various phenomena and content that are otherwise difficult to understand. Many simulations allow students manipulate elements within the model or simulated experiment. Manipulating elements and seeing different visualizations enhance students' understanding about the phenomena that they are working on and also improves their reasoning and science process skills (Huppert & Lomask, 2002). Some products are also designed to immerse students in problem-solving scenarios where they need to make decisions and apply the knowledge that they have learned. Akpan and Andre (2000) found that “the flexibility of these kinds of learning environments makes learning right and wrong answers less important than learning to solve problems and make decisions. Simulations promote learning about what-ifs and possibilities, not about certainties” (p. 18). In addition, simulations also allow students to do experiments that are time consuming and impossible or dangerous to perform in the classrooms (Steed, 1992). Thus, virtual labs, for example, are commonly employed in science classrooms (e.g., http://smartscience.net).

Digital Images and Movies

In science classrooms, teachers use various digital images and videos to enhance scientific inquiry and students’ understanding of science concepts. Images, clips, and movies help students to understand complex and abstract concepts (Linn, 2003). Students reinforce their understanding when they see the objects that they are not otherwise able to see. For example, in earth science classes, students can develop better understanding of plate tectonics, volcanoes, hot spot formation, and caldera formation after seeing images and watching short clips or movies of these concepts. Numerous reliable websites provide teachers science with related images and movies. For example, teachers can easily find short videos on YouTube, Vimeo, vSocial, DailyMotion, and OurMedia (Bell & Park, 2008). Teachers can develop and refine existing web-based images and movies using video editing software such as iMovie for Macs and Windows MovieMaker for PCs. Allowing students to make their own digital movies is also necessary since it enhances students' understanding of science and development of scientific skills (Yerrick, Ross, & Molebash, 2003).

Modeling Software

Science teachers use various instructional software tools in their teaching. One instructional software program used in science classrooms is *Logo*. Logo is a programming language that allows students to design and create models (Colella, Klopfer, & Resnick, 2001). The latest Logo software version, StarLogo, provides many activities for students to enhance their understanding of dynamic systems and also abstract concepts such as ecology, evolution, and motion. Students improve their problem solving skills through writing their own models with StarLogo (Colella, Klopfer, & Resnick, 2001).

Model-It is another software package which allows students to create models of complex science systems (Metcalf-Jackson, Krajcik, & Soloway, 2000). While using this software, students plan, build, and test their models depending on their specific research questions. In their models, students can include multiple variables and test the relationships among these variables. For example, if students work on water quality they might create variables such as streams, factories, trees, and people and explain the relationship among these variables and describe how they affect water quality through creating dynamic models (Novak & Krajcik, 2006). The Model-It software also fosters collaboration among students (Metcalf-Jackson, Krajcik, & Soloway, 2000). Students work together, choose variables, design their models, discuss their models with their peers, and evaluate on their models.

Concept Mapping Software

Concept mapping software programs (e.g., Inspiration, CMap, and PicoMap) are tools that allow students to create concept maps electronically. A concept map is a graph that includes nodes that represent contents and lines that demonstrate relationships among nodes. Based on Ausebel's theory of meaningful learning, Novak and Godwin (1984) developed concept mapping as educational tools to "…tap into a learner's cognitive structure and to externalize, for both the learner and the teacher to see, what the learner already knows" (p. 40). The effectiveness of concept mapping on student achievement has been reported in many studies (e.g., Horton, McConney, Gallo, Woods, Senn, & Hamelin, 1993). In science classrooms concept mapping has been widely used as an assessment tool (Ruiz-Primo & Shavelson, 1996). Teachers ask students to create concept maps before and after the instructions to track change, if any, in students' conceptual knowledge.

Digital Microscope

Science teachers use digital microscopes (also known as digital scopes or flex cams) to project images into a computer or a projection screen for viewing by all students. A digital microscope has various advantages over a typical microscope. Unlike typical microscopes, digital microscopes are capable of capturing high resolution images and video clips. Moreover, through using digital microscopes teachers and students can record real-time and time-lapse images or movies of dynamic systems that are too slow to observe (Bell & Bell, 2002). These images and movies can be stored in a hard disk or imported into analysis or editing software to edit and to combine with special effects such as voice-over audio. Research demonstrates that digital microscopes enhance collaboration and student engagement (Dickerson & Kubasko, 2007) and allow students to actively engage in their science learning process (Bell & Bell, 2002).

Online Discussions and Forums

Electronic discussions and forums enable students to join discussions that focus on course content. Science teachers can design online discussion forums in their own course websites and they post daily or weekly discussions of course content. Students answer questions that are posted by the teacher and also reply to their peers' responses. Online discussions allow students to reflect on their learning while they are communicating and collaborating among their peers (Swan, 2001). In an online discussion environment, the teacher should be a facilitator who provides support and guidance for students to successfully communicate in the environment and who create questions and activities that encourage students to participate (Markel, 2001).

Student/Classroom Response Systems

Student or classroom response systems, also known as "clickers", help teachers create interactive classroom environments (Fies & Marshall, 2006). Many science teachers use clickers in a way to get instant information about student understanding and learning. In general, at the end of a class or a unit the teacher asks multiple choice, true-false, or yes-no questions to students and each student then submit his/her response using the clicker. The computer gathers students' answers and the data analysis software automatically reviews the responses. The teacher then displays the data and shows the results to the students. Clickers allow science teachers to see student feedback in real-time and to address or focus on the areas that students have difficulty understanding.

Various studies have demonstrated that clickers increase students' engagement (e.g., Deal, 2007).

The Web

The Web can be an invaluable tool for science teachers to foster student inquiry. Teachers can go online and reach numerous data and information to use in their inquiry practices. In addition, teachers can use the Web to access real-world data or join ongoing authentic science experiences. For example, the GLOBE environmental science program that makes use of a number of technologies allows students to do scientific investigations for studying the local environment (www.globe.gov). Web sites such as Google Earth (www.earthgoogle.com) and NASA (http://www.nasa.gov) also provide teachers valuable information that they can use in their instruction.

Interactive White Board

In recent years, interactive white boards (also known as SMART boards or active boards) have become common tools in science classrooms. An interactive white board is an electronic device that interfaces with a computer. The computer software enables teachers to add text, videos, pictures, audios, graphs, animation, games and jigsaw activities into their instruction in order to address all students' needs. Today, while many teachers use interactive white boards as replacements for traditional boards, only a few teachers effectively employ these tools in their classroom practices (Armstrong, Barnes, Sutherland, Curran, Mills, & Thompson, 2005; Hennessy, Deaney, Ruthven, & Winterbottom, 2007). Research demonstrates that the use of interactive white boards increase students' level of participation and engagement if only teachers would use them appropriately (Armstrong, Barnes, Sutherland, Curran, Mills, & Thompson, 2005).

Teachers should use student-directed teaching strategies while they are applying interactive white boards in their instruction.

In this chapter, I first explain Deci's (1975) model of intrinsic motivation and how I appropriated his conceptualization of human motivation and behavior in order to understand how science teachers' knowledge, beliefs, and identity influence their uses of technology. The missing pieces in Deci's model, knowledge and beliefs, are further discussed in this chapter. As previously emphasized, the conceptual framework of this study which guided the design and data collection phases was heavily built on Deci's model. In this chapter, effective ways of using variety of educational technology tools are also discussed. In the Methods chapter that follows, I explain the theoretical and methodological approaches that were used in this study.

Chapter III: Research Design and Methods

Designing a good qualitative study requires the researcher to choose appropriate approaches. In order to fully explain the design of the study, in the next couple paragraphs, I present my epistemological views, research paradigms that gave direction to the study, the theoretical perspectives that were used, and the methodology and methods that were applied. It is important to note that as Patton (2002) argues there has not been a consensus among the qualitative researchers on how to classify a qualitative research. Qualitative researchers classified theories, paradigms, and methodologies differently and generally the boundaries among them are blurry. While Patton's (2002) organization includes 16 theoretical and philosophical perspectives, Denzin and Lincoln (2000) categorize seven paradigms/theories, on the other hand, Crotty (1998) classifies five main theoretical perspectives. For example, Patton's list is longer than Crotty's list since Patton categorizes some of the taxonomies such as ethnography and phenomenology as a theoretical perspective while Crotty organizes them as a research methodology. Denzin and Lincoln, on the other hand, include Marxist, ethnic, and cultural studies in their list in addition to the ones that are suggested by Patton and Crotty (i.e., positivist/post positivist, constructivist, feminist, queer theory). Patton (2002) advises that the qualitative researcher should make decisions on the framework of the study based on what he wants to study. Instead of simply trying to choose a theory, paradigm, or methodology to label the study, the researcher should go further to find the one that fits the study and to follow the assumptions and principles of that perspective during the design, data collection, and data analysis of the research process.

Epistemology

It is well documented that an educational researcher's epistemological positioning affects the research study design and data analysis. As Daly (2007) argues "epistemology is the source that ultimately gives direction to the inquiry" (p. 22) since epistemology is "a way of understanding and explaining how we know what we know" (Crotty, 1998, p. 3). Many researchers argue that there are two types of epistemology. The first epistemological position is objectivist. According to the objectivist position, "there is a concrete, knowable reality that exists independently of our thought process" (Daly, 2007, p. 23) and science aims to explain this reality. On the other hand, subjectivist position upholds a belief that "there can be no separation between the knower and the known because all knowledge is constructed through a meaning making process in the mind of the knower" (Daly, 2007, p. 23). While most researchers argue that a researcher can only hold either positivist or objectivist position, few researchers (e.g., Crotty, 1998; Miles & Huberman, 1994) argue that these two positions are incompatible and they fall into a continuum. While the former group states that the qualitative research fall into the category of subjectivist epistemology and quantitative research represents objectivist epistemology the latter group points out that both qualitative and quantitative approaches can be placed somewhere in the continuum. Daly (2007) points out that a qualitative researcher might in fact hold objectivist assumptions. For example, the use of the strategy of inter-rater reliability in qualitative research shows that the researcher holds objectivists assumptions since the demand for arriving a "correct" or "accurate interpretation of data" (Daly, 2007, p. 26).

In this qualitative study, I used various objectivist practices to analyze the data while I am mainly holding subjectivist epistemological view. The codes that emerged from the data were counted to find the patterns or frequencies of the codes. The codes were mapped out following the approaches suggested by Miles and Huberman (1994) to determine relationships between codes.

Paradigm

I agree with social constructionists/interpretivists who believe that "all reality is constructed reality" (Daly, 2007, p. 31) and knowledge is socially and historically constructed. Social constructionists believe that there are multiple realities and they tend to understand it from their own perspectives. Thus they argue that reality or meaning is not discovered, but constructed by people (Crotty, 1998). Values, language, and culture impact on the individual's representation of the multiple realities.

In the social construction paradigm, the researcher conducts qualitative studies through collecting interview or observation data. Thick descriptions of the participants are written to demonstrate their experiences of a particular phenomenon. The researcher plays a very critical role in creating the meaning of the data since he co-constructs the meaning of the participant's experience of the research phenomena. When presenting the findings, the researcher does not just simply report the results as a positivist would. The researcher presents how categories emerged from the data and these categories are interpreted. As Daly (2007) suggests, the researcher should use the "interpretive voice" while presenting the findings of a study within social constructionists paradigm. Thus, the findings chapter of this study (chapter V) mainly includes information about how the codes are generated, how the model that represents the findings was created, and how I interpreted the data. The presence of my voice in this chapter aims to help the reader to understand that the chapter is not just simply reporting what teachers said and practiced in their classrooms.

Theory

This study largely utilized cognitive theory, in particular intrinsic motivation theory (Deci, 1975). In chapter II, intrinsic motivation theory was explained in detail. In this study, I tried to connect intrinsic motivation theory to the act of technology integration in science classrooms. To the best of my knowledge no one had previously attempted to investigate technology integration applying Deci's model of human motivation. The theory was used to create the conceptual framework of the study. Maxwell (2005) suggests that a qualitative researcher should be very careful when using an existing theory since he may rely heavily on it or not use it enough. I heavily used the theory; however, I was also critical of the theory and suggested extensions. Chapter II and VI includes my critiques of the theory and my explanations about how I adopted this theory to understand science teachers' technology integration into their classrooms.

Methodology

This study is qualitative in nature. An interpretive multi-case 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. Rather than just describing various factors that may influence science teachers' technology integration through presenting what teachers said and practiced, this study aims to create a model that conceptualizes how science teachers' beliefs, knowledge, and identity contribute to their technology enriched classroom practices through analysis and interpretation of the data.

Creswell (2007) defines case study research as "the study of an issue explored through one or more cases within a bounded system (i.e., a setting, a context)" (p. 73). In a case study, it is very critical that the case which can be described as a phenomenon or unit should be intrinsically bounded. According to Merriam (1998), in order for a case to be bounded, there should be end or limit in terms of the numbers of participants who could be interviewed and/or observed or the time that needed to be spend in data collection. The case should be specific.

In a case study, choosing which case(s) to study is very critical. There are various ways to select a case for a study. A case might be selected since it represents a large population or it is unique, exceptional, and unusual, or it is accessible. In this study, multiple cases were selected to investigate the phenomenon. The following paragraph describes how cases were selected for the study.

Participants

Teacher participants include a middle school earth science teacher, a middle school life science teacher, and a high school physics teacher. Benson taught earth science, Matt taught life science, and Jack taught physics. They were purposefully selected from 60 novice secondary science teachers who participated in a study during their first three 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, Fletcher, Kern, Roehrig, & Brown, in review). Based on interview and classroom observation data, it was determined that only three of the 60 teachers frequently used technology tools in their instruction; hence, they were selected for the present study. This study functions as an independent sub-study which is an extension of the Luft et al. investigation.

All three teachers, Benson, Matt, and Jeremy, participated in the same teacher preparation program. These teachers earned their teaching license while working towards their Master in Education degree. The present study mainly took place in the second semester of their third and fourth year teaching. During the time of the study, Matt was taking courses to complete his M.Ed.; on the other hand, Benson and Jeremy had both completed their M.Ed. All study participants were white, male, and in their early thirties. To preserve anonymity, pseudonyms are used throughout this document. Table 1 includes the demographic information about the teachers.

Table 1

Demographic Information about the Teachers

Teacher	Academic Degree	Teaching Subject
Benson	BS and MS Environmental Science, M.Ed.	8^{th} grade Earth Science
Matt	BS Integrated Science with a Life Science focus	8^{th} grade Life Science
Jeremy	BS Physics, M.Ed.	9^{th} grade Physics

Benson has a bachelor's and master's degree in Environmental Science. During the time of the study, he was teaching 8^{th} grade Earth Science in a public junior high school in a suburban area. In addition to teaching science, Benson was working as a technology coach in his school and district. He provided professional development activities for teachers in his district to help them actively and effectively use interactive white board in classroom instruction.

Matt has a bachelor's degree in Integrated Science with a Life Science focus. In his third teaching year, Matt started to teach in a private middle school in a well-developed suburban area. The school offered many opportunities for teachers and students such as small class sizes, extracurricular activities, excellent student-teacher ratios, and easy access to various technological tools. Matt was very pleased to be able to teach in this school.

Jeremy has a bachelor's degree in Physics. In his first three years of teaching, Jeremy taught Physics in a public high school in a suburban area. The following school year, Jeremy taught Physics in a small charter high school where he was the only science teacher.

Methods

Data Collection

Data collection for the present study occurred during spring 2008, summer 2008, and spring 2009. These data include classroom observations, classroom artifacts (e.g., student hand-outs), and interviews. Table 2 shows the timing of data collection.

Table 2

Timing of Data Collection

Participant	Spring 2008	Summer 2008	Spring 2009
Benson, Earth Science teacher	-Classroom observations (P) -Post observation interviews (S) -Classroom artifacts (S)	- Semi-structured Interview (P)	- Semi-structured Interview (2) (P)
Matt, Life Science teacher	-Classroom observations (P) -Post observation interviews (S) -Classroom artifacts (S)	- Semi-structured Interview (P)	- Semi-structured Interview (2) (P)
Jeremy, Physics teacher	-Classroom observations (P) -Post observation interviews (S) -Classroom artifacts (S)	- Semi-structured Interview (P)	- Semi-structured Interview (2) (P)

Note. P: primary data source, S: secondary data source

Classroom observations. Using an adaptation of The Oregon Teacher Observation Protocol (OTOP; Wainwright, Morrell, Flick, & Schepige, 2004) to guide classroom observations (see Appendix A for the observation protocol), I observed each teacher's classroom teaching 8 times during the spring of 2008. As a non-participant observer, I recorded extensive field notes that identified the type of classroom instruction, technology tools that were used in the instruction, and interaction patterns between the teacher and students.

During the classroom observations, I hoped to observe teachers' technology rich classroom practices. Thus, before scheduling any observations, I talked to the teachers about the goal of the classroom observations. Benson told me that I could observe any of his class as he used technology everyday in his teaching. Jeremy and Matt, on the other hand, suggested that I observed particular units. Jeremy suggested for me to observe him while he was teaching Newton's laws and electricity. Matt advised me to observe him during his organisms unit. However, later Matt also suggested for me to observe some of his classes on water quality. Table 3 shows the observed units.

Table 3

Observed Units

Teacher	Units	Number of class periods observed	Schedule
Benson	The atmosphere and climate The atmosphere and weather	8	Block /90 minutes
Matt	Living organisms Water quality	8	Regular/50 minutes
Jeremy	Newton's laws Electricity	8	Block/90 minutes

Classroom observations started with Matt. I first observed his living organisms unit. Later, I observed Benson while he was teaching weather, climate, and atmosphere. Afterwards, I observed Jeremy. To observe his unit on water quality, I went back to Matt's classroom at the end of the spring semester of 2008. Benson and Jeremy were teaching 90 minutes-long classes while Matt taught 50 minute-long classes. All participating teachers were observed at least eight times. There were more classroom observations conducted with Benson and Jeremy since their units were longer and they taught in block schedule. I did not attempt to observe Matt more because during the last classroom observations I found that I was seeing similar patterns, teaching techniques, and ways of using technology in his instruction.

Post-observation interviews. Depending on the availability of the teachers, I talked to teachers after the classroom observations. These informal discussions focused on lesson planning and possible ways to modify lessons. Matt had a preparation period after the class that I observed. Thus, several times he invited me to go to the faculty room to discuss the observed classroom instruction. Jeremy and Benson did not have enough time to talk to me right after the observed classes. During the short break time, we sometimes talked a little about the observed class if they were available. While I digitally recorded the conversations with Matt and me, I did only take notes while I was chatting with Jeremy and Benson since the conversations were short. Post-observation interviews were used as a secondary data source.

Interviews. In summer 2008, I conducted a semi-structured interview with each teacher to capture his beliefs about science teaching, learning, and technology. The vast majority of the interview questions were adapted from the teacher beliefs interview (Luft & Roehrig, 2007). The teacher beliefs interview 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 on the original questions. For example, the question in the teacher beliefs interview, "how do your students learn science best?" were modified as "how do your students learn science best in a technology-supported learning environment?" In addition to these modified questions, questions that provided information about teachers' school context, lesson planning strategies, science teaching strategies, previous experiences with technology, and their ideas about technology integration were asked during the interviews (see Appendix B).

It is important to note that, before I interviewed the participating teachers I did interview another teacher who teaches science and uses technology to pilot the interview protocol. Based on the feedback from the teacher I made small changes on some of the questions. The original protocol was found to include too many questions; thus, a couple of the questions were taken out. This pilot interview also helped me to identify some probing questions.

In early summer 2008, I interviewed the teachers. Each interview took 45-60 minutes. Interviews were digitally recorded and then transcribed. Since I observed each teacher many times and had various conversations about their school, students, and teaching they were very open and honest during the interviews. As I interviewed them, I also felt very comfortable since I spent long time in their classrooms. In addition to answering my questions, they offered informative details on their school environment and teaching philosophies.

In the early spring 2009, I requested a follow-up interview. I completed preliminary data analysis in early spring 2009 and found that I was unable to fully answer my research question with the existing data. I needed to learn more about teachers' beliefs about teaching and learning science with technology and their personal characteristics (i.e., who they are as technology using teachers). Thus, I designed a semi-structured follow-up interview. I followed Ruben and Ruben's (2005) suggestions while designing the interview protocol. As the authors suggest, the interview questions should allow getting depth and detail, vivid, rich, and nuanced responses. All the main questions, probes, and the follow up questions should be clear and understandable. Leading questions, yes-no questions, and complicated long questions should be avoided. Interview questions are included in the Appendix B.

While interviewing the teachers I followed particular strategies. As Seidman (2006) points out during the interviews the researcher should talk less and listen more, ask follow up questions but not interrupt the interviewee, listen carefully and ask probing questions for clarification and concrete details. Furthermore, the researcher should not give his own opinions regarding the phenomenon and should not show approval or disapproval of what the interviewee says. The researcher should prepare the interview protocol carefully and follow it cautiously (These strategies were also followed during the first semi-structured interview.)

Each follow-up interview took 60-90 minutes. As in the case of the first semi-structured interview, Jeremy's interview was the longest one and Matt's interview was the shortest one. I digitally recorded the interviews and then I transcribed them verbatim.

Classroom artifacts. From each classroom observation, I collected student worksheets and laboratory handouts. Those provided information about teachers' lesson plans and teaching strategies. They were used as a secondary data source.

Table 4 shows data collection instruments and the purpose of their use.

Table 4

Data Matrix

Research question	Data source	Purpose	Method
How do science teachers' beliefs, knowledge and identity contribute to their uses of technology?	Interview	To gather information about teachers' knowledge and beliefs about teaching, learning, science, and technology	Semi-structured interview protocol with opportunities for probing. Each interview took 45-60 minutes
	Classroom observations	To take field notes on teachers uses of technology in their instruction	Taking field notes while observing each teacher teaching two different units (8 classroom observation for each teacher)
	Classroom artifacts	To collect items that can provide information about lesson planning and implementation	Asking teachers for extra copies of student worksheet and laboratory hand-outs
	Post observation interview	To gain some information on teacher reflection on the observed class	Quick 5-10 minutes- long informal interviews (Based on the availability of the teacher)
	Interview (2)	To gather in depth information on teachers' beliefs about student learning and science teaching with technology and teachers' identity	Semi-structured interview protocol with opportunities for probing. Each interview took 60-90 minutes

Data Analysis

In this multi-case study design, an inductive approach was used to analyze the data, particularly the process of "constant comparative analysis" (Strauss & Corbin, 1990) was applied to create meaning from the complex data through developing categories and themes and to complete within and cross-case analysis (Miles & Huberman, 1994) (see figure 5 for the data analysis procedure). During the data analysis, I used NVivio 8.0, a qualitative analysis software application, to code interview transcripts and field notes from classroom observations. Using NVivo assisted me in managing my data set. I created an NVivo project with my data in early spring 2009. My first codes were basically *free nodes*. I then did the follow-up interview with the teachers in late spring 2009 and uploaded the transcripts into my NVivo project. I started to analyze my whole data set in late spring 2009.

The process of constant comparative analysis involves open coding, axial coding and selective coding. Open coding involves comparing, conceptualizing, and categorizing data. Each concept in a teacher's document coded for a category. A category is a label for a concept. As the concepts were coded, I compared them with the previous concepts that were coded in the same category to find common patterns as well as differences in the data (Glaser, 1965). That process also helped me to find sub-categories. While naming a sub-category or a category I tried to use emic codes (Maxwell, 2005) that are direct quotations of teachers. I believe that this process helped me to represent the data better.

Making comparisons is a part of axial coding that allows the detailed discovery of categories and relationships between categories. At this stage, I read and reread my data set while focusing on my conceptual framework. I added several new categories, changed the places of some subcategories to find the connection among the categories. Afterwards, I found the frequency of the codes. Finding frequencies of the codes is not a proposed strategy by Strauss and Corbin (1990) and it is not a necessary step of axial coding. I used Miles and Huberman's (1994) strategies while finding the frequency of the codes.

Following axial coding, I started writing case profiles for each participant teacher. Interview transcripts, classroom observation notes and classroom artifacts were used to write individual cases. Each case followed the same structure: a summary of teachers' teaching experiences, school contexts and identity, a detailed explanation of the teacher's beliefs and knowledge about teaching, learning, science, and technology, and their classroom practices.

Selective coding involved relating the categories and concepts to a core theory which is a higher level of axial coding. It is important to note that, in this study, selective coding was not applied to build a theory since the sample size of this study does not allow me to create a well-developed theory. I employed selective coding to develop the main themes.

Data analysis also included cross-case analysis (Miles & Huberman, 1994). Grouping categories, making comparisons, and recording themes for each case and comparing those themes across cases were the strategies that need to be followed for cross-case analysis. Cross-case analysis enabled me "to build a general explanation that fit each of the individual cases, even though the cases vary in their details" (Yin, 1994, p. 112). To complete cross-case analysis, a *matrix* was created to display and organize the categories and concepts (Miles & Huberman, 1994). A mixture of summary phrases and direct quotes was used to create the matrix. The matrix is an effective vehicle to summarize the data, see the themes, and compare one case to another. This also helped me to determine if the findings aligned with previous research.

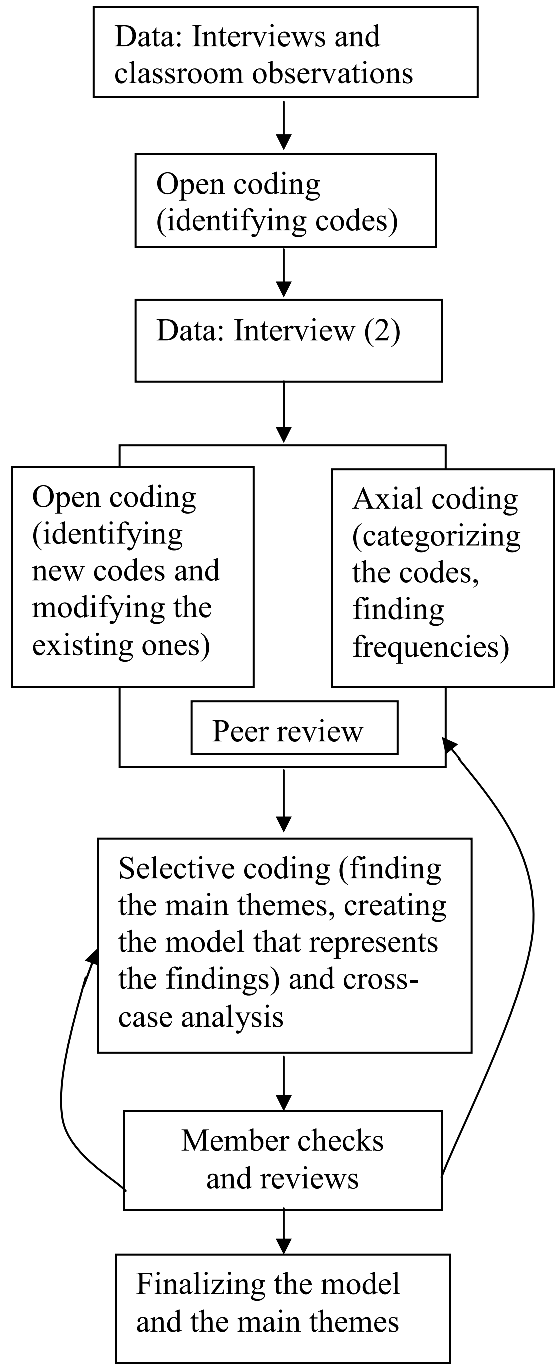

Figure 5. Procedure for the data analysis

Validation

As Creswell (2007) points out educational researchers use various terms (e.g., credibility, validity, reliability, transferability, and authenticity) while discussing the validation in qualitative research. The choice of the terms is heavily relied on the researchers' perspective and research paradigms that they apply in their research. Whatever term they use, educational researchers have agreed on the importance of conducting "trustworthy" qualitative research.

Creswell (2007), in his definition of validation include many criteria to be able to employ "accepted strategies to document the accuracy of" (p. 207) the study. There are many types of strategies to achieve validation of a study. Triangulation or the application of different data collection methods to collect data from multiple participant data sources is one of them. In this study, I used several data collection methods (interviews, observations, and classroom artifacts) and triangulation enabled me to fully understand the phenomenon under investigation. The other strategy is member checking. I did member checks by contacting participant teachers to ask them if the themes and my interpretations are plausible. This is a very critical strategy to establish validity. Long term observations or spending long time in the field is also critical. Gathering data for a long period of time helped me to learn my participant teachers and their school environment better. This process also allowed me to build trust with the teachers. Thus, they were really open and honest during the interviews.

Peer examination is another strategy that qualitative researchers should follow. When I finished the preliminary data analysis I created a model that represents my findings. I presented this initial model to my colleagues and an educational researcher to comment on the findings. Based on their feedback changes were made on the model. Finally, clarifying my bias is also critical. Thus, at the beginning of this chapter I discussed my theoretical orientations. In the next section, I present my background to represent my past experiences, assumptions, and worldview.

Researcher Background

My initial interest in educational research arose during my undergraduate education in science. Science has always been my favorite subject. However, research on students' achievement and engagement on science has demonstrated that most students dislike science. Reasons may vary but the most common reason students strongly dislike science is because they are taught science traditionally. Many science teachers force students to memorize facts, but this traditional approach does not allow students to fully understand concepts. Thus, K-12 students have low science achievement scores and show low interest in careers in science, which has become one of the greatest educational challenges in many countries around the world. To find a solution to this critical challenge, soon after receiving my BS in Biology, I committed to furthering my graduate studies in science education. I constantly searched for ways to increase my understanding of learning and instruction in science education and to take leadership positions to increase the quality of K-12 science education. In 2004, I came to the U.S. to pursue my master's and doctoral degree in science education.

After I received my MA in science education in summer 2007, I then transferred to the Ph.D. program in science education. I worked in several research projects during my doctoral program. In these research projects, I was responsible for (1) providing training for science teachers to help them integrate technology and inquiry-based activities into their instruction, (2) designing culturally relevant science, technology, engineering, and mathematics (STEM) curricula for American Indian youth and providing on-going support for teachers during the implementation of the curricula, (3) developing Model Eliciting Activities (MEAs) (also called case-based problems) that enable students to improve their problem solving skills and critical thinking abilities in STEM disciplines, and (4) providing training for high school biology teachers to teach neuroscience in their classes.

All of the experiences I gained through my graduate studies in the U.S. have provided me with invaluable opportunities to further my learning and teaching experiences and to improve my research skills. I believe that as teacher educators and researchers, we should provide teachers with a number of practical applications that stem from educational theories, examples of student-centered classroom practices, and how-to lists to encourage them to reform and reshape their teaching. With my enthusiasm for technology-enhanced, inquiry-based science learning and my continued faith in the effectiveness of this type of learning, I hope to achieve my ultimate goal, which is to contribute to the improvement of science education. I truly believe that to better prepare students we must first prepare better teachers, and that belief is what guides my work.

Limitations of the Study

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 and all of them are male. These 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. I attempted to find female participants through using a *snowball sampling technique* (Bogdan & Biklen, 1998), asking Benson, Matt, and Jeremy whether they knew female teachers who achieved technology integration. They suggested a couple female teachers who worked in their schools and who integrated technology into their teaching. However, I decided not to include these teachers since they taught subjects other than science and they did not share much in common with my participating teachers. Second, I was not able to conduct post-observation interviews with all the three teachers after each classroom observation. Jeremy and Benson did not always have enough time to talk to me after the classroom observations since their next class period started in five minutes. Third, my study did not investigate students. I heavily focused on the teacher practices in the classroom. However, in the interviews I tried to learn how students might influence on teachers' choices of technology tools and their classroom practices. Only Benson suggested that I collect data from his students. He allowed me to give a survey to his students regarding the use of technology in the classroom and their learning. However, I did not give a survey to his students since I could not collect that type of data from other two teachers' classes. Finally, I carried all the data collection and analysis by myself, but since these teachers participated in a bigger research study before I conducted my dissertation study, several of my colleagues and my advisor collected data from these teachers' classes and they knew the teachers well. So this situation actually helped me to see if my interpretations are accurate from their perspectives.

Chapter IV: Presentation of the Cases

This chapter presents three profiles – Benson, Matt, and Jeremy (pseudonyms). Each profile is presented in the same structure starting with brief information about the teacher's educational background, his school context, and personality. Following that the teacher's knowledge and beliefs about teaching, learning, science, and technology is discussed. Last, the teacher's technology rich classroom practices are presented. The three teachers in this study were deliberately selected to have some common traits to avoid differences in other factors, so before presenting individual cases, I will first share the commonalities among the teachers.

The first common theme among the teachers in this study is that they are highly motivated to use technology in their teaching. They "enjoy" using technology and they feel "confident" using technology in their teaching. As mentioned in the previous chapter, they were chosen for this study since they use technology frequently and effectively. Another commonality among the teachers is that they earned their teaching licensure from the same institute (a public university in Midwest U.S.) through completing a post bachelor teacher education program; all three teachers were in the same licensure cohort. The program heavily focuses on reform-based teaching. In their middle school and high school science methods courses teachers had various opportunities to practice inquiry-based activities and technology is embedded in some of those activities. In addition, in the program, teachers were required to take a content-specific technology course. This course allowed teachers to learn and practice particular technology tools (i.e., Vernier lab probe) that are commonly used in science classrooms.

The teacher education program in which the teachers were enrolled provided a unique opportunity for them to earn their master in education (M.Ed.) degree. After completing required courses to earn their teaching licensure, teachers can take twelve more credits and receive their M.Ed. While Benson and Jeremy hold M.Ed., during the time of the study, Matt was taking courses to complete his M.Ed.

All of the teachers in this study received professional support in their first three years of teaching from the university that they received their teaching licensure and M.Ed. They participated in an induction program that aimed to help teachers improve their practices. They had all been teaching for three years as licensed teachers. Finally, all the three teachers are male and they were in their 30s during the time of the study.

Benson's Profile: The "Engager"

Benson has a BS in environmental studies. After finishing college, Benson decided to teach. He worked for approximately five years in nature centers, environmental learning centers, and outdoor schools where "kids are always *doing* something." Benson enjoyed teaching informal science classes; however, since he worked in each center for maximum nine or twelve months Benson decided to get a teaching licensure and a master in education to start teaching in a formal school setting to get a stable job. Benson has been teaching in a public junior high school in a suburban area in Minnesota since 2005. The school serves students in 7^{th} through 9^{th} grade.

Benson taught five sections of 8^{th} grade Earth Science and one section of an elective technology course during the time of the study. Benson worked collaboratively with a team of 8th grade science teachers. There was not a school level mandated curriculum or common assessments that Benson needed to follow. However, Benson worked together with the other two science teachers in his team closely. They framed the "big ideas" of what they wanted to cover in their earth science curriculum and then decided individually on specific strategies for implementation.

The school has an alternating day block class schedule (88 minutes classes) and it has about 900 students. Approximately 20% of the students are eligible for free or reduced-price lunch program and 79% of students are white (NCES 2006-2007).

Integrating technology into teaching and learning is one of the main priorities of the school and the district. The district provides teachers various in-service teacher training opportunities to integrate technology into their teaching. In addition, the school provides teachers various technology tools to use in classroom instruction. Most of the classrooms have interactive white boards. Teachers can check out the classroom clickers (student response systems) or lap-top carts.

As the Activeboard Lead Teacher for the district and a Google Certified Teacher, Benson has trained other teachers in his school and district to integrate technology into their classroom practices. In the following quote, Benson explained the transformation in his school and his role in that change.

> ….When I first came to the school there were very few teachers using projectors and laptops…Now, almost everyone is using and I do not know when that shift happened. I do not credit myself for that but I think when I came into my department no one was doing it and then suddenly I decided using it [interactive white board] everyday…It was just me figuring things out and then sharing that with other people like if I want to use *Blogs* in the class I have to figure that out

> and then tell other people. If it was successful, I tell everybody if not I do not tell anybody.

According to Benson, becoming to a Google certified teacher added many things into his career. To become a Google Certified teacher, Benson made a one minute long video where he showed how and why he uses interactive white board in his teaching. After his application was selected, Benson went to the one-day long teacher professional development in Chicago where he learned about Google products and other innovative instructional strategies. In the Google Academy, he met with people who have passion to use technology in the classroom instruction. Benson actively participated in the Google Academy online community to collaborate with other Google Certified teachers.

Benson's Identity

Technology plays an important part in Benson's life. He uses social networking sites such as Ning, Facebook and Twitter in his personal life, so for him "it is very natural to extend them to the classroom." According to Benson, teaching with technology is "the easier way" for him to teach science. He uses the social networking sites both to collaborate with other teachers and also with his students. Before he started collaborating with other technology enthusiast teachers on the social networking sites, Benson thought that "[he] was very isolated just in his room and maybe a few teachers around [him]." However, "now [he] interacts with people from all over the country constantly." Benson expressed that he really likes to collaborate with those "amazing" people in the social networking sites.

When it comes to his colleagues, Benson thinks that he is more "flexible" than other teachers in his school. Benson expressed that, his colleagues are "more written structured." They like to plan detailed lesson plans; they want to know "how the lesson is going to work." Benson, on the other hand, likes to make decisions on the fly and other teachers in his school do not feel comfortable doing it. For example, Benson once wanted to use the software called, Voice Thread, in his classroom. Voice thread is a software program that allows students to prepare presentations that includes videos, pictures, and their own voice. Right before the planned instruction, Benson found that students could not use the program since they cannot upload videos or pictures for some reason. On discovering this, he quickly decided to use Google presentation. Benson also explained that instead of the presentation "I could do a double bubble [map] on the notebook and show some video clips and do some strategies around those and do a demonstration in the classroom…but I wanted to get the computers so they could do some research." So when Benson found that the technology that he wanted to use in his instruction did not work properly, he nimbly chose to use another application and he was very comfortable with that. Benson is also very interdependent. He closely works with his colleagues on giving decisions about what to teach; however, he decides how to teach it. Unlike most of his colleagues, Benson uses technology frequently.

Benson is a risk taker; he likes experimenting new technology tools. He constantly works on finding innovative ways of using technology in his classroom. He has integrated various tools in his teaching. Time and the availability of the tools are the most critical criteria for him on giving decisions on what technology tool to use in his instruction. For example, in the previous years Benson asked students to complete iMovie project on volcanoes. Last year, Benson found that preparing iMovie presentation took too much time for his students, so he decided to use Google presentation. Google presentation is a simple version of iMovie. According to Benson, “in a way [he] is going backwards, but it [Google presentation] adds the collaborative aspect which is moving forwards and the fact that web based is cool.” While preparing Google presentations students spend more time on the research phase not on the technical part like they did in previous years while preparing iMovies.

Benson’s Knowledge and Beliefs about Teaching, Learning, Technology, and Science

Benson expressed that technology “gives [students] an opportunity to create something.” Allowing students to create something to illustrate their learning, uniqueness, and strengths is an important factor for Benson to use technology in his teaching. Benson believes that students learn when they actively engage in their learning. Thus, in Benson’s classroom, students should be active participants. He explained that “It [technology] is very engaging; I mean you just draw a simple line on the [interactive white] board and all the kids went “waay”. Thus, the engagement fact plays an important role in Benson’s decision on employing technology in his teaching. For him, technology integration means allowing students to use technology in the classroom. As he puts it,

> If you do power point… the kids still have to just watch it and if you are really good at demonstrating how things are on Google Earth you are still the one doing it and the active board starts to give the kids involved a little bit. Moodle all those links everything that I put on there still all me. [However] when you give them [students] a forum and give them a chance to type, they love it and you see their interest goes up. So the great thing about Ning or technology is that when you use it the right way, it gives the kids a chance to create their own stuff and then totally their engagement goes up.

Benson believes in the effectiveness of using technology in the classroom, but he argued that for many years the way that we tried to integrate technology into the classrooms was wrong. The “top-down” models of technology integration where the teacher is the only person who uses technology in the classroom is not very effective for student learning. For Benson, the model of real technology integration “cannot be all in the hands of the teacher… students have to play a role.”

Benson pointed out that students learn by “doing” and in his classroom students do “hands-on using the computer.” Another factor that leads him to use technology is because Benson believes that “pictures can tell more than words.” He is a “visual learner” and he thinks that with the content that he teaches, earth science, “visual representations are important more than other parts.” He expressed that not all of his students learn the way that he learns and that not all of them like using technology as a learning tool. Thus, he differentiates his teaching style. He explained that when he gives a book reading assignment, he can see the relief on some of his students’ faces. According to Benson, the students who are not fluent in technology skills, “they are behind in reading, behind in school skills, and now there is one other thing that they are behind in: The technology!” In addition to differentiating his teaching, Benson designed an elective course on the use of various computer applications to help students to use technology effectively. He pointed out that in this class he taught the technology tools “that can help them to be better students.” Benson also pointed out that he was not ‘teaching them [students] necessarily the tricks that are good to add on to the internet browser to make it better.” Instead he designed this course to teach students “what they can do [on internet], how they can search or how to build information.”

Benson believes that his role as a teacher in the classroom is 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 them involved." Benson explained that his role is not necessarily "an entertainer, but going beyond that." It is his responsibility to "clearly define the fun stuff versus what students need to do."

In addition to the topics that are emphasized in the national and state standards, Benson taught the concepts that he thought "interesting." During the first year of his teaching, Benson followed the curriculum that was "handed to him" when he started teaching in his school. The curriculum, for example, had a big unit on astronomy. After using that curriculum for a year, Benson decided to make changes on the curriculum, he took out some parts and added more specific topics such as energy transformation. Now, Benson teaches the topics that are in the standards and the concepts that he thinks "appropriate."

According to Benson, clickers help him a lot in knowing whether or not the students understand the class material. Benson used clickers to quickly learn if the students "grasp the big ideas" that he is teaching. Students give responses to questions that require them to synthesize what they have learned. Benson asked multiple-choice questions such as "what is a day? what is a year? or what causes seasons?". Benson also used clickers to catch students' misconceptions on new content. In addition to clickers, Benson uses online tests to measure student understanding. Also Benson pointed out that using clickers allowed him "having instant feedback" which helps him a lot in making a decision on when to move on to a new topic or what to teach next.

Online discussion forums also help Benson in making decisions on when to start teaching a new topic. Benson's decisions depend on students' responses to the discussion forums or his questions that he asks in the class. If students having trouble with a big concept such as “density”, Benson would spend another day or two on that topic, but if students have trouble with small concepts such as remembering the names of the layers of the atmosphere, Benson quickly reminds students the names of the layers and then moves on the new topic. Depending on the availability of time, Benson sometimes opens up discussions to discuss what students wrote on the online discussions and guide students where and how to find extra information if it is necessary for students to be able to post a better response to the online discussion.

In all of his classes, Benson wants students to improve their critical thinking skills. Benson gives a lot of responsibilities to his students. The assignments required students to work collaboratively and to use technology. Students prepared Google presentations and iMovies. According to Benson, using those tools is an incentive for students; it encourages students to learn and provides ownership. Benson expressed that when “students see their iMovie played, they are like ‘Ohhh! I did that’.” For Benson, it is very critical in his instruction to give students “[technology] tools that they can accomplish the mission or the task in a way that is not linear.”

When Benson thinks of science, he often times think of “like the jobs or careers whatever associates with science.” For him, “the process of science is not necessarily a linear thing but a way of doing something.” Interestingly, in the interview Benson expressed that “I love the science that I teach, but I do not have the science brain.” When I asked him to tell me more about that he responded as follows:

> I do not know, I cannot explain it but certain people start talking about science and usually I get turn off. That is why I like the technology because I have this other thing I can happily bring in.

Benson also expressed that he likes environmental science which is his content area, but he does not have any interest in chemistry or physics. In his third year of teaching, he had to teach the 9^{th} grade physical science course and he thought that "it was horrible. Chemistry was just horrible. Physics was horrible. It was just so hard…I have no passion for it, no joy whatsoever…" He continued,

> It is the earth science part that I get into it. I like teaching but the mind set of the scientists and the problem solving that it is like in standards they have all the things you should teach and then they have like the history, nature of science section. I think that part is cool, that is the part that I try to use…

Benson pointed out that teaching students "the everyday stuff" is more important and "useful" than just teaching students the scientific facts. Benson does not think of himself as a scientist. He just wants to show students how amazing the world is. As he puts it,

> For me and my class, it is about understanding the world around you and the appreciation for it and in a way how crazy it is like "wow this is amazing!" Like you can be falling from a balloon 100,000 feet in the atmosphere and the air will slow you down alone. As the air gets thicker you actually slow down dramatically, isn't that insane?

For Benson, it is really hard to separate science and technology and that is one reason for him to teach science with technology. Benson said, "That is just the way I teach." Technology is part of science and our every day lives, so for Benson technology should be a part of student learning.

When asked what a science teacher needs to have and know to teach science with technology, Benson drew the following figure.

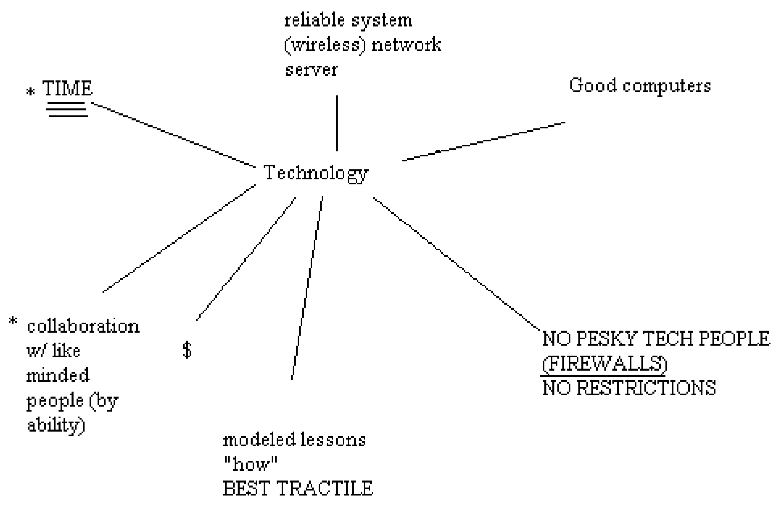

Figure 6. Benson's concept map on technology integration

Benson expressed that having enough time, good computers, a reliable system, and model lesson plans are very important in using technology in the classroom. Collaboration with other teachers whose goal is using technology in their instruction is a critical component in technology integration into his classroom. On the other hand, Benson pointed out that having "pesky tech people" in the school makes technology integration hard. Benson described technology reluctant people as "pesky tech people" and in the interviews Benson mentioned about his frustration of working with this group of people. Benson expressed that those people "they do not get the big picture about why they should do it [use technology] or how it can be helpful." Benson explained one of the incidents that happened in the workshop where he taught technology tools to teachers:

> I was sitting with somebody helping them Moodle, and they were saying, 'What should I do with Moodle?' and I was like 'What do you want to do?' and then

> they were like ‘I do not know, just tell me what I should do and how I should do it’ and then I am like ‘Well, I need to know what you want to do with it’ and they were came back to me one more time and they said ‘Tell me what to do’ I am like ‘You have got to be kidding me. I cannot just tell you what to do that does not make any sense…’ I was like ‘Do you want the kids to be able to download it or do you want them to see it?’ You know it was like should I upload the word document or should I cut and paste the words in to a web page, so it becomes visible and they were like ‘Ohh.. I guess I want them to see it’ I am like FANTASTIC, then we are going to do this, and they were like ‘Ohh, yeah.’

Benson also expressed that technology reluctant people “do not know what to do with technology and what would be outcomes of using technology.” In the professional development workshops, this group of teachers who fear technology “hijack” the workshop by shouting regularly “I know you are way up there, but I am still trying to figure out how to click on the …button” and Benson expressed that “they think that is entertaining.”

Having enough funding is another necessity for integrating technology into his classroom practices. As Benson puts it,

> If you are willing to try it 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. I think very few people pull it off without doing anything outside of the school and, so you have to do that too with technology.

Even though Benson had easy access to tools such as computers and clickers, he expressed that sometimes it is hard to reserve the laptop cart since other teachers also use it. But Benson did not emphasize the importance of having access to technology much. On his map, Benson put stars on next to the concepts “time” and “collaboration” to emphasize that those are the most important concepts in his concept map. Using technology requires spending extra time on learning the technology tool, adapting it for classroom practices, and designing classroom activities that includes the technology tool.

However, Benson expressed that collaborating with other technology enthusiast teachers decrease the amount of time that is required to integrate a technology tool in his classroom. For example, there is a technology integration group on Twitter that Benson joined to "interact with people all over the country" and to learn new resources and to share information with them. So if Benson wants "to find out a resource or a web site" he just writes a message on the Twitter group and then he gets "hundreds of messages" from the group members. Collaborating with other technology people helps Benson decrease the amount of time that he needs to spend to use a technology tools in his classroom teaching.

Benson's Technology Rich Classroom Practices

Benson's enthusiasm for using technology in the classroom instruction can be easily captured by anyone in his classroom. He is motivated to teach with technology and he has acquired skills in doing so. During the classroom observations, I found that Benson was physically very active. He was moving around the classroom in unpredictable patterns. Since he taught in 90 minutes long classes he used various teaching strategies in one class period (e.g., demonstration, interactive discussion, and laboratory).

> Anytime you try to do something linear it does not work. So somehow you've got to give them tools so they can accomplish the mission or the task in a way that is not necessarily linear; because any time I start to try something out in a linear fashion and I felt it does not work.

During the classroom observations, Benson used many technology tools in his teaching, but the interactive white board was the one that he employed every day in his instruction. In his interactive white board, Benson had a huge collection of digital images, pictures, graphs, jeopardy games, audios, and videos regarding the topics that he teaches. The other technology tools that he used were: the clickers, a lot of computer applications such as simulations/animations, and online discussions. He had a Moodle course site that he updated everyday during the academic school year. In this class web site, Benson provided students all the digital images, short clips, and videos that he showed in the classroom. After completing the classroom instruction, Benson uploaded the digital class material onto the class web site. Students can found information about the assignments and daily agenda on the course site.

In Benson's classes, each student keeps a science notebook and on the Moodle site Benson had "a virtual notebook" that shows students what they are supposed to include on each page of their notebook. On the course site, there are also a couple links where students can learn about the earthquakes that recently happened around the world (http://www.iris.washington.edu/seismon/) and current weather radars to learn about the weather conditions around the world. There is an online discussion forum where students ask questions to Benson and to their classmates and respond to the questions that Benson posted. For example, Benson created a discussion board on Earth Saving Day and students wrote 90 responses. Students wrote about "the simple action that they would take on Earth Day 2009" and posted responses to their classmates' posts. Finally, students took their online quizzes on this course site.

When asked how he designs technology rich lesson plans Benson explained, "I think the first thing I always try to do is the engagement thing at the beginning. I usually have some thing at the beginning that is media rich or visual." For Benson, catching students' attention through showing short video clips or movies is very important. He also expressed that he was simply experimenting various tools in his teaching to find the most appropriate one and the ones that fits his goals and teaching. He tried to design lessons where students can actively participate.

> I am experimenting different types of projects that I can use. I try to figure out best one to use for kids…I do not know, I try to get movement. I mean when I am designing slides for the boards I mean there is always some component where I try to design so the kids have that actually go up and *do* something. So it is not all me.

Benson considered student's difficulties and variations in learning when designing a lesson. Benson also tried to design lessons that have "a big question" meaning a question that students should try to answer during the lesson.

> The lessons that I have most successful had big questions like 'Why is the sky blue?' And in the whole day focus on that…It just seemed to be packaged very nicely. There should be some visuals, little video clips or some audio so lots of different stimulus.

While designing a lesson, Benson also focus on using various activities, strategies in his 88 minute block classes. He also added that there has to be a "defined break to break up 88 minutes"; otherwise, students loose their attention. In the classroom observations, I realized that Benson had at least one short break during the each class period.

I observed Benson while he was teaching about atmosphere, weather, and climate. I observed the same class of students all the time. There were 32 students in the classroom. 16 of them were female consisted of two Somalian, two African American, and 12 Caucasian. From 16 male students, 14 of them were Caucasians and two of them were African American. Each student sat in individual desks facing Benson's table and the interactive white board. The walls were full of maps and pictures. Since the district and the school pay attention to concept mapping, on the walls, there were words (e.g. interpret, predict, hypothesis) that students should use in their concept maps. There were also drawings that explain how to create different types of concept maps (i.e., bubble map, double bubble map). At the back of the classroom, there was a seismograph that allowed students to learn whether or not an earthquake occurs during the class period. The other part of the classroom is a laboratory space. There are six lab tables where students can perform laboratory activities adjacent to Benson's room.

Student engagement is the most critical piece in Benson's teaching. Every class Benson started talking about the earthquakes that occurred in the previous day, showing students pictures from the live weather camera, and telling a story to students or showing them a video related to the content that he was going to teach. Most of the time, after the engagement activity, Benson asked question(s) to students and wanted them to post a response on Moodle if they want extra credit. Students needed to complete research on the internet to be able to answer those questions such as "where does your drinking water come from?" or "what is your earth saving plan?"

Table 5 shows Benson's observed lessons.

Table 5

Benson's Observed Lessons

Unit: The Atmosphere and Climate	
	Lesson: Layers of the atmosphere
	Lesson: Greenhouse effect, global warming, climate change and Ozone
Unit: The Atmosphere and Weather	
	Lesson: Wind
	Lesson: Water cycle
	Lesson: Clouds
	Lesson: Pressure
	Lesson: The weather lab
	Lesson: Air pressure activities

Benson started teaching the unit on atmosphere by telling students a story about captain Joe Kittenger who jumped from a helium balloon 20 miles above the ground in 1960. After showing students a YouTube video about captain Kittenger, Benson explained to students about the air pressure and how it affected Kittenger's body. Following that Benson showed students digital images of the layers of the atmosphere (stratosphere, troposphere, thermosphere, and mesosphere). Students then started to make their bubble maps on pressure, temperature, and the layers of the atmosphere on their notebooks. Benson drew the following map on the interactive white board and asked students to use that map as a starting point and add more links to the concepts.

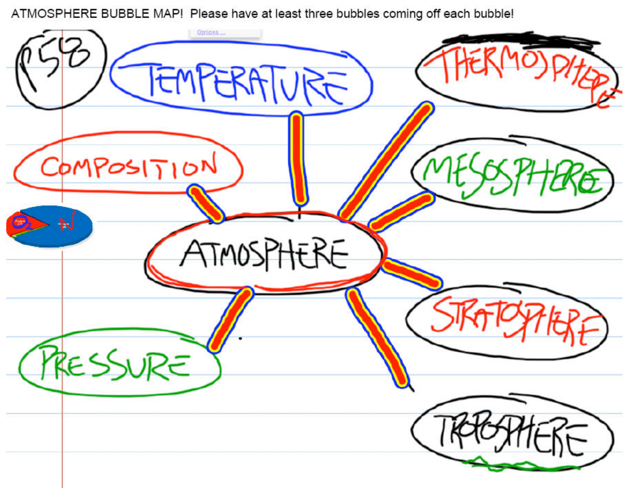

Figure 7. Benson's concept map on atmospheric layers

Following that, Benson showed students graphs of pressure, temperature, and density. Benson asked each student to grab a clicker and responded his questions about the graphs. Benson asked almost ten multiple-choice and open ended questions and based on students' responses he spent extra time on some of the questions to explain the answers of them in detail. Benson also asked students to apply the answers of the questions to the Captain Kittenger's story. For example, when he asked students the question, "Does the pressure in the atmosphere increase as you get closer to the ground?" Benson wanted students to think about the Kittenger story again and make connections. When most of the students gave an incorrect answer to the question, Benson put a graph on the board that shows that pressure is maximum at sea level and explained this to students through providing various examples. Benson talked about how his body swelled up when he went to the swimming pool once.

Benson always explained scientific concepts to students by giving examples from the real world, for example his swimming pool anecdote. He often times wanted students to connect the new information that they had learned to the things that they have experienced in their every day lives. Instead of teaching students the layers of the atmosphere and what makes the layers by just giving them the explanation, Benson asked students to figure it out by themselves through looking at graphs of temperature, density, and pressure, and connecting to the Captain Kittenger story.

When Benson finished asking clicker questions, he showed students a YouTube clip of a space shuttle. Benson wanted students to apply the new information that they learned about atmosphere to the moon. Benson showed digital pictures of the moon, and students learned that “the moon has no weather, atmosphere.” Then, Benson asked students “what color is the sky from the moon?” Most of the students responded that it is “black.” Benson showed them another video that shows a launch of a space shuttle and astronauts on the moon. Following that Benson drew the below figure on the board and students copied it onto their notebooks.

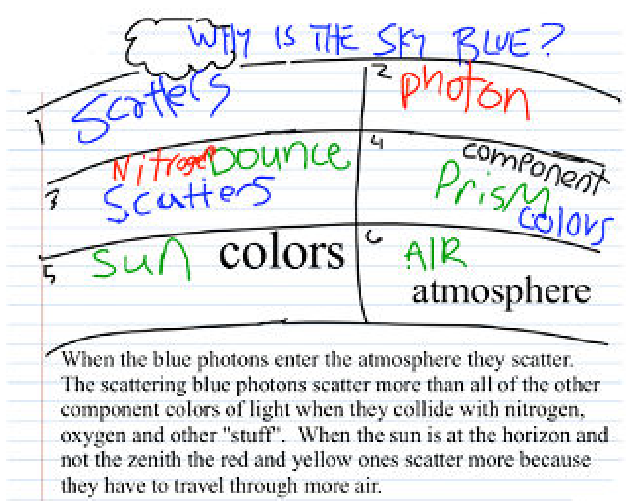

Figure 8. Why is the sky blue?

Benson uploaded the clips, the graphs, and the digital pictures on the Moodle course site and asked students to watch them again later. Before the class finished, students completed their concept maps and notes, Benson checked each student's concept map to find whether students understand the class material.

The next class period, Benson started the lesson by talking about an earthquake that occurred in Britain the previous day. Benson asked students how might that happened in Britain since there is no plate boundaries there. After a short discussion on the possible reasons for that earthquake, Benson asked students to choose a location to look at on the live weather camera. After quickly watching the live weather camera as a whole class on the interactive whiteboard, Benson asked students to complete a worksheet on layers of the atmosphere. On the interactive white board there were two simulations about a space shuttle and a weather balloon and their altitudes when they moved through the layers of the atmosphere. Students watched those to complete the worksheet activity. In the activity, students were required to decide which object (e.g. human, airplane, and cloud) belongs to which layer of the atmosphere.

While students were working on the worksheet, Benson asked them to stop working and to look at the board because the units on the worksheet and in the simulation did not match. Benson showed students how to convert units by using Google. Benson showed them how to convert feet to km. According to Benson, "it is the most relevant skill that [students] learn" during that lesson. Following that, Benson talked about how students need to be careful while choosing the most reliable information on the internet.

After students had completed their worksheets, Benson put the worksheet up for everyone to see on the interactive white board. Benson called a student name randomly and the students came to the board and choice a digital picture of an object and put it on one of the layers of the atmosphere. Benson reminded students that some objects can be in two layers. For example, an air balloon can be put in stratosphere and also in troposphere. After giving the correct answers, Benson showed a short clip about northern lights. Following the short discussion on northern lights, Benson asked students to glue the worksheet on atmospheric layers on their notebooks and start reading the article, "Big Drop," about the need to develop a suit for a high dive when astronauts are turning back to earth. Benson asked students to think about the following questions when they read the article.

- What mineral is the faceplate of the suit made of?
- What are the characteristics of that mineral that made it good as a faceplate?

After students read the article and shared their responses for the questions, as a whole group they made a concept map on the interactive white board. Benson asked students to make a double bubble map comparing the atmosphere near the ground to the atmosphere to higher up where space jumpers and Captain Kittinger were jumping from. Ten minutes before the class finished, Benson asked students to complete another activity. Students worked in groups of four to answer four questions that Benson wrote on four posters. Each poster was placed on a different laboratory table. Each group wrote their response for one of the questions and then moved on the other table to answer the other question. The questions required students to summarize what they have learned in the unit so far.

For example, to be able to answer the question "why is the sky is blue?", students should have thought about pressure, density, and temperature.

In the next observed class, Benson taught about global warming. Benson started teaching about global warming by showing students two graphs that show the variation in temperature and CO_2 for the last two thousand years. In this lesson, Benson wanted students to interpret the graphs by using the words "Support, compare, summarize, infer, trace, predict, evaluate, explain, describe, contrast, analyze, and formulate." The following section describes some of the dialog between Benson and the students at the beginning of this activity. The conversation also shows how Benson wanted his students to think critically, synthesis information, and interpret graphs. It is important to note that the interactive discussions below is typical of those occurring in each observed class.

B: What is the main idea of this graph? (Benson is showing a graph on the board)

S1: CO_2 variation.

B: What do you mean by it?

S1: I do not know. I read the title.

B: Let me ask you this, what is the time scale on the x?

S2: It is in thousands of years.

B: How about in the second graph?

S2: hmmm….

S3: What is ppmv?

B: It is part per million by volume… What causes the dramatic rise in CO_2? Any one?

S4: The increase of green house gases.

B: You gave a very *scientifically accurate* answer but *justify* your answer using this graph!

S4: Industrialization…

B: That was a good one! Move on and *infer* what will continue to happen over time?

S6: Hmmmm, I do not know!

B: There is multiple answers, *predict!*

S6: I have no idea!

B: What is going to happen to this line? (He is showing the line that represents CO_2 level)

S7: Going up!

B: Why? *Justif*y it, why did you choose up versus down?

S7: I do not know!

B: I told you I am going to push you little bit!

S8: Because the line tends to go up.

B: Perfect, any other *interpretation*.

S9: I do not believe it, but there is another one. It is going to go down because in the past it was like going up and down and then up again.

B: What do you want to know more about to better understand this graph?

S7: How can we stop it?

B: What else do we need to put here to do it more clearly?

S10: Separate two maps.

S11: More pictures, because some people need pictures to understand.

B: How would this graph change if there were no trees on earth?

S12: There will be more $C0_2$, because trees eat it.

B: How this graph changes if there were more people on earth?

S12: More CO_2!

B: Why does the CO_2 change over time?

S13: Because of the people. The industrial revolution! More greenhouse gases!

B: Associate with industrial revolution! What is the relationship between the increase of CO_2 and the time when it began to increase? (B was pointing out the ice age cycles)

S14: Ice age covered trees and CO_2 increases…

B: Is there another thing here that answers this question? What is going on during industrial revolution?

S14: Start burning coal and other things.

B: Tell more!

S14: Start building railroads….Big factories, they run all those machines…

B: Last question, how could you disprove the connection between global warming and CO_2?

S15: There are things going on in the past…

B: What is the value of reducing the amount of CO_2 in the atmosphere? Tell us why do we care?

S15: There would be less global warming.

B: What is your reason for that? If it is less global warming why would that be good?

S15: We can live longer.

…

After this activity, Benson showed students the following drawing and they continued to discuss greenhouse gases and global warming. They also watched "the green house effect movie" and the "CO2 in the atmosphere movie" from YouTube. Students than completed an online survey on global warming on Moodle course site.

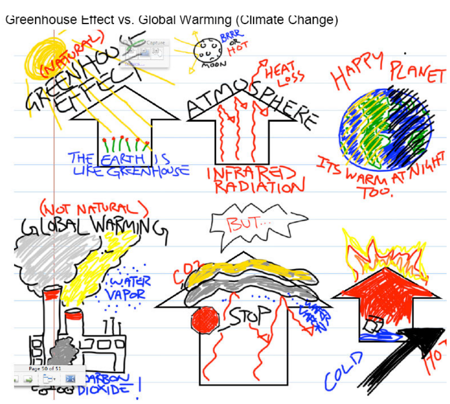

Figure 9. Benson's concept map of global warming and climate change

Benson believes that many of his students hold misconceptions about ozone and global warming. Thus, he decided to teach about ozone. Benson showed a simulation about the structure of the ozone and then had students to complete an activity in which students needed to put the following sentence in order.

- CFC's drift up into the stratosphere
- UV rays break up CFC's and separates chlorine from rest of the molecule
- Free chlorine atom breaks up ozone molecule (O_3)
- O_3 blocks UV but O_2 does not. This results in an ozone hole.

On the Moodle site Benson added the following websites for students to watch later. These are five minute long movies from NOVA.

Climate Change
http://www.teachersdomain.org/9-12/sci/ess/watcyc/climatechange/index.html
Earth System: Ice and Global Warming
http://www.teachersdomain.org/6-8/sci/ess/watcyc/esglaciers/index.html
Antarctic: Sea Level Change
http://www.teachersdomain.org/6-8/sci/ess/watcyc/sealevel/index.html
Natural Climate Change
http://www.teachersdomain.org/6-8/sci/ess/watcyc/naturalchange/index.html
Ozone Movie
http://www.teachersdomain.org/9-12/sci/ess/watcyc/ozonehole/index.html

Students took a quiz on the layers of the atmosphere, density, temperature, pressure, greenhouse gasses and climate change. Following spring break Benson started teaching the new unit on "Atmosphere and Weather." The first lesson of the unit was on wind. At the beginning of the class, Benson let students quickly shared their spring break. For less than ten minutes students talked about their spring break and then Benson started teaching the wind. Benson asked students "Why does the wind blow?" Students offered answers such as "because of the differences in temperature and pressure" and "because of earth rotation." Then, Benson showed his flight ticket from Minneapolis to Seattle on the board and asked students to talk with their neighbor "why" the ticket was on the board, why they were looking at it. Three minutes later, a student said that they were looking at the ticket because of the wind. She continued "wind helps airplane up." Benson then drew an airplane wing on the board and wrote high pressure on the top of the wing and low pressure on the bottom of the wing. "This is science" said Benson showing the airplane wing on the board and then briefly explained how it works.

Benson then asked other students "How is the plane ticket related to the wind?" One group of students realized the difference in flight times. "It took 30 minutes longer to go there" said a student. Benson responded "How? The miles are same!" None of the students responded. Benson then drew a map of U.S. on the board. He showed Minneapolis and Seattle on the map, wrote how long it took to go there and come back from there. "Clearly, something is going on here! The distance does not change but when you are flying there it takes much time!" said Benson. A student came to the board and drew the wind from west to east and said that "the wind caused it." To help other students to fully understand how the wind influence the flight time, Benson gave a couple more examples such as how it is easy to drive a bike with the wind blow same direction and told students that we actually experienced with these concepts every day in our lives.

Benson passed out student worksheets on the wind. The first question was "Why does the shower curtain billow inward when you take a shower?" Students could not find a good explanation. Benson then asked students to listen to a National Public Radio podcast on shower curtains as a whole group. The radio show host is talking with a manager of a shower curtain company. The manager basically explained temperature and pressure differences: the hot air inside goes up and the wind push from the outside and the low pressure is inside and high pressure is on the outside. Students looked very excited while listening to the podcast.

The second question on the worksheet was “Why would you run a ceiling fan in the winter?” and the third one was, “How can a heater on one side of a room heat the whole room?” Benson warned students that these are tricky questions. Students spent a couple minutes on each question and then Benson wrote the answers on the board. He told them the big word that they need to learn was “convection.” After a short break, Benson drew a diagram on the board to explain how air masses constantly moving and changing the temperatures. “This is how the wind is formed” said Benson showing the diagram. When students copied the drawing on their notebook, Benson asked them to work on the second set of questions on the worksheet. Benson reminded them to draw pictures that represent their answers to the questions.

In the next observed class, students learned about water cycle. Most of the class time was spent in the laboratory. Before the laboratory activity, Benson showed students a couple of digital images of the water cycle. Students had a hard time in understanding the ground water so Benson drew pictures on the interactive white board to explain it in detail. Then, Benson put the laboratory worksheet on the board and asked students to read it and then grab the materials to complete the activity. Students were supposed to create a mini water cycle using the materials included water, ice cube, hot plate, ring stand, aluminum folio, and beaker. Students worked in groups of four and designed their own experiments. Benson warned students that he will only collect one student laboratory report from each group; thus students should work collaboratively. Students drew a diagram of their water cycle model in the lab report before building their model. After each group shared their procedure with Benson, they went to the laboratory tables and completed their experiments. In their lab report, they explained the words evaporation, condensation, and precipitation. Most of the groups first positioned the beaker on a stand over the Bunsen burner. They covered the beaker with aluminum folio and kept the beaker over the steam until water droplets collect on the outside of the beaker. They then moved the beaker away from the burner. In this guided inquiry activity, some of the groups could not represent all the parts of the water cycle in their experiment. When students completed the laboratory activity, they then made a concept map of water cycle. As a last activity, Benson asked students to complete a jigsaw game on the interactive white board. He designed the activity as a review of the water cycle. In this game, students did not use the clickers, instead Benson called students randomly.

In the next class, students completed the "cloud laboratory activity" to understand how clouds are formed. In this directed inquiry activity, students used a clear two-liter bottle with a lid, water, and a match to form cloud. Students worked in groups of three to four. They first wrote their hypothesis and the procedure to follow in their experiments. During the activity, Benson asked students to explain to him "what happened in the experiment" and "why it happened." Since a couple of the students were absent that day, after the class Benson videotaped himself while he was doing the lab activity. He uploaded the video onto the Moodle course site for the students to watch it. In that video, Benson poured some water into a clear plastic 2L soda bottle. He lighted a match and then put it into the bottle. Then he capped the bottle and shook it for 10 seconds. Benson squeezed the bottle, caused the pressure and increased the temperature inside the bottle. When he released the pressure a small cloud occurred inside the bottle. At the beginning of the video Benson reminded students to write down their hypothesis. When he completed the lab activity he asked students to write down their conclusions.

For most of the next class, Benson used demonstrations with a vacuum pump and marshmallows to explain to students about low and high pressure. Benson first put the marshmallows in the vacuum pump and asked students to predict what will happen when all the air goes out of the vacuum pump. Students wrote down their predictions and then Benson turned on the vacuum pump. Students were excited when they saw that marshmallows expanded. Then, Benson asked students to predict what would happen when he let the air back in the vacuum jar. After he completed the demonstrations, they discussed where the low and the high pressure were when Benson pulled the air out and the let it back into the vacuum jar.

In the next observed class, students completed "the weather laboratory activity." Before the lab activity, Benson asked students to grab the clickers. On the interactive white board Benson wrote "saturated" and then asked students to discuss with their neighbors what saturated meant. After a couple minutes, students gave their responses and Benson wrote these answers on the board. He then asked students to vote for the most accurate answer.

Benson did not assign a particular clicker for each student; students grab any of the clickers. Thus, Benson did not track each student's progress through checking his/her responses over the course. He focused on the whole class response not the individual. So Benson did not know who gave a correct or wrong response to his questions. He tracked how many students voted for which multiple choice answer. Based on students' responses Benson spent some time on explaining the correct answer. If most of the students were wrong, Benson spent a longer time to explain the answer or asked a similar question to the previous one to help students to figure out the answer by themselves.

Benson projected the weather laboratory activity worksheet on the interactive white board and then quickly explained students what they needed to do. Students were supposed to go to the laboratory tables to look at ten different weather maps and determine where the precipitation would occur. Students worked in groups of two or three and each group rotated around in the laboratory tables. After completing the activity, students went back to the classroom and worked on the second part of the worksheet where they answered questions based on the data that they collected. When students had completed the second part of the worksheet, Benson called on students randomly and asked them for their responses for the questions. Students had a hard time answering one of the questions which was "if a front is headed toward the Twin Cities we can expect….." Thus, Benson asked students to grab their textbooks and look at the definition "front." A student read the definition from the book to the whole class and then Benson started to explain the term in detail. Following is the map that shows how Benson explained the concept of front.

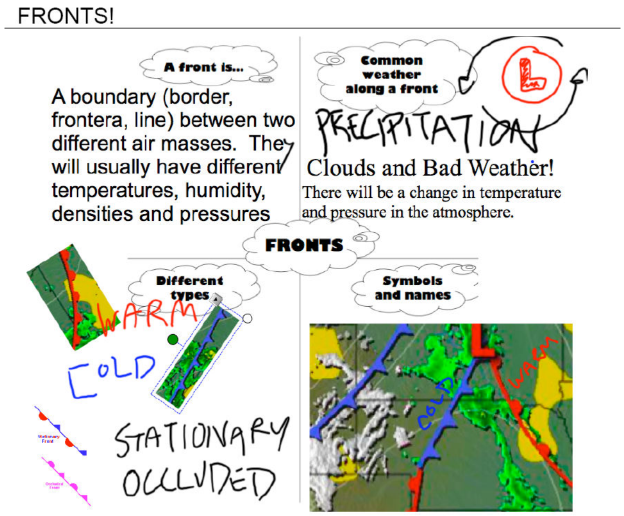

Figure 10. Benson's "front" Map

After that Benson performed the "dew point demo." Benson had four beakers in different sizes. He poured water in the biggest beaker and then told students the water actually represented air at 80 degrees F in this demonstration. On the interactive white board he wrote that "humidity is the amount of moisture air can hold." Benson then poured the water from the biggest beaker to the third beaker which represents air at 70 degrees F. He asked students "what happened?" A couple students gave responses such as "it rains." When he poured the water from the second one to the smallest beaker and asked students "how full is the smallest beaker?" The students responded as "100%." Benson nodded and told students that "the air is completely saturated." Benson then asked students, "what happens if he heats up the air?" None of the students gave an answer. Benson poured the water from the smallest beaker to the beaker that represents 70 degrees F air. Students saw that only 20% of it was full of water now. Benson then explained students that their skin is "nasty" during the winter since "there is no enough moisture in the air." Later, Benson showed students a couple of digital images to help them understand how clouds are formed at the dew point.

In the last observed class, Benson started the class by showing students a current weather image that shows that a jet stream coming toward Minnesota. As a whole group, they discussed where the low and high pressures were on the map. Benson asked students to find other jet streams for extra credit. Benson then explained to the students what they were going to do that day: MCA practice tests and an air pressure laboratory activity. Students first completed a practice MCA test since they will take MCA in a couple weeks. In that practice test, students read an article and answered nine multiple choice questions. After students completed the test, Benson asked students for their responses and then explained to them what they needed to do specifically for the test. Following the practice test, to increase student engagement, Benson did the "air aerobics" demonstration in which he demonstrated students low and high pressure through inhaling and exhaling air.

Students completed "air pressure activities" in the laboratory. In these directed inquiry activities, students followed the procedures provided by Benson. In one of the activities, students picked up a plastic bottle and laid it horizontally on the laboratory table. They then rolled up a tiny piece of paper and put it in the mouth of the bottle. They kept the bottle horizontal and tried to blow the paper into the plastic bottle. They recorded their observations, drew them on their worksheet, labeled where the high and the low pressure was, and then explained what they observed. In the second activity, they filled a cup with water and placed a paper over the top. They then turned the cup upside down. After they completed the activities, as a whole group they discussed them.

The next class students completed a quiz for the "Atmosphere and Weather" unit and then Benson started teaching the new unit.

Matt's Profile: The "coach"

Matt has a BS in integrated sciences (biology/oceanography). He started his teaching career working as a substitute teacher at the school where he is currently teaching. Matt received his teaching licensure to teach middle school general science and high school biology. After earning his teaching licensure, Matt taught in a charter school for two years. He was not happy at the charter school as he could not teach science the way that he wanted to teach. Matt expressed that there was a disconnect between his philosophy of teaching and the school's philosophy. Matt pointed out that in that school, teachers were seen as "the master of the content and… it is [the teacher's] job to kind of pour [their] knowledge into [students'] heads." The school did not also have enough materials such as computers and laboratory equipment. His school principal informed Matt that he did not need to use all those materials instead he should focus on direct instruction. Thus, Matt decided to move to another school. During the time of the current study, Matt taught in a very prestigious private school in a suburban area where he had been "pushed the way [he] would like to teach as opposed to being pushed back from the way [he] would like to teach". In the following quote Matt explained the school characteristics,

> It is an environment that is very active and involved. You have students who tend to be very strong students and very motivated to be here … both internally and externally motivated … and the teaching staff is very committed to excellence in driving the students towards what their potential is.

The school serves grades six through eight. Matt taught 8th grade life science and physical science and 7th grade pre-algebra. He taught all the science classes in one classroom and the mathematics class in another classroom. In the school the average class size is 16 students. The school serves approximately 400 students with 90% of the student population categorized as white.

There were four science teachers in the school and Matt worked collaboratively with the other 8th grade science teacher and the 7th grade mathematics teacher. When Matt started to teach at the school, the 8th grade science teacher was assigned as Matt's mentor. Matt shared his science classroom with 7th grade science teacher, and a technology user with whom he enjoyed learning new ideas and tricks.

The school provides various materials and equipment for teachers. Classroom laptops, laptop carts, interactive white boards, Vernier probe ware, microscopes, and digital microscopes are just some of the equipment that teachers have easy access to. There are also two computer labs in the school. In his science classroom, Matt had five laptops that were dedicated to his classroom and an interactive white board that Matt received during the second year of the current study. He also had access to laptop carts that provide one laptop each for his students. The school also provides teachers in-service training opportunities on learning technology tools such as Vernier probe ware and interactive white board.

Matt's Identity

Matt is a science teacher who likes to teach a subject in different ways. He does not prefer to stick with a single type of lesson plan that he finds to work in his classroom. Instead, he likes experimenting with new ways to help students understand science better. In his words,

> I think that I am myself fairly flexible. I like when lesson can go 3-4 different ways. Some teachers once they got that plan they do not want to depart from that plan. They want to follow right through from step to step. I enjoy that flexibility and I find that I am more flexible. I can take things in different directions.

Matt is not afraid of trying new and different things in his instruction. Unlike many other teachers who "do not necessarily want to try out something new" Matt likes exploring new technology tools or teaching strategies in his teaching. One thing that allows Matt to experiment with different technology tools in his teaching is that "[he] has comfort or familiarity with the technology." According to Matt, having comfort with technological tools makes it easer for him to experiment with technology tools that he has not used before. In the following quote, he explains this in detail,

> For example, with my classroom Moodle site, I am constantly looking at different ways that I can use to help support my teaching. So I post a regular agenda what we are doing each day online and I started posting my notes online. I started using online assignment submission; students want to do that and I think it is something because I am familiar with and used to doing with other online courses in the past. I feel like I have little bit more ability to experiment or little more…. What is the word that I am looking for? Not just familiarity but comfort that I am not worried and that allows me try out things and see if they work.

Matt also does not panic if a technology tool that he plans to use in his instruction does not work out during the instruction. He fixes it in the manner of a calm, relaxed person. In the following quote he explains his troubleshooting strategies.

> I do a little analysis. I try to figure out why it did not work and what I might do differently next time to see if I can make it work more effectively. During the lesson, I tend to try assessing what is not working and see if I can make it work…We had our internet go down as a school, it was offline for 4-5 hours during the period of time I planned to use it…When that happened I just tried to twist the assignment to make it work with the resources that we had available or even do a little bit of the next day's work so the next day we could come back to that other online tool or resource that was not accessible.

Matt constantly looks for opportunities to improve his knowledge and skills about technology tools. He attends professional development programs that are specifically design for teachers to help them integrate technology into their teaching. He completed a couple of trainings on technology tools. Matt attended training on technology tools such as Vernier probe, Java applets, Google applets, and concept mapping through the university where he received his licensure. In his M.Ed. program, Matt also took a couple of classes on online learning and technology tools for teachers to use in classroom practice. Matt gained experiences with various technology tools through these formal professional development opportunities but also through training himself. Matt expressed that "I have got a fairly significant knowledge about technology and technological tools that I try and keep up by reading new things and seeking out opportunities for further training in different technologies." He explained that "knowledge helps [him] be more comfortable and confident as [he] tries out new technologies and technological tools and helps to support [his] learning and ideas in that regard."

Matt reported that using technology in his instruction is "natural" for him. He felt he became "dependent on" the technology tools that he used in his classroom. Matt is willing to apply the technology in his teaching and he keeps "trying things" to find "what works and what does not work" in his teaching.

Matt likes to collaborate with other teachers. For example, he connects with online communities such as the moodle.org. Matt visits this Moodle development site regularly to read posts or to post questions for things that he is interested in doing with Moodle. Many other teachers get back to him and provide responses to Matt's questions. Communication helps Matt to design a more interactive class website.

Matt closely worked with other science teachers in his department. There was a mandated curriculum that all 8th grade science teachers followed but as Matt expressed teachers have "fair amount of freedom" on deciding topics. All 8th grade students perform water quality experiment every year. Matt worked with a teacher who has been teaching 8th grade for few years "to make sure [he] is kind of doing the same thing." Matt also worked with teachers who taught subjects other than science. Some of those teachers tried to integrate technology in their teaching; thus, Matt helped them on technology tools that he used in his class and that he found effective on student learning. Matt taught those tools and applications such as online discussions to other teachers.

Matt expressed that in his teaching each year he performed things that he could not do the year before. More and more he has been integrating student-centered instruction and technology tools in his teaching. He "enjoys" teaching science. In addition to being a formal science teacher in his school, Matt also worked in the summers directing a day camp program for his school.

Matt's Knowledge and Beliefs about Teaching, Learning, Technology, and Science

> My personal 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 or again in their own hands as opposed to when I am presenting.

By constructivism Matt meant that "students are actively engaged in formulating their knowledge." He further explained constructivism as

> …checking on what matches and does not match, what fits what [students] have already known, what does not fit what [students] have already known, what makes sense and what does not. So the students are engaged in this process of evaluating new information that they are taking.

Matt emphasized that students have to see "how [the new information] fits [to their existing knowledge], what the limits of this information are and what the connections of this information are." He stressed that "it is not something that I can force to happen", students "need to do that independently or personally."

Matt believes that students learn best when they are "active" and "intellectually engaged" into the classroom activities. In the interviews, various times he expressed that he tries to use hands-on activities in his teaching as much as possible. He pointed out that "students are actively engaged with the material" in a hands-on activity. He continued,

> It is more than me giving them the material or presenting the material. They are actively engaged with working with it, even if it is like digital something, and not something that they put their hands on, they are still engaged in that particular activity.

Matt used various strategies to engage students in science by asking questions that students find "meaningful in terms of their everyday life" and by making them wonder about how things around them happen or what makes them happen. For example, while Matt was teaching about meiosis, he explained to students that one of his friends who worked in a genetics lab at the university conducted studies with twins. Matt asked questions on the effects of genetics and environment on humans. Students got highly engaged and offered responses to Matt's questions and offered various questions that they would like to learn about the topic of genetics. For example, a student wanted to learn what happens to the children if parents drink too much alcohol, another student asked questions about hermaphrodites. Matt expressed that holding this interactive discussion also allowed him to catch students' misconceptions on meiosis. While Matt answering a student's question, "how grandparents affect our skin or eye color" a student expressed that he thought "in mitosis genes come from parents and in meiosis genes come form grandparents." Matt reminded students about mitosis and then explained the similarities and differences among mitosis and meiosis.

Matt expressed that having laptops dedicated to his classroom helps him a lot in implementing hands-on activities. Having multiple computers in the classroom allows students to engage in the activities instead of just watching what Matt projects on the board. "It makes the instruction more student-centered and engaging." He believes that technology can certainly help students in learning. As he puts it,

> 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 I think.

However, he also pointed out that learning with technology is not "just pushing the buttons [of a computer]" or "clicking [the links] without thinking about the process or the concept." When using the technology tools students have to be "actively engaged and think about the process that they are thinking through."

Matt expressed that his role as a teacher is “fundamentally a sort of a coach” and a “guide.” Matt was “coaching students through their ideas and helping them to learn supporting their learning.” He was also “directing” meaning “kind of knowing where [he] wants the students to go with their ideas” since he does not want his students “sort of just go wherever” they want to go. Thus, Matt tried to “give directions in terms of students’ ideas” to make sure that they are moving the direction that he wants them to move in. Matt was also a “resource person” who tries to make sure that the technology is always working adequately.

When I asked Matt how he knows whether or not his students understand what he teaches Matt reported that,

> I know my students understand when they can explain it to me or explain it to each other and to others who maybe not in my class. When they can explain or to teach it someone else that is how I know they really got that.

Matt said that when students understand a topic “their perception of that topic changes” and according to Matt when he sees that “aha moment” he knows that they “get it.” Matt then added that he also used formal assessment such as tests and projects to measure student learning. During the time of the study, Matt also started using online forums to track student learning.

Matt also reported that allowing students to use technology in the classroom helps him understand if learning is occurring in his classroom.

> If we are doing a lesson, for example, using web research… if I only had one laptop and present it to students it would be me showing things and the students might be listening. They might be paying attention, but they can just easily be thinking about something else. When I put the tool in front of them and make

> them use it then they need to be engaged, they need to be working on it. That is easier to make them responsible for their own work when they are doing it themselves. I can see how far they have gotten, what they have reached or not, well, [if] they are paying attention to what I am presenting.

Matt also reported that when his students use technology he has faced less classroom management issues than normal. He expressed "it is easier for [students] to be off task or talking to friends" when he is presenting something in front of the class. He pointed out that he typically has less of that problem when students are involved in work.

When choosing the technology tool to use in the classroom, Matt focuses on whether the technology tool fits his goals for the classroom activity. He looks at what his "objectives and goals are for a specific activity or class and then tries to tailor the technology tool that would best achieve that goal." In the following quote Matt explains more about how he decides which technology tool to use in his teaching.

> One of the things that I sort of enjoy using technology tools that something that I think comes naturally, something that, when I am planning a lesson I said OK, what tools might have been able to use to help get this idea and often times some of the technological tools are the first come to my mind because of the way that I operate even myself. So I try to find things that are active that try to show information in a couple of different ways or avenues that would be engaging to student interest.

Matt expressed that in his classroom, there were also students who do not like using technology, who need specific directions on what to do on the computer. These students made the lesson move slow. Sometimes, other students get bored. Matt was aware of the problem and expressed that "he really needs to work on it." When I asked him how he helps students who do not enjoy using technology in the classroom, he responded that:

> I try a couple different ways. I give them the resources that have those specific pieces of information. I post my notes on my Moodle site so that they can go back to those and reread them and copy them... I give them list of objectives so they

> know what they are responsible for and that helps I think alleviate some of the anxiety of not knowing quite what you want me to get out of the lesson. It is easy for them if I write them on the board, "know this", they like that. If I give them an activity that does not necessarily have an answer written out somewhere sometimes that adds little bit that anxiety, but by giving them practice sort of the type of information that I want them to be able to give back, I feel like that helps.

Matt also expressed that it is important to give specific instructions for students before they use the technology in any classroom activity. Otherwise "the students feel confused especially if they do not use that technology a lot themselves or if something is new to them." He reported that he should also have a "specific goal" to use a technology tool. Matt expressed that in his first year of teaching in his current school "[he] used some of the technology just for technology sake without having a sound instructional focus for why [he] use[s] this specific technology" but he thinks in the second year of teaching in his current school he planned little bit more. In the following quote he explains his problem that he faced in the first year of teaching in his current school.

> …I set an [online] forum without having a specific end inside or specific topic to generate a good discussion and as a result I would not get a good discussion… I was using [online] forums without a specific goal in my mind and they became less useful as a result that there was not getting at. I was not framing good questions to frame a whole discussion around and as a result some of the discussions became sort of trivial and not very useful for the students either they kind of felt like it is waste of their time.

As a result of this experience, Matt decided to use online forums not as much as he used in the previous year. He structured a different type of forum that he called "free forum" where students join synchronous online discussions with Matt before they take a test in the classroom. It is a study chat that allows students to ask questions to Matt regarding the course material that will be on the test. He expressed that "I am more of a focal point of the discussions where it is mainly students come in and ask me specific questions.

Matt expressed that giving unclear instructions to students in a technology rich classroom caused him to facilitate for students more than he would like to. In another lesson, students were used internet to find information on urban water cycle. Matt asked students to use a website on waste water treatment through the Minnesota Department of Health website. Matt wanted his students to explore the website through finding answers to the questions such as "Why do people pump water in water towers? What is the average water usage in that US resident? Where does water go?" Matt asked these questions to "guide students from one stage to the next"; however, Matt expressed that students got lost on where and what he wanted them to click on and the information that they are looking for.

Matt does not have full authority on what to teach and what not to teach in his classroom. As mentioned before all 8th grade science teachers followed a curriculum and they worked closely to "synchronize" their teaching over the school year. Matt also had "extensive" classroom observations made by school principal; thus, he followed the other 8th grade science teacher who is also Matt's mentor. Matt met with his mentor once in every week informally and they talked about the lessons that they will teach that week. Matt pointed out that he received "a lot of good support in terms of planning what [they] are doing to day to day."

When Matt thinks of science he thinks of "a process of sort of searching out the truth of universe, trying to assess, what the universe is made of and how we can understand that sort of finding the truth of the way that universe functions and all of it." Matt expressed that science emphasizes on "evidence and measurable and observable quantities of the natural world" and that makes science different than the other disciplines. Matt believes that he represents science the way that he would like to in his teaching.

> One of the sort of readings that I use this year and I also used last three years is the AAAS science document's first chapter of the nature of science and this year specifically my students more of a challenged with getting figure it out…Just sort of the language and a little bit less able to hit the meaning from them. I think I will be going to change the way I did next year to make it little stronger for them as well. I am planning on trying to do in once in a quarter. I have them do an assignment where they would do some just individual research about some science work that they are interested in and some science news, and then rewrite that more sort of for general audience and summarize that article and hopefully expose them to some of the realities what is actually going on in scientific research.

Matt pointed out that it is very important to teach science with technology.

> I think specifically in science there are things that technology can allow you to do, you cannot otherwise do. For example, if I want to have students looking at wave dynamics I do not necessarily have access to a physical wave generation device that I can use but I can use simulations or I can connect that so they can get certain extent of an authentic experience or real experience even we do not have access to the actual objects. I would say also because science is so technologically involved …That the work of science really involved technology is good to students coming up through have a fairly significant basis in technology to help them when they make that transition eventually towards actively working in a scientific field.

Matt is an advocate of inquiry-based teaching and he thinks that using technology can support inquiry-based teaching.

> Certainly the two have a lot in common and that certain technology tools really make inquiry easier or more accessible to students. I would say probe ware is very useful in that account because probe ware probes can allow you to visually see what is going on and that otherwise you would not have access to. So using motion sensors to look at the motion of friction cars and they can say 'it looks like it is going with same speed maybe it is slowing down little bit when they can actually see the data plot distance versus time and the speed is very constant and that facilitate learning in a way that you cannot observe with their eyes.

When I asked what a science teacher needs to teach science with technology Matt drew the following diagram.

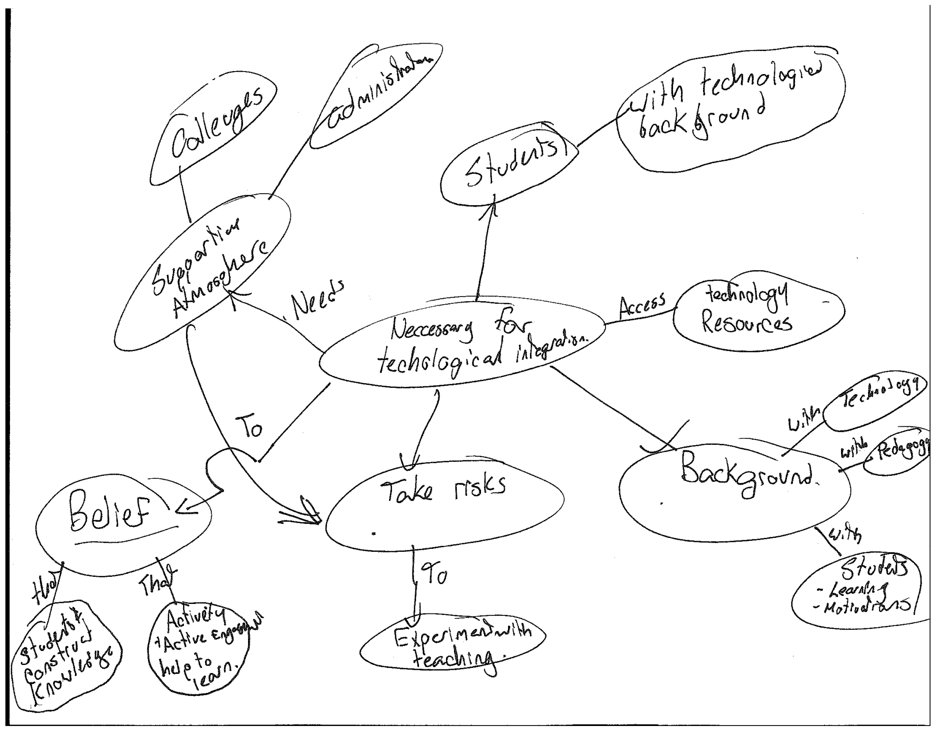

Figure 11. Matt's concept map on technology integration

Matt first drew the center bubble and wrote down "necessary for technological integration." The next thing that he wrote was "technology resources" and linked it to the center bubble and wrote down "access" on the link. While he was explaining his map, Matt stressed out the importance of having easy access to the tools. He was reminded of the situation that he had in his first school. He expressed that it was "a real challenge" for him to integrate technology in his teaching in that school since the school did not have enough technology resources.

The next concept that he focused on was "background." Matt expressed that a teacher needs to know enough about the technology tools, student learning, and have pedagogical skills to use technology in the classroom. He continued that the teacher should also take some risks meaning experiment with his/her teaching, try new things with technology to see if those meet his/her goals or not. He reported that "some technology tools work and some do not and the only way kind of find out what works is that just try different things and see! Do not worry if you are not quite sure because the kids will pick it up faster than you did probably!" He continued that the teacher needs to have students with technology background and expressed how his students are tech savvy.

> The students are so technologically savvy; they very quickly pick up techniques or applications of something even before I do sometimes. They say 'Did you know you can do this?' sometimes I said 'No! I did not know that. That is cool! Thank you for showing me!' I have a student yesterday showed me how to zoom in any application using control and then the two fingers on Mac.

The last two concepts that Matt added into his map were "supportive atmosphere" and "beliefs." Matt believes that a teacher cannot integrate technology into classroom practices without having support from colleagues and administration. He then expressed that that support allows the teacher to take risks and try new things in the classroom. Finally, Matt pointed out that a teacher "would definitely need to have the belief that students construct knowledge" and "active engagement help them to learn science better." He expressed that if a teacher does not believe in that "there would not be necessarily a point to use technology tools."

> I think my knowledge around student learning and my beliefs around student learning through constructivism and through student centered classroom focus me on using tools that allow experimentation and try and error and looking at the way that knowledge fits together with other pieces of knowledge in unique and hopefully interesting ways.

Matt's Technology Rich Classroom Practices

Matt used technology in several ways in his teaching. He mainly used technology to explain or clarify an idea, display content information, demonstrate a skill, and assess student learning. He also allowed his students to use technology. Students search on internet, collect and analyze data, write up research reports and present those. Matt also asked his students to post responses to the discussion questions that he posted on the class Moodle site. Students' responses allowed Matt to "figure out what students know about the new concept" before Matt taught about it and what they have learned about the new concept after Matt taught the concept. To measure student learning Matt also asked students to draw electronic concept maps. In addition to these tools, Matt used various simulations and animations in his instruction.

Vernier probe ware is another technology tool that Matt employed in his classroom instruction. For example, in his physical science class, students used probe ware while Matt was teaching Newton's laws. He gave students small cars and asked them to predict "what would have happen to the car under certain circumstances such as when the car is being constantly pushed." Students then used motion probes and conducted experiments to look at distance vs. time, speed vs. time, and velocity vs. time graphs. In his life science classes students used Vernier probe ware while they were conducting research on water pollution in Minnehaha creek.

Matt also used interactive white board in his science and mathematics classes to present information. Matt expressed that interactive white board allowed him to show students what exactly he is doing like how he was modeling, drawing, or searching for information. According to Matt using digital microscope also allowed Matt to show his students what he sees under the microscope, in other words, what he wants them to see.

When asked how to design technology rich lesson plans, Matt responded that he needs to set up his objectives first. “Once you establish your objectives then you can design your lesson, activity or curriculum around that objective.” The second step for Matt is then “choosing technology tools that are going to be most effective tools” for students to learn the particular topic. Matt then tries to find ways “to connect” what he is teaching to the “students’ experiences.” Matt explained that the lessons should be engaging and bring to the surface students’ misconceptions. Matt pointed out that the curriculum that he used in his current school was actually predesigned so he did not come up with the lessons with himself. He strictly followed the curriculum; however, he employed educational technology tools while teaching the topics in the curriculum. He also applied techniques such as online discussions or concept mapping to catch students’ prior knowledge and misconceptions before he started teaching each new unit in the curriculum.

When I asked Matt to observe his teaching when he uses technology, Matt suggested that I should observe his life science class while he was teaching about organisms. Matt closely followed the school curriculum while he was teaching about organisms. Students completed directed inquiry activities following the procedures in their textbook. Some inquiry activities took more than one day. The table below shows seven lesson plans that Matt taught in the organisms unit.

Table 6

Matt's observed lessons in the organisms unit

Lesson 1: What are organisms? (describing and naming organisms and exploring physical characteristics of organisms)
Lesson 2: Wow bugs (getting a closer look, learning about using microscope)
Lesson 3: Investigating black worms (1.Drawing and measuring a worm 2.Determining the pulse 3.Investigating regeneration black worms)
Lesson 4: Creating your own pond
Lesson 5.Wisconsin fast plants
Lesson 6.The cabbage white
Lesson 7. Exploring cells

I observed Matt's 8th grade life science class. The class met every other day, three times a week, for 50 minutes per class. There were 14 students in the class and 10 of them were female. All the students were Caucasian accept one Asian female student. In Matt's science classroom, there were about ten medium size tables in the middle of the classroom. Two tables were attached to each other and two to four students sit around each table. There were five lab tables at the back side of the classroom.

In the first lesson, students discussed organisms as a whole group. Through interactive discussions, students learned about how to describe and name organisms and how to look at organisms' physical characteristics. Students read about different organisms in their text book and completed a simple card activity on organisms. Matt had a set of cards with pictures of different organisms. Students filled out the information about the organism's scientific name, behavior and described it. Matt expressed that he only had one set of the cards so it was not a very engaging activity for students. Matt reported that for next year he would like to make virtual copy of the cards and put them on the class Moodle site or create a Google docs document and put them there for students to see all of them.

In the next lesson, students learned how to use microscope. Matt first asked students to read the section on microscope on their textbook. Following that, Matt showed the parts of a microscope to the students. He emphasized the lenses. When he finished, students went to the lab stations to complete an activity in groups of three to four. When students went to the lab stations, Matt gave each group rulers, stop watches, and lenses and asked students to look at the ruler and stop watches by hand lenses and draw what they saw. Matt was planning to give students Wow Bugs to make observations using microscope. However, Matt found that Wow Bugs did not hatch over the weekend; thus, he asked students to look over different objects instead of Wow Bugs. After students completed their observations, Matt asked them to look at the board where he projected what he was looking under his digital microscope. He showed them how the lines on the ruler look different when he changes the magnification of his microscope. Matt then put his hand under the microscope and asked students examine it under 4 and 100 magnification. Matt then described to students the guidelines for "scientific drawing." On the board, he drew how his hand looked different in different magnifications. He explained them how to draw the lines, write labels and note the magnification. Students then grabbed microscopes and started to look at a piece of newspaper under different magnifications. Each student drew what he/she saw on the microscope. Matt checked each students drawing and gave feedback before the class finished.

The next observed class was dedicated to black worms. At the beginning of the class, Matt explained students what they needed to do:

1. Observe the black worms – Draw them using the guidelines that they learned in the previous class.
2. Second inquiry: pulsations of black worm – Count a black worm's pulsation for 15 seconds or 20 seconds. Try a couple of different measurements
3. Third inquiry: regeneration – Cut the worm and look at it over the next couple weeks to observe how it regenerates.

Matt then asked students to open up their text books and read the introduction for the lesson. When they finished reading, each group grabbed a microscope, filter paper, and a worm to make observations. Matt asked students to draw what they saw. A couple minutes later, Matt started to look at students' drawings and he found that they did not draw the way he taught them in the previous class. Students did not label properly and wrote wrong magnifications. Thus, Matt decided to use the digital microscope again to show students how he makes observations and then how he draws his observation.

After the brief overview on guidelines on scientific drawings Matt asked students to count the pulsation of the black worm that was under his digital microscope. Matt magnified it onto the projector. Following that Matt showed students how to cut the worm. Students watched on the screen while Matt was cutting the worm. Students then cut the segments of their worm and labeled their Petri dishes since they will make observations in following weeks. While students were working on labeling their Petri dishes, Matt was looking at the black worm under his digital microscope to capture a good picture of the segments to put the picture on the class Moodle site. Before the class finished, Matt asked students the similarities and differences among the earth and black worms. Students offered answers such as “a black worm needs some aquatics, earth worm is not aquatic” and “they both have open circulatory systems.” Matt briefly summarized the differences and similarities between earth and black worms before the class finished.

In the next lesson, students planted Wisconsin fast plant seeds. At the beginning of the lesson, Matt explained students the procedure they need to follow. Students worked in groups of three-four and each group planted two seeds. Students grabbed the materials and plant their seeds and then labeled their containers in 20 minutes. For the remainder of the class time, Matt wanted students to observe and draw a Wow Bug. He put a Wow Bug under his microscope and then he projected what he saw on his digital microscope to the board. Matt started to try capturing a good picture of the Wow Bug that was under the digital microscope. At some point students got disengaged. Matt realized it and a couple minutes later he asked one of his students to try to capture the photograph so he can control over the students. Finally, a good picture was captured and then Matt projected it on the board. Matt gave information about the magnification and asked students to draw the Wow Bug on their notebooks using the guidelines that they have learned previously. He wanted students to label as many parts as possible. While students were drawing, Matt uploaded the picture on the class Moodle site. Students who finished their drawing early critiqued one of their classmates’ drawings. Students then grabbed the

Wow Bug individually to see its' behavior. Before the class finished Matt passed the students' quizzes from the previous unit.

At the beginning of the next class, students made observations on their Wisconsin fast plants for a couple of minutes. This class was dedicated to creating ponds. Matt first explained to students what they are going to do in the class. On the board, Matt wrote "organisms in ponds" and then opened up a discussion. Matt originally planned to ask students to draw an electronic concept map on organisms in ponds; however, in the first class period he found that there was a problem with the school server. Thus, he decided to employ an interactive discussion on organisms in ponds and then asked students to write down six organisms that can be found in ponds. While students were working on completing their list, Matt found that the server was up again. He decided to draw a concept map as a whole class. Students offered organisms such as turtles, mosquitoes, leaches, ducks, and fish and Matt added them on the concept map. Since Matt projected his computer screen on the board, students were able to see the concept map while Matt was adding the concepts on it. After Matt added the organisms on the concept map he turned off the projector and opened up a discussion on levels of organization in a habitat. Matt explained to students that they were responsible for learning the following words: population, ecosystem, niche, biosphere, and habitat. Matt wrote definitions of each of these words on the board. Students took notes on their notebook. Students did not have enough time to build their ponds in this lesson. Matt reminded students that they would build their pond the following day. The next class was dedicated creating ponds and observing a cabbage larva.

Matt set up a camera to capture pictures of a cabbage larva while it was hatching for 50 hours over the weekend. From those hundreds of pictures Matt made a four minute long video that showed how the cabbage larva hatched. Matt was excited about the video. Matt showed the video while he was explaining the details of the hatching process. Matt then asked students to look at the picture of a life cycle of a cabbage white butterfly on their text book. He asked them to look at how long it takes a chrysalis to turn into a pupa and a pupa to turn into an adult. Students provided answers and Matt then put a chrysalis under his digital microscope and projected it on the board. He asked students to draw it on their notebook properly. Matt reminded students that he will set up the camera again to catch when the butterfly emerges. Matt uploaded various pictures of cabbage butterfly larva and the videos on the class Moodle site for students to look them up later. In the remaining part of this observed class, Matt taught mitosis and meiosis. Matt showed animations about mitosis and meiosis from the following websites: http://www.johnkyrk.com/mitosis.html and http://www.johnkyrk.com/meiosis.html. These animations allowed students to observe the similarities and differences among mitosis and meiosis.

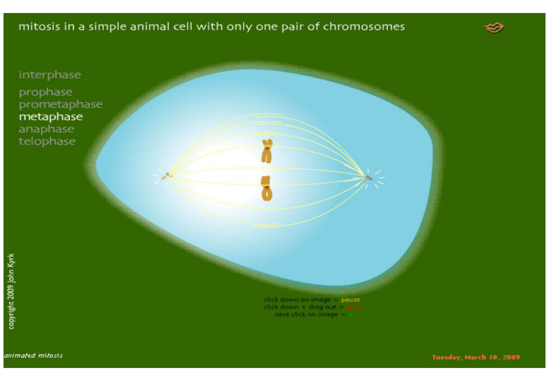

Figure 12. A screen shot of the mitosis animation

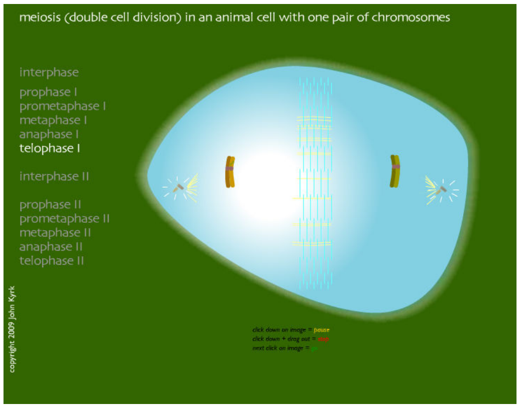

Figure 13. A screen shot of the meiosis animation

In the remaining part of the unit on organisms students completed a project to learn "how the structure of an organism's body parts influences the way those body parts function." Each student chose an organism that interest him/her and completed an internet search on the organism's kingdom, niche, habitat, interaction with other organisms, structure, and the influence of the structure on the function. Students were told to use a minimum of four sources; at least two must be a print source such as an article that was published in a scientific journal. Each student wrote a report and presented their research to the class.

Matt invited me to observe the same class when he was teaching about water quality and stream ecology. All the 8th grade science students in Matt's school conducted a research on water quality in Minnehaha creek in Minnesota and wrote laboratory reports in a newspaper article format. This guided inquiry project took almost two weeks. Before students started on their project, Matt taught about watersheds for two weeks. Students learned what forms a watershed, used topographic maps to identify water flow, practiced chemical testing techniques (e.g., pH, temperature, dissolved O_2, nitrates, and phosphates), learned about turbidity and nutrition inputs, and fresh water organisms. Matt opened up three online discussions during this unit. In the first discussion, students answered the following question and posted a response to their classmates' posts: "With your understanding of watersheds from class, write a one paragraph answer to the question: What forms the boundary of a watershed?" While not many students joined this discussion, almost all the students posted responses and critiques to the following question that Matt asked in the second forum: "How should we take our knowledge and continue to help our society and our environment? What action steps can we apply from our knowledge to make our world better…" In the last forum, Matt wanted students to complete one post with a question (students should have added their own discussion topic) and reply to one post with an answer or part of an answer." Like the first forum, the last forum did not receive many responses.

Before the class went to the Minnehaha creek to collect data, Matt dedicated a couple lessons to show students maps of the Minnehaha creek using Google Earth. By looking at maps, students followed where the creek is going, learned about the terrain around the creek and the land usage around the creek. The reason Matt chose to use Google Earth was to "give an accurate representation of what the environment around the creek as oppose to using maps where [students] cannot really see it." Google Earth provided various features that allowed students to "get realistic understanding of the land" around the creek. According to Matt, Google Earth fits really well with how he teaches. It is very "responsive", "dynamic" and allowed Matt to show many parts of the creek and to be able to answer students' various questions about the creek.

Matt also asked students to visit a few websites to get more information on water quality of the Minnehaha creek before they designed their research studies. Students, for example, went through the Minnesota Department of Health's website to learn more about the waste water treatment and water quality. These online searches helped students to improve their knowledge of water quality.

Matt also taught students how to use Vernier dissolved O_2, pH, and temperature probes using tap water in the classroom. They also conducted experiments with chemical indicators to determine the chemicals such as nitrate and phosphate present in the tap water. After they learned how to use Vernier probes they went to the Minnehaha creek. The overall research question that students attempted to answer in their research study was "How healthy is the Minnehaha creek?" A couple weeks later, students went to the creek second time to collect data to see the change, if any, in chemicals and physical characteristics of the creek. Students also collected biological samples during both of their trips.

Students were asked to write a 5-6 page long report what Matt called "Minnehaha Creek Newsletter" that gives information about the portion of Minnehaha Creek that they studied. Matt wanted students to write the report as a scientific report that includes an introduction, materials and methods, results, and discussion sections. Matt asked students to submit the newsletters online to give them better feedback using the track changes on Word.

Matt reported that he would like to implement this project as more student-centered in the following school years. He expressed that by allowing students to determine their own research questions he can make the activity more open-inquiry. Next time, he also would like students to use Google docs to prepare their reports. Matt pointed out that students can easily share data and look at others' reports if they use Google docs. Furthermore, he said that he can give feedback at each stage of their reports.

As a follow up this Minnehaha creek project, students completed another research project called "water quality issue presentation." Students reviewed the topic that they wrote about for an article in their Minnehaha Creek Newsletter. They did some additional research to have enough details for a full presentation. Some of the topics that students chose for their research were: Mercury, drinking water quality, rain gardens, shoreline buffer. Students chose from one of the following types of visual representations to complete the assignment: PowerPoint slideshow to accompany their lecture (4 + slides with limited text on each slide), a brochure to hand out to the class, or a poster to accompany their lecture. Most students prepared Power point slides to present their research.

Jeremy's Profile: The "hands-on" Teacher

Jeremy has a BS in physics. Soon after graduating from college Jeremy decided to earn a teaching licensure to teach high school physics. When he received his licensure Jeremy had hoped to work as a physics teacher; however, he ended up teaching physical science since there were not any job openings to teach only physics at that time. He taught 9^{th} grade physical science in a suburban public high school in his first three years of teaching.

The school serves students grades nine through twelve. Jeremy characterized his school as a “very interesting place.” The school is “the largest high school in the state” with a population of about 3,160 students. According to Jeremy, the school district is “financially one of the well-off districts in the state.” The school has some socio economic diversity but not as much as a typical suburban high school has. Approximately, %84 of the students are white (NCES, 2006-2007).

The school provides various technology tools for teachers to use in their teaching. As Jeremy expressed if a teacher wants equipment for labs, a smart board, or materials for demonstrations; the school has the funds to get them which is “very unusual for a public school.” There were also computer carts available to teachers and there were almost enough for one for each student in a class. The science department also had a dedicated science computer cart with ten computers on it. The Vernier probes that the school has can be hooked up to the science department’s computers. The school also had computer labs and a media center which has enough computers for each student in a class – the class sizes in the school is around 30 students.

However, Jeremy did not like the “political atmosphere” in the school. What Jeremy meant by political atmosphere is that “what goes on behind closed doors, how [the administration] make decisions, how the administration carry itself, and how they seem through the students to the parents through the teachers eyes.” Jeremy expressed that “I have seen too many things that an untenured teacher should not see… I have seen colleagues get cut up in the administration and I have seen colleagues not getting tenured.” Jeremy reported a particular situation that bothered him a lot. In the following quote Jeremy talked about another physics teacher in the school,

> He has a way of teaching that is totally unlike anything we find, anywhere else at least that I have seen. His name is Tim (pseudonym), he teaches Astronomy, he is very integrated with his curriculum… He integrates culture into the curriculum better than I have ever seen before, he himself has indigenous heritage, and he puts a lot of that into his curriculum because that is who he is and how he thinks…Some students like it some students do not. A few of the students that did not like it complained to the administration that he was not teaching science, he was teaching Indian science which is completely a lie, it is not even true. The administration put him through a lot of really bad stuff, a couple years ago they took away his physical science classes he used to teach, he does not teach them anymore, they assigned him to teach chemistry which he can do. He has license in all areas...Science curriculum that he uses can really start to generate interest in the students, instead they have taken everything that he loves away from him. He used to have his own classroom which you should after 25 years in the district. He does not have his own classroom anymore. He is on a cart. They have given him no space to put stuff. A lot of his stuff, his curriculum has a lot of hands on, it requires a lot of equipment. He is homeless and the administration constantly checking him. He does not even one little thing wrong, they are trying to fire him, but he has got his lawyer on his side. It is a total discrimination. That is just one thing I have seen you know last couple years.

The situation affected Jeremy negatively because he worked closely with that teacher. Jeremy expressed that he has “learned more from him than he has in his entire college career about being a human being, being a global citizen, and being a teacher in a global society and how to bring in cultural relevance and how to match students’ needs with what is going on.” The administrator who was Jeremy’s supervisor knew that Jeremy was “proud of his association with Tim” and he was not happy with that. Jeremy’s supervisor was the person “who was pretty much initiated all the stuff against Tim.” Since Jeremy collaborated with Tim and he used some of Tim’s lessons in his classroom, the administration decided to let Jeremy go after he taught three years in that school. Jeremy expressed that his supervisor was “very narrow minded.” Furthermore, according to Jeremy his supervisor was “very into fill in the blank, fill in the bubble, take multiple choice test” and that is very different than the way that Jeremy wanted to teach.

The school administration claimed that the main reason they let Jeremy go was that Jeremy did not pay enough attention to chemistry in his curriculum. He should have taught chemistry at the first half of the course and then physics in the second half of the course. Jeremy decided to teach physics first and chemistry later in the semester. Since the administration made classroom observations in the first part of the semester, Jeremy was observed only teaching Physics. The administration then argued that Jeremy did not spend enough time in teaching chemistry. Jeremy explained the situation in detail.

> When I came into the school three years ago I had a mentor at that time. She was a Physical Science teacher and she gave me everything she has and I taught it basically in my first semester. Then, I started really look at things in the standards kind of rearrange things that I ended up changing quite a bit of what we did, developed, since I am pretty strong in physics teaching. I changed the whole a lot of stuff there. I made it more in depth; I made it more inclusive with the student; I made it more student centered, basically completely changed the Physics curriculum and I ended up doing this I mean doing the Physics curriculum first. It used to be chemistry first and physics second. Because they are all chemistry teachers in that department and it is natural for them to do chemistry first and physics later. For me, it is natural physics part first. I just set the foundation for everything we did in chemistry. So I decided to do that and that has been working great for the students, the test scores, scores have been going up, I really feel like the students have deeper understanding of things once we get into the chemistry and not so much the surface level any more. They are actually thinking about energy now instead of just punching in numbers. So I feel like it has been really successful, but what has ended happening then is my supervisor says 'OK!, you put Physics first. I have not seen you teach chemistry for a while so you must not be teaching at all. You must be ignoring chemistry part.' The problem is that when chemistry was first he used to end up doing his observations during first part of the semester. So when I flipped them now it seemed I am doing only physics; because he is only coming during this part of the curriculum. He does not come into the second part of the semester when I am doing chemistry so he taught I was not teaching chemistry at all. And that is just the way it goes, I guess, I gave to him a gigantic rebattle, 15 page rebattle to his comments about that, I laid down day by day list of what I did in my classroom showing him 33 days of Physics and 33 days of chemistry and bunch of days some of between them and some are testing days or whatever. I showed him my test scores for last 2 years, how they are above, the other teachers are either doing what I am doing or sticking the chemistry curriculum. I showed him page to page data, he likes data. I do not think he even read it so that is why I was thinking that OK! It is just not

> curriculum thing; it is not just numbers, not just stepping issues, there is something behind it all. Some kind of politics that goes on out there…sort of way that we have to deal with things, and it is not just kind of environment that I want to be.

The situation that Jeremy expressed above and his close friendship with Tim caused Jeremy to leave the school. I observed Jeremy in his last year of teaching in this school. Jeremy expressed that the school "was great, but I think it is little bit too narrow minded for me to stay there for my entire career." Jeremy continued to collaborate with Tim after he left the school. Jeremy is still using Tim's ideas and lesson plans "with his permission."

Jeremy started to teach in a charter high school in his fourth year of teaching. I conducted the follow up interview while Jeremy was teaching 9th grade physics in this school. Jeremy was the only science teacher in the school. The school environment is very different than Jeremy's previous school. The school serves students from nine through twelve grades and the population of the school is around 100 students. It has a very diverse student ethnicity. The attendance, high drop out rates, and behavior problems were the challenges that Jeremy faced in this school.

Regarding the technology tools, Jeremy expressed that comparing to his previous school this charter school has "virtually nothing." He reported that "I was actually very surprised when I came to this school to learn we actually have a couple of projectors." In addition to the projectors, the school has about 15 desktops dedicated to students.

Jeremy's Identity

Jeremy loves learning and teaching physics; in other words, physics is his passion. Jeremy expressed that his science teachers in high school were very "influential." In 10th

grade, Jeremy "started to become a student" before that he was "hanging out in the class." His 10th grade chemistry teacher encouraged him and helped him see that science is "interesting." His 11th grade physics teacher caused him to fall in love with physics. Later on, Jeremy took two advanced chemistry and physics classes. According to Jeremy, "those two courses really solidified [his] desire to be in the sciences somewhere doing something whether it is engineering or teaching."

After being exposed to some advanced science topics, Jeremy started to "develop his own way of doing things" such as taking apart an electronic gadget to find how it works. Jeremy expressed that he likes knowing "how things work" and for him that is one of the biggest reasons for being a physics teacher. In his classroom, he provides various opportunities for his students to engage in science through allowing them to learn how things work.

Jeremy collaborates with other science teachers. The science teachers in his first school got together during the school time and did some differentiation planning together. They discussed various ways to teach particular topics and they prepared common assessment for finals. Jeremy continued to work with his colleagues in the charter school. He also networked with his friends from college and cohort. They "talk with each other on the phone once a week and meet every two weeks to develop stuff together." Jeremy also joined the "gopher state physics group" that started by a "legendary physics teacher" 15-20 years ago. The group meets on the first Saturday of every other month. In the meetings, teachers share ideas to develop new lesson plans.

Jeremy also attends the Minnesota Science Teacher Association's meetings to network with other science teachers, to see what they are doing and to get some ideas from them. Furthermore, Jeremy attends American Association of Physics Teachers meetings. In addition to learning new ideas of lesson planning, Jeremy improves his content knowledge in those meetings. For example, Jeremy purposefully attended one of those meetings to learn more about quantum theory. According to Jeremy, his students always ask him questions about the quantum theory and he went to the meeting to learn new things to present to his students.

Jeremy likes to use technology in his everyday life and teaching. He is willing to learn more about new technology tools to integrate in his teaching. Thus, he participates in professional development workshops on technology integration and continues to take graduate level courses where he can learn about technology tools. Jeremy expressed that he would like to design his own simulations so he plans to take a graduate level course to learn about Flash.

For Jeremy it is a continuous endeavor to teach science with technology. As mentioned earlier, Jeremy did not have access to various technology tools in his second school. Even the school did not have available technology tools, Jeremy worked hard to create solutions such as borrowing educational technology tools or collaborating with university educators who brought new tools into Jeremy's classroom.

Jeremy's Knowledge and Beliefs about Teaching, Learning, Technology, and Science

Jeremy believes that to learn science students should enjoy science. Thus, for Jeremy using hands-on activities and visual applications are very important. Those elements of teaching that "allows students to see the concepts and to get a gut feeling of these concepts and it allows them to kind of do little bit of their own discovery within that concept." By hands-on Jeremy meant doing a lab activity that allows students to work in groups, collect and analyze data, and share their findings with other students. As he puts it,

> Hands-on! I think it has been working so far. I have been in classrooms where it is not hands-on and the students are bored. The students do not seem to learn anything. They are not having fun with what they are doing. It just does not seem to work out. I stick with my philosophies. It has got to be hands-on!

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 expressed that it is his role to ask questions to students to address their misconceptions and to involve them in science.

Jeremy assessed student learning through using informal and formal assessment techniques. He reported that,

> I do a lot of informal assessment. As the day goes on I just ask questions to see how things are going, look at their answers and whatever activity that they are doing. I try to give a quiz every few days if I can. That gives me an idea. The other thing, when I have some spare time at the end of the class when I am talking to students, you can always tell if the students really understand. When you ask 'what do you think about this activity?' and based on their answers I can get an idea how well they really understand at that point. Sometimes at the end of the classroom they do not think any word worth to say if they do not really understand that. That is really good for a teacher to be able to do it last minute of class if it is available, talk with students and see what they think about this or that activity.

Jeremy expressed that how he teaches goes along with his philosophy of teaching. For him, everything "has got to be hands-on and should cover the standards." He pointed out that he covers the standards for the benefits of his students; to help students to be able to solve the problems on the MCA test. If he cannot cover all the standards, he tries "to give them the nice preview of things, teach things that they are going to come up maybe in their chemistry class that are kind of difficult for the students." For example, depending on the time he has, Jeremy sometimes teaches gas laws as a preview for chemistry class. He expressed that "gas laws are actually in the standards so if we need to leave something out that is going to be the gas laws" because students are going to get that in chemistry.

Jeremy had a syllabus for each class that he would like to follow strictly. However, he expressed that if he finds most of the students did not understand a certain topic he spends an extra day or two to revisit the concept. When I asked him how he understands if his students understand or not he reported that he can understand through listening students' conversations when they are performing a lab activity or working on a class problem. Jeremy said that,

> It is always fun to walk around and actually hear the students discussing the topics and arguing with each other. That is when real learning is going on. You do not hear very often because they are students and they do not really get into things that much unless they are really interested in. You also know just by reading what is in their labs. You know just go there and listen them. How do you read the measurement on them? Graduated cylinder? Some students think you got to read the top of this and some of them think bottom and they talk and little argue. They then ask Mr. Johnson 'What is the real answer? How do we do this? I say 'Let's read the bottom of this' and then ask 'Why do you think we need to read the bottom?' So we can actually get this little discussions going on, that is when they are learning real stuff.

For Jeremy, technology plays a critical role in teaching and student learning. Jeremy reported that when his students ask questions, he tries to answer those questions with "a nice visual." He pointed out that using visual applications provides "great discussion during class." Furthermore, Jeremy expressed that using a lot of visualizations in his classroom "gives students gut feeling of what is going on." Jeremy explained that if students see the visual representations of the concepts they can better understand.

> 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 actually quicker 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 also expressed that he is a visual learner and he needs to see images and other visual media. When he was in high school his teachers used technology and Jeremy found that "technology works so well" for him and most of his classmates. He reported, "I grew up using technology and finding out interesting ways to use it. It seems like a natural bridge to put into the classroom for me." He thought that his students got to see the visual.

> As a learner, I always personally try to understand things visually. I am very much a visual learner, hands-on learner. If I can understand things obviously I will develop a major gut feeling for these things. I want my students to feel that and most of my students are visual learners as most people are.

Jeremy also expressed that students are into the technology; they use it all the time and they are comfortable with that so they should also use it as a learning tool. Jeremy believes that using technology in the classroom has a lot of 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 in just short amount and 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 expressed that some equipment and apparatus used to conduct physics experiments are expensive. Not all science teachers can afford to buy such equipment. However, in Jeremy's view, teachers do not need to buy that expensive equipment if they use simulations.

Jeremy believes that using technology in the classroom enhances how he presents the information. For him, the technology is not "absolutely" necessary for teaching; he has taught science without technology. However, he reported that "if I have got some avenue to get it available, it has to be there [classroom]." This reflects the situation that he faced in his current school. Jeremy did not have access to many technology tools in his classroom. However, he continually tried to find ways to find technology tools to use in his teaching. He borrowed some technology tools from the Science House in the Science Museum, he tried to find ways to buy old Vernier probes from other schools and he searched for any opportunity to use technology in his classroom.

Jeremy believes that he has little more experience with technology than a lot of science teachers in the state.

> Maybe it is because I am younger maybe it is I grew up with more comfortable with them. I think it is such a valuable tool because our students are so into it why not go along with it and see if you can fit it into your classroom. So I tend not to fear the technology quite as much I see colleagues in the past.

Jeremy reported that many science teachers do not use technology because of "fear." He expressed that he does not fear the technology instead he feels comfortable using technology in his teaching.

> [Non-technology using teachers] are very smart people; they catch things very quickly, but they just did not grow up being very tech savvy. So it is that fear aspect of a lot of people, you just kind of have to be willing to take it on. Yes, it is challenging, yes it takes a lot of time on first but one become little profession with it.

For Jeremy, science and technology cannot be separated. Science is a "changing field" and Jeremy told his students that "science right now maybe totally different in 100 years ago, just like we thought we are done with physics 100 years ago, but not even close. We do not know anything about physics right now." In the following quote Jeremy explained it in detail,

> …Newton's laws seem like set the stone, but to be honest they are not. We have already seen through many experiments that Einstein's ideas are actually little bit more accurate then Newton's. Even Einstein might be wrong who knows? We still have not proved him totally right or wrong. So it is an ever changing field with the same time we know enough at this point where we are able to benefit our society. We are able to make advances and really more comfortably than 100 years ago because of our new knowledge. So it continues to developing, but it is important for us to develop for our own ways of life.

He believes in general he represented science in his classroom as he wanted.

> …You always have to be cautious as a teacher because you are going to have students that have all sorts of different views. Many of our students especially in freshman level think you have to either be a science person or you have to be a spiritual person you cannot be either and I try to help them realize that it does not have to be that way. You can do it both ways; I mean that is perfectly fine.

When I asked Jeremy to draw what a science teacher needs to have to use technology in classroom instruction, Jeremy drew the following diagram.

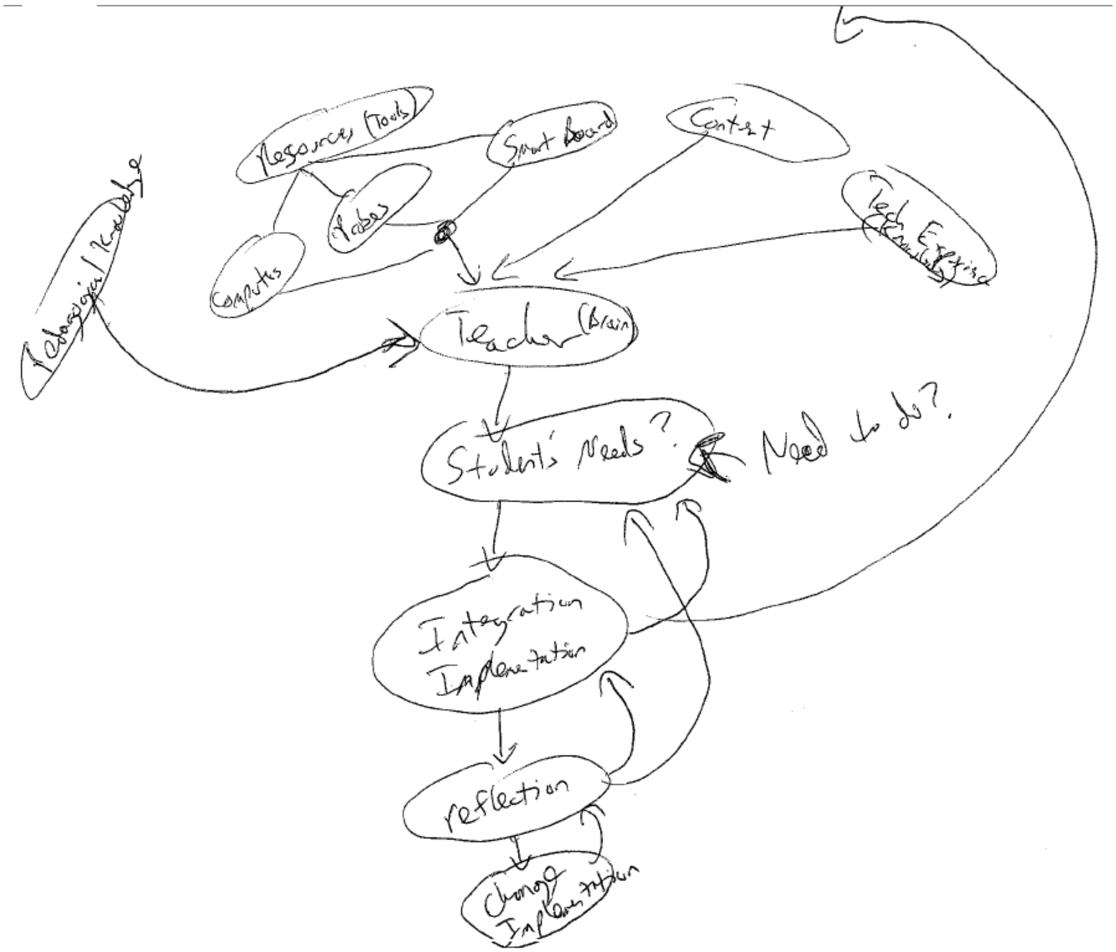

Figure 14. Jeremy’s concept map on technology integration

The first concept that Jeremy wrote on his drawing was “teacher (brain).” Then, he wrote down the second concept which was “resources.” He wrote some technology tools including probes, computers, and smart board under this category. He then added the following concepts: content knowledge and technology experience. He expressed that pedagogy should be also there. Thus, he wrote down the pedagogical knowledge. He then reported that those were his “four big elements that they have to all present within the teacher themselves. You have got to have pedagogical knowledge, content knowledge, resources, and technology knowledge.” He expressed that

> It is almost like a computer diagram, hardware software all that kind of stuff, that is going to come into the process or teacher and from there the teacher has to decide 'OK! How am I going to fit all these elements together to teach the content with the knowledge that I have technological and pedagogical along with the resources that I have?'

The next concept that Jeremy wrote down was "students' needs." According to Jeremy, based on students' needs a teacher decides what he needs to do with technology. He then gave an example, "you are not going to use a Vernier probe with the 1st grader. It is just not going to happen with them. Students are not ready for that. If students are ready than you can do it." Jeremy then went on "once you found out your students' needs then you can start to develop your curriculum or lesson. Yes, you integrate then, you take all those ideas, integrate them for your lesson integration, implementation maybe in the same spot." After that point "reflection" comes. Jeremy expressed that after using the technology in the classroom a teacher needs to think about it, make changes if it is needed for the second application, or think about the other possible application to use. For Jeremy, it is "a big feedback loop." If a technology tool does not work the teacher needs to change it instead of just saying "oh, it did not work. I am not going to try it again."

Change/implementation was the last concept that Jeremy wrote down on his concept map. Jeremy expressed that "eventually you might come to a point this cycle stops, but as your students develop you are going to have to keep doing this, and as technology changes you have to keep going through the whole thing."

Jeremy's Technology Rich Classroom Practices

Jeremy taught three 85 minute long sections of 9th grade physical science every day. Jeremy was observed when he was teaching units on Newton's laws and electricity.

I observed Jeremy's second period class. There were 24 students in the classroom including 12 girls and 12 boys. 22 students were Caucasians, one student was Asian and another one was Hispanic. Each student sat on individual desks facing of the interactive white board and Jeremy's desk. Nine laboratory tables were at the back side of the classroom. There were cabinets at one side of the room for laboratory equipment. The walls were full of posters that have physics content.

Table 7

Jeremy's observed lessons

Lesson1: Using extrapolation
Lesson 2,3,4,5: Newton's first, second, and third law
Lesson 6,7: Static electricity
Lesson 8: Current electricity

Jeremy used various technology tools while he was observed. He used interactive white board everyday in his instruction. Also, Jeremy used a lot of simulations and animations, and digital images in his instruction. All the simulations that Jeremy used were from http://phet.colorado.edu/index.php – The interactive simulations in this website were developed through the PhET project at the University of Colorado. Jeremy's students submitted several of their assignments electronically. Jeremy has a class website and there is an assignment drop box for electronic assignment submission.

During the observations, Jeremy did not use Vernier probes; however, in the interview, he explained how he used motion detector while teaching Newton's laws in the previous fall. Another tool Jeremy was not observed to use but talked about in the interviews was Webassign (http://webassign.net/). Webassign is an online homework and grading website. Teachers can design their own assignment or pick questions from the test bank that was created by other teachers. To increase the amount of student assignments that turned in Jeremy planned to use Webassign. Jeremy's students also did not use online discussion forums during the classroom observations. However, in his new school Jeremy tried to include online discussions in his teaching. According to Jeremy, online forums are great tools to open up student discussions. They are also really effective since it gives students time to think and process what they have learned. "Students are comfortable with it and they are more willing to answer the questions" Jeremy said. However, Jeremy reported that a teacher needs to have easy access to computers to use online forums.

When I asked Jeremy how he designs technology-rich lesson plans he responded that it depends on what resources he has available. He continued,

> …If I got all the Vernier stuff available what I have done so far is that I try to create a situation for students where they can get these fundamental hands-on concepts like the matching a motion graph with the motion probes or using video analysis to track a motion of a projectile to see what the x and y motion looks like. So that was kind of fun. So just for them to be able see these formulas that are very confusing that we put on the paper. They learn where this formula comes from and where these concepts come from. I show them I am not lying these are really proved; you do not have to take my word any more and see it yourself. So that is one thing with the stuff available. As far as designing with other kinds of technology, I really consider what kind of concept we are really talking about. Is it very confusing? Is it very theoretical concept like energy conservation? You cannot see energy; it is all theoretical and very abstract which is the big reason for that simulation that since I have been using that for the last two years. The students' understanding of energy conservation has increased. It has been awesome for them to see those graphs up and down as the skater goes up and down. If I am doing some sort of abstract concept like that it is imperative to use some sort of visual that gives them more of base to build their theories on.

When I prompted if Jeremy considered students' misconceptions while planning a lesson, Jeremy expressed that in general he searches for misconceptions and addresses them "on the spot with pictures or simulations" that he has available. Jeremy also explained that using hands-on activities or inquiry-based activities helps him to catch students' misconceptions. According to Jeremy, finding an appropriate way to include technology, hands-on, and inquiry into his teaching is very critical and it can be very difficult in different contexts.

> You have to create different situations for different groups. Depending on how you differentiate it you make sure that all those inquiry based relevant to the students as well as being able to keep their interest. It is tough! At this age students were so fast; they learn the technology and so quickly use it and they constantly having new information bombarding at them all the time. That is kind of the generation that they are in. You really have to think about how they are going to react to the certain situations, not a lot of students sit down and do worksheet these days.

In addition to using various educational technology tools another unique thing in Jeremy's teaching is starting each lesson with asking students a question. The question of the day was always related to that day's concept. Most of the time, the questions were open ended and required students to think about what they have learned so far in the current unit. Sometimes, depending on the unit, Jeremy asked problems in which students needed to do calculations to find the answer. Jeremy reported that these questions help students to think critically and to analyze what they learned in the class. Students' answers to the questions also gave Jeremy an idea of whether or not students have understood the concept that he recently taught.

During the first observed class, Jeremy taught about data collection, data analysis, using extrapolation and writing hypotheses and laboratory reports. Jeremy started the class by asking students the question of the day which was “Why do we use extrapolation?” Jeremy gave students two minutes to think about their answers. When he asked students to share their answers a student responded that the purpose was to “not to waste your time to test your data.” There were no other responses.

Jeremy decided to explain exploration on the interactive white board by drawing a graph. He drew a linear graph on the board and asked students to assume that they have a data set and the graph represents their data pretty well. He asked them what he should do to extrapolate the graph. A student responded that “it can go two ways.” On the graph, Jeremy showed what the student meant by going two ways. Other students seemed to understand now. Jeremy then told students that they do not have to test all their data. If they have some limitations they can use their extrapolation. Jeremy then gave an example. He showed students a small laboratory glass container and told them they cannot measure something close to zero using this measuring container. He said that they can assume how much they have in the container if they do not have a smaller container for more accurate measurements. He then wrote on the board “we use extrapolation to predict values that are outside our range of measurements.” When students copied that sentence on their notebook Jeremy told students that they will perform a laboratory activity.

Jeremy handed out a laboratory worksheet that included the steps that students needed to follow in the activity. Jeremy then showed students the laboratory equipment: Fuji film canisters, water, Alka-Seltzer tablets, and yard sticks. Afterwards, Jeremy demonstrated what students needed to do: put some water into the film canister, break Alka-Seltzer into quarters and add a piece into the canister, shake the canister, put it on the floor, and wait around one minute. When the “rocket” went to the ceiling students were so excited. Jeremy asked them how to change the situation because he did not want the rocket touch the ceiling. Students offered answers such as adding more water or adding less Alka-Seltzer. Jeremy told students that they need to add mass, “pennies!” Jeremy then taped five pennies on the container and performed the experiment again. He reminded students to use the same amount of tape in their experiments. Jeremy told students that one of the group members will measure how far the container with pennies goes up.

Before students started their experiments, Jeremy asked them about the dependent and independent variables in this experiment. Students responded that number of pennies is an independent and height is a dependent variable. Students then started to work in groups of three. Each group wrote down their hypothesis and the dependent and independent variables of their own experiment. At this time, a student asked the following question: “Are we looking at the height of rockets or how pennies affect the height?” Jeremy responded that they should try to answer the second question.

Jeremy reminded the students that they can change the number of pennies four times and they can do three trials for each of them. Students recorded the height each time and then took the average of them. While students were doing their experiments Jeremy walked around the lab tables and checked their experiments. A student asked Jeremy to put extra Alka-Seltzer into the canister. Jeremy explained that the amount of Alka-Seltzer only let the container goes up in a shorter amount of time; it does not change the height of the rocket.

When students completed their experiments the class went to the hallway to perform the experiment as a whole group. This time they were able to make more accurate measurements since the container did not touch the ceiling. When the class went back to the classroom, Jeremy made a graph on the interactive board. The graph represented the class data. The next day, students went to the computer laboratory to make a graph of their own data. They used Excel to make graphs. Each group submitted their graph to Jeremy.

Jeremy started the lesson on Newton's first law by asking the question of the day: Which one has more inertia: a clown car moving at 10 m/s or a dump truck at rest? A student immediately offered an answer after Jeremy wrote the question on the board. "The dump truck" said the student and then explained "because the gravity has more effect on it." Jeremy asked "what do we call it?" the student responded "weight". Jeremy asked "the dump truck has more what?" A couple other students responded that "mass." Jeremy briefly talked about mass and weight and the difference between them. Jeremy then showed students a digital picture of a car and a truck. He asked students how they can know the car or the truck has more inertia. "More mass more inertia" said a student. Jeremy told students they will learn about Newton's laws in the next following days. But he also reminded students that they were already familiar with Newton's laws particularly the second one, but they just do not know the name of it.

Jeremy asked students if they can tell him the Newton's laws. A couple students offered answers such as "every action has reaction" and "motion and rest." Jeremy told them there are three Newton laws and in his opinion 2nd law is the most important one. Jeremy continued "you told me the 1st and the 3rd one, you are expert on 2nd one, but you cannot tell me. How can you tell me you can understand the 1st and 3rd one without knowing the 2nd one?" Without waiting for any answer Jeremy started to talk about the first law. He pushed a chair in one direction and then he pushed the same chair in an opposite direction with less force. Jeremy then asked students "what happens"? Students did not offer any response. Jeremy then wrote down "mass=inertia" on the board. Students copied the following statements that Jeremy wrote on the board. "A mass in motion stays in motion until acted upon by unbalanced force" and "the amount of inertia depends on mass."

To help students to better understand the concept, Jeremy showed them a digital picture of an asteroid hitting on earth and asked students how that picture shows inertia. A student offered a response "Asteroid moving through earth." "Yes, it keeps going until the earth exerts a force on it. The asteroid has a lot of inertia" Jeremy responded. Jeremy then showed a digital picture of a motorbike driver flying off a bike after hitting a barrier. Jeremy explained to students why the driver kept going. Afterwards, he showed a couple more digital pictures of a space craft orbiting around the world, someone pushing grocery store cart full of food, someone trying to push a dump truck. Jeremy asked students why we can push a grocery cart but not a dump truck. A student responded "we are not strong enough." Another student said "the bigger you are it is getting easy." Jeremy corrected him "No, not big! The stronger you are."

Jeremy then asked students to complete the following sentences:

1. Force and inertia ………
2. All motion starts because…..
3. All motion stays the same because…. and all motion ends because of…..
4. Force causes motion to …. Inertia causes motion to…..

After a couple minutes, Jeremy asked students to tell him their answers. As a whole group they completed the statements. Jeremy told students that before the first half of the class finished he wanted to address a common misconception: the difference between inertia and momentum. He briefly explained the difference between inertia and momentum through giving examples from students' everyday lives. Students learned that momentum is related with mass and velocity and if an object does not have velocity it does not have momentum.

In the second half of the class, students completed a lab experiment that allowed them to observe what factors affect the force applied on an object. Jeremy provided students with three objects of different masses, balance, ruler, sand paper, spring scale, aluminum foil, and tape. Students followed the steps that Jeremy wrote down on the laboratory worksheet that he handed out. Students first measured the mass of object one, recorded it on their data table, attached the object to the spring scale and pulled it along a distance of 1m. at a constant speed and recorded the force in Newtons. They followed the same steps for the second and third objects. In the second part, they attached an object to the spring scale and pulled it along a distance of 20 cm. at a constant speed and read the force in Newtons. They then taped the piece of sand paper to the table and pulled the object along the same distance on the sand paper, and read the force in Newtons. Finally, they repeated that activity with aluminum foil instead of sand paper. For the rest of the class time, students solved the problems about weight and mass on the worksheet.

In the next observed class, Jeremy started his teaching by asking students the following question: If a cup of coffee has a weight of 7 Newtons here on earth, what is the weight of the cup of coffee on the moon? (g on the moon is 1.7 m/s/s). Students worked on the problem for a couple minutes and then Jeremy called a student to tell him how he solved the problem. Following the student's directions Jeremy solved the problem on the board. Jeremy then told students that they will learn about Newton's second law.

While handing out a worksheet to the students, Jeremy asked them what acceleration is. A student responded that "acceleration is change in velocity over time." Jeremy wrote the equation on the board: a=V/t. Jeremy then asked students how they can change velocity. A student said "turn" and another one responded "speed up or speed down." Jeremy nodded and said "either of these will result in acceleration." He then continued "if you want to change the motion of something you need to have force on it. Unbalanced forces change velocity. With more mass, it is more difficult to change velocity."

Jeremy did a quick demonstration to teach students force. He pushed a chair and asked students how they can measure the force that acts on the chair. None of the students responded so Jeremy showed them the spring scale. He put an object to the scale and asked students what is the thing that cause the spring distort. He told students that the answer is gravity and Newtons is the unit. Jeremy then wrote the half of the sentence on the board and asked students to complete it.

1. The acceleration of a mass is…

After students completed the second half of the sentence, Jeremy did another quick demonstration. He pushed a chair and while doing it he told them he put a large force on that and asked them if the acceleration is high or low. A student responded "high". "If I push it slowly" Jeremy asked. Another student said "acceleration is low." Jeremy then said that "so the acceleration of mass is directly/inversely related to force applied. Which one do you think? Directly or inversely?" None of the students responded; thus, Jeremy explained them it is directly. Students then completed the second half of the second sentence.

2. The acceleration of a mass is inversely related to….

Jeremy this time pushed three chairs while applying them the same amount of force that he applied to one chair and told students the acceleration of a mass is inversely related to force. Jeremy then wrote the equations on the board: a=F/m, F=ma, and m=w/g.

Students then started to work on the problems on the worksheet. While students working on the problems, Jeremy told me he was planning to use a video camera to do video analysis using Vernier motion detectors. However, the school has only one video camera and another teacher was using it. Jeremy also did not use any Vernier motion detector during the classroom observations. He used them while he was teaching motion in the previous semester while teaching the unit on motion. Students completed laboratory activities on acceleration and projectiles. Jeremy expressed that the motion detectors in his school were very old and "clunky." They did not give good results either. Thus, Jeremy did not include those in his teaching during the spring when I did classroom observations. (Note: The school administration decided to buy a new set of motion detectors for the following school year.)

When students solved the problems on the worksheet, Jeremy showed them a simulation called "Motion in 2D" from http://phet.colorado.edu/. In this simulation students learned about position, velocity, and acceleration vectors. The simulation allows students to see the velocity and acceleration vectors when the ball moves. Since the simulation was running in Jeremy's computer and he was projecting it on the interactive white board, Jeremy moved the ball with the mouse (see Figure 15). He asked students which vector is acceleration and which one is velocity. Students gave correct answers and showed high interest.

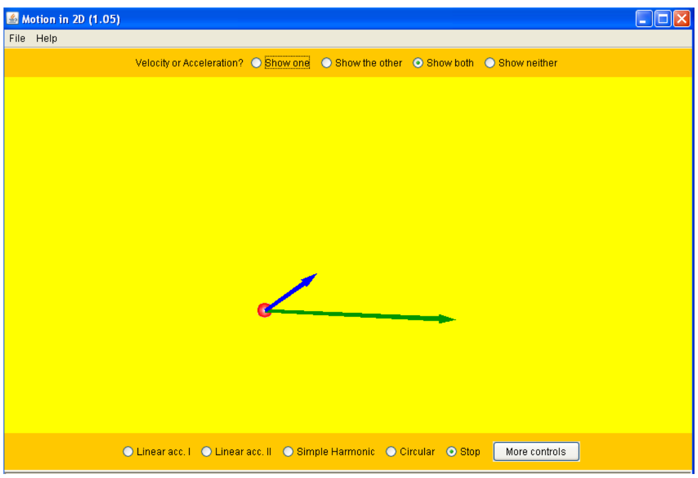

Figure 15. A screen shot of a motion 2-D simulation.

Jeremy then showed another simulation which was similar to the first one. In this simulation Jeremy moved the ball by setting the position. He chose linear and circular motion and asked students to analyze how vectors change.

After watching the simulations, students started to do a laboratory activity to find the effects of mass and force on acceleration. Students worked in groups of three to four. They changed the mass of a cart and indirectly tested how much acceleration it experienced when acted upon by a constant force. Each group got an array of different masses, one cart, two rubber bands, one wooden slinger, spring scales, and a yard stick. They collected data and made a data table and a graph of the variables on their data table.

The following day, students completed the second half of the laboratory activity. The lesson started with the question of the day activity. The question that Jeremy wanted his students to answer was: A robot kicks a toaster with a force of 20 N and it accelerates at 10m/s/s. What two things can be changed about the situation to double the acceleration of the toaster? This time, students had hard time to answer the question. Thus, Jeremy briefly reminded them the Newton's second law and then they solved the problem on the board. Students then started the second part of the laboratory activity. They used the same set-up that they used in the previous day. In this part, they found out how the force applied to an object effects the acceleration of the object. They kept the mass constant and changed the number of rubber bands on their slinger. Students made a data table and graph. At the end of the activity, students went back to their seats and Jeremy gave a small black chalk board to each student. These were for the informal quiz. Jeremy asked a couple of Newton's second law problems and each student wrote his/her answers to the boards. Jeremy showed a digital picture that represented each problem. For example, he showed a digital picture of a soccer player who kicks a ball and then asked the question. The question was "A soccer player kicks a ball with a force of 100N. If the ball has a mass of 1.5 kg., how fast will it accelerate? After students wrote down their answer and showed them to Jeremy, Jeremy solved the problem on the board. He asked about 10 questions.

In the next observed class, Jeremy taught Newton's 3rd law, work, and force. The question of the day was: explain how a rocket lifts off the earth's surface. Jeremy put a digital picture of a space shuttle rocket on the board and drew the force vectors that acted on it when it is lifting up. To explain Newton's third law in detail Jeremy used a couple more digital pictures and drew the forces that acted on the objects on those pictures. For example, Jeremy showed students a picture of two basketball players and explained them how they push the earth and how the earth pushes them back through drawing the force vectors.

Then, Jeremy told students they will do a laboratory on work. Before students started the laboratory activity, Jeremy briefly introduced the concept of work. Jeremy told them "work is a special type of energy" and did a couple quick demonstrations. He pushed the chair and then the wall and asked students if he did work. Students responded that he did not do any work when pushing the wall. Jeremy nodded and said "If I have no affect on an object I have done no work." Jeremy then wrote the equation on the board: work=force*distance. He drew a small box on the board and a force vector of 50N. He moved the box a distance of 25 m. and then asked students how much work does he do? Students quickly made the calculations and offered an answer.

For the laboratory activity, Jeremy created a context. He told students he was moving the next weekend and he has lots of stuff to move. He needs to move his stuff to the truck and since the truck has wheels he needs a ramp. He told students they will mimic the situation in the class. Students went their laboratory tables. Each group got a car, masses, spring scale, and a piece of wood as a ramp. Jeremy reminded students to make a data table and think about dependent and independent variables before start the activity. Students needed to record angle, distance, force (how much force it take to pull that car on that angle), and work (how much work it take in this amount of force and at that distance). Jeremy recommended students to measure at least four different angles. The next day, they went over the laboratory results and then students took a test on Newton's laws.

I also observed Jeremy when he was teaching his electricity unit. Jeremy started the first lesson on electricity by asking students the units of the atomic masses shown on their periodic tables –There is a periodic table stick on to each table. A couple minutes later, Jeremy wrote "Atomic Mass Unit" on board and asked students what it means. A student responded "weight of proton." When Jeremy asked students how they calculate it a student said that "adding protons and neutrons." Jeremy then handed out a worksheet that includes atomic mass problems (In these problems, students were supposed to find # of electrons and protons of an element or based on the given numbers they were supposed to find what the element is). Students worked in pairs to solve the problems. Ten minutes later, Jeremy asked students what their answers were. He quickly went over the questions and then moved on to the electricity. He showed a demonstration that involved "Van de Graff generator" which is a static creating device. Jeremy then put a picture of Bohr's model of the atom on the board and explained students why they studied atoms for the last couple days. He then continued "we now know that where the electrons stay and we are going to learn what happens if the electrons go around." Jeremy then briefly explained static electric.

Jeremy wrote the terms “charging by contact, charging by friction, and charging by induction” on the board and asked students to explain what they mean and to give an example for each of them. After students worked with their laboratory partners for ten minutes to answer Jeremy’s questions, Jeremy asked students to observe him while he was showing demonstrations. Jeremy blew up a balloon, tied off the end, and then let it float away. The balloon went to the ceiling. Jeremy then put some pencil shaving on the top of the Van de Graff generator and turned it on and pieces charged up. In the next one, Jeremy showed students a piece of cloth made by rabbit fur. He rubbed the balloon with the piece of the cloth and then the balloon stuck to the cloth. Jeremy then put the charged balloon near a small water stream from faucet and the balloon attracted the water. Jeremy then blew-up two balloons, tied the ends in a knot, and tied thread to the ends of each balloon. He taped the balloons on the ceiling. Afterwards, Jeremy rubbed each balloon all over with the cloth. While balloons tend to get close to each other when they were uncharged they wanted to be far away as much as possible after they were charged.

In addition to using the above demonstrations to explain students the different types of charging, Jeremy also used two simulations from http://phet.colorado.edu/. The first simulation, balloon and static, was designed to help students understand why a balloon sticks to their cloths. In this interactive simulation, students viewed the charges in the sweater, balloons, and the wall when they rubbed a balloon on a sweater, then let go of the balloon – It flies over and sticks to the sweater.

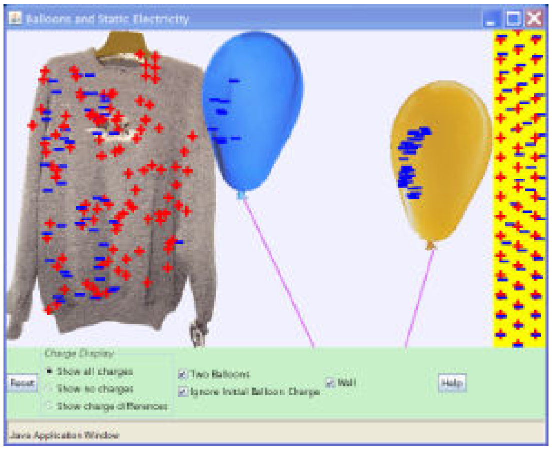

Figure 16. A screen shot of the balloons and static electric simulation

In the next simulation, John Travoltage, students view the transfer of electric charge.

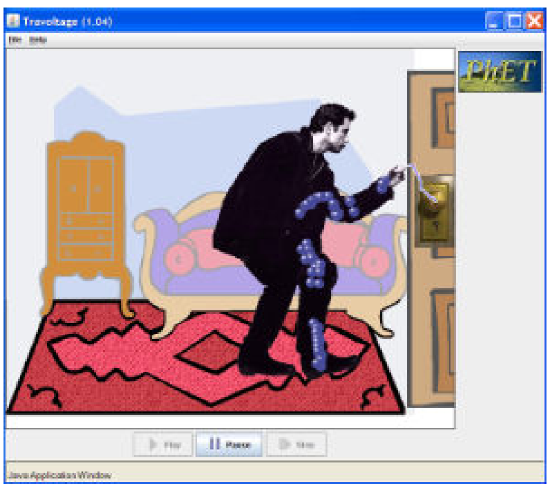

Figure 17. A screen shot of the John Travoltage simulation

Jeremy run the simulations on his laptop and projected them on the interactive white board. While students were watching them, he asked students questions like "which balloon negatively charged, where did the negative electrons come from, or why the electrons spread our when I rubbed John Travoltage's leg?

In the next day, students completed laboratory activities similar to the demonstrations that Jeremy showed in the previous day. The purpose of the laboratory activities was to observe the properties of the static electricity. Jeremy handed out laboratory worksheet that included the steps that students needed to follow. Students completed four different activities in groups of three to four, wrote down their observations, and then they answered the questions on the worksheet regarding the activities. The laboratory activities were included rubbing the balloon on head and try to pick up small pieces of paper by holding the balloon above them; rubbing the glass rod with fur and bring the glass rod close to the pit ball; rubbing plastic rod with the fur, depositing the charge from the rod onto the top of a Petri dish that is lined with aluminum foil at the bottom and contains pepper on top of the foil; sticking two pieces of tape on desktop, pulling both pieces of the desk together and pulling the apart, bringing the nonstick sides of the tapes together, sticking the strips of the tape side by side onto the smooth surface and then pulling them off with a quick motion and bringing the nonstick sides near each other gain.

After teaching static electricity, Jeremy taught current electricity. Students completed a laboratory activity to learn the factors that determines the brightness of a light bulb. Students worked in small groups. In the laboratory activity, students followed the steps that Jeremy wrote for them to build circuits. They first built a circuit with one bulb and read the amount of current using ammeter. They then built the circuit with two bulbs (two light bulbs in series) and then read the current again. Students connected the voltmeter to the first and second bulb and read the voltage. Students then built a circuit, two bulbs in parallel, connect the voltmeter to the first and second bulb and read the voltage. Finally, students built circuits with three bulbs- three bulbs in series, three bulbs in parallel, two bulbs in series, one in parallel, two bulbs in parallel, and one in series.

In the next observed class, Jeremy taught Ohm's Law. Jeremy started the lesson by asking students the question of the day: Would you rather build a string of lights in series or in parallel and why? Before students started working on the problem Jeremy reminded them there is no right or wrong answer. Some students responded that they wanted to build a string of lights in series or in parallel but could not explain their reasoning. Jeremy then drew a parallel and a series circuit on the interactive white board. He explained students

> Both of them work. There are couple things. In parallel, the bulbs are brighter since the voltage is being distributed among these bulbs. If one of the bulbs burns out in series none of them work, but in parallel series if one of them burns others can continue work. We need more wires to build parallel series. Personally, I would rather to pay for a parallel circuit. Think like you have 100 bulbs and 2 of them burn how can you figure out which one is burned out…. It is all how you defend it.

Jeremy then told students that they will work with a simulation about Ohm law. Jeremy downloaded the simulation into the laptops before the class started, so students in groups of 2-3 grabbed a laptop and started to work with the simulation. Jeremy asked students to answer the following questions as they work with the simulation.

> 1: What happens to the current when the voltage is changed?
>
> 2: What happens to the current when the resistance is changed?
>
> 3: Make a summarizing description of the relationship between voltage, current, and resistance

The simulation, Ohm's Law, was from http://phet.colorado.edu/. In this simulation, students were able to see how the Ohm's law relates to a simple circuit. Students changed the voltage and resistance and saw how the current changed according to the Ohm's law.

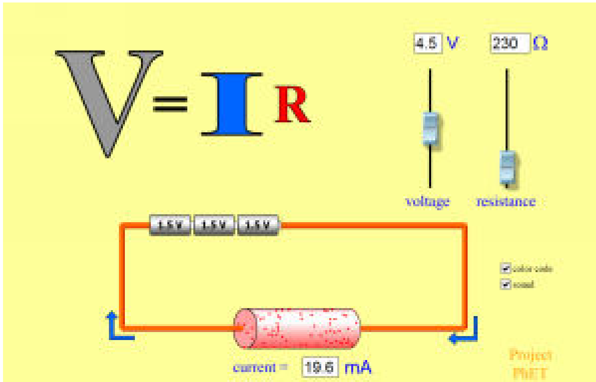

Figure 18. A screen shot of the Ohm's law simulation

Students worked with the simulation about 15 minutes. Jeremy then explained them Ohm's Law. He wrote down the equation on the board and explained what the symbols represent and the relationship among the symbols (V, I, and R). Afterwards, Jeremy asked students to work with another simulation. In the simulation, circuit construction kit (AC+DC), students built circuits from schematic drawings, used ammeter and voltmeter to take readings in circuits, made calculations to find the resistance of their resistor.

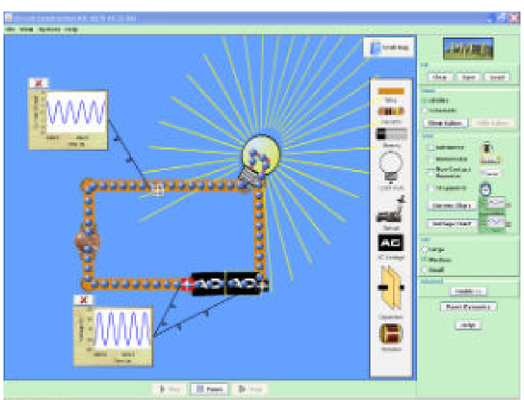

Figure 19. A screen shot of the circuit construction kit simulation

Students worked on the simulation about 15 minutes. Jeremy asked students how they built the circuits and what they got for resistance. He then passed out a laboratory worksheet. Students went to the laboratory stations to complete the laboratory activity called “good Ohm cooking.” Students build circuits to measure V, I, and, R in order to verify Ohm’s law. In the second part of the laboratory activity, students chose an unknown resistor, set up a circuit, and then read the current and voltage of the circuit from the ammeter and voltmeter in order to find the resistance. Since some students did not finish all the parts of the laboratory activity, the next day students continued to work on the same laboratory activity. That was the last activity in the electricity unit; next day Jeremy gave a quiz to the students to assess their learning and then moved on to a new unit.

Chapter V: Analysis and Discussion

In this chapter, I first present the codes that emerged from the data and then answer my research question: How do science teachers' beliefs, knowledge, and identity contribute to their uses of technology in their instruction? As mentioned in chapter III, NVivo 8.0 was used to analyze teachers' interviews and the field notes from classroom observations. The NVivo 8.0 allows organizing and coding the data for specific categories (nodes). NVivo 8.0 also permits grouping the nodes as tree nodes and free nodes. Tree nodes contains parent and child notes and free nodes are the nodes that do not conceptually related to the tree nodes. In NVivo 8.0, a tree organization of nodes can be created and all categories and subcategories can be demonstrated. The categories can be also count and compared which allows for cross-case analyses.

I followed a specific strategy to code the data. After reading the data set, the first set of interviews and the field notes from the classroom observations, I started coding each teacher's first interview. These codes were basically free nodes. I then followed the same process for the classroom observations. Afterwards, I created a simple tree organization of codes; however, I found that I had many free nodes that did not fully belong to the tree nodes. After reviewing the free and tree nodes various times I decided that they did not fully characterize teachers' decision making process and uses of the technology in the classroom. Instead, the codes represented information about various factors that involves in technology integration. The current study does not focus on all the factors that involve in technology integration; however, it only focuses on knowledge, beliefs, and identity of the teachers and more importantly the influence of them on teachers' technology integration efforts. Thus, the follow up interview was conducted with each teacher. Following that, I read and reread the follow up interviews, the first interviews and the field notes and then coded all of them. This represents the open coding in the constant comparative method (Strauss & Corbin, 1990). I selected and named the codes from the analysis of the data. I tried to code every piece of the data as much as possible. The categories that emerged quickly from the data were *beliefs*, *the technology tools and their characteristics,* and *technology use in the classroom*. As I coded an incident for a category I read the incidents that were coded under that category previously and compared the new incidents with the previous ones. At the end, I had the following categories: *beliefs, knowledge, classroom practices, technology tools and their characteristics, and identity*. Each category has 5-10 subcategories – in the constant comparative method, subcategories represent propositions.

The next stage, axial coding, was organizing and classifying the codes. At this stage, I revisited the conceptual framework of the study and made necessary changes on my codes. I reread the data and compared my categories and subcategories. I added some new free nodes and categories, changed the name of some of the categories, and rearranged many of the codes. At this stage an educational researcher (a professor) who has many years of experience with qualitative data analysis and also NVivo gave me feedback on my new codes. I created a tree organization of the nodes (see Appendix C). Seven categories emerged from the data: *Environment (school context)*, *intrinsic motivation*, *teacher identity*, *reward/satisfaction*, *technology use in the classroom*, *TPACK, and reflection*. Each category included subcategories. For example, TPACK has four sub categories. These subcategories are *knowledge and beliefs about curriculum materials (educational technology), knowledge and beliefs about instructional strategies for teaching science with technology, knowledge and beliefs about purposes and goals for science teaching with technology, and knowledge and beliefs about student learning with technology*. I tried not to borrow the codes from existing studies. Most of the codes were taken from participants' own words – emic categories (Maxwell, (2005). For example, *pictures tell more than words* and *technology is just the way I teach*, are direct quotes from the teachers.

Three free nodes were not included in the tree organization of the nodes. These nodes are: *background, memory,* and *PCK*. These are not included in tree nodes for different reasons. *Background* is the free node that includes information about how teachers decided to become a teacher and this code is not fully related to the research question. *Memory* is a node represents only a small piece of data in one teacher's interview. In this code, the teacher, Jeremy, explains about his high school physics and chemistry teachers and how they influence his teaching. Finally *PCK* represents data that teachers talk about their practices that do not include any technology tools. In Jeremy's second interview I found clusters of this code. In Matt's and Benson's interviews there were few small incidents that were placed under the category of PCK.

Before I started the selective coding process to find the themes/assertions that emerged from the data I did further analysis of codes on NVivo 8.0. I counted the codes and then grouped them as follow: frequent, common, and rare. The frequencies of the some of the codes are found larger than the others. Frequent means the code occurred more than eight times (The most frequent category was coded 16 times; thus, I decided that any category that was coded nine times or more can be grouped as frequent). Common means that the code represented all three teachers. Rare means less than four occurrences of the code were found in the coding scheme. Table 8 shows the categories, codes, and frequencies.

Table 8

Categories, codes, and frequencies

Categories	Codes	Number of coding references			
		Benson	Jeremy	Matt	Code frequency
Environment (School Context)	Environment (School Context)	1		2	3
	Available resources	4	10	2	**16**
	Colleagues and administration	1		2	3
	•*School politics*		2		2
	Curriculum	1		4	5
	Mandated school tests	1	1	1	3
	Students				
	•*Kids are tech savvy*	2	1	2	5
	–*Students are more flexible than we are*	1			1
	–*Students feel comfortable*		1		1
	•Non-tech-savvy students	3		2	5
	•Student characteristics		2		2
Intrinsic motivation	Intrinsic Motivation				
	I enjoy using technology	1	1	1	3
Reflection	Reflection				
	Reflection during and after the instruction	7	4	2	**13**
Rewards and satisfaction	Rewards and Satisfaction				
	Increase in student understanding		1		1
	Kids love technology	5	5	2	**12**
	Saving time and being more efficient	1			1
Teacher identity	Teacher Identity				
	Collaborating with teachers	5	3	1	**9**
	Determined	1	7	1	**9**
	Exploratory behavior	3	5	5	**13**
	I am a visual learner	1	2		3
	I am flexible	4		2	6
	I become dependent on technology			1	1
	I do not fear the technology		1		1
	I feel comfortable with the technology	1	1	2	4

	I like knowing how things work		1		1
	Interdependent	3			3
	Make decisions on the fly	1		2	3
	Risk taker		1		1
	Teacher-leader	6			6
	•Frustration with non-tech-savvy teachers	2			2
	•Technology integration specialist	2			2
	Teacher's multiple roles		2	1	3
	•*I am an engager*	1			1
	•*I am coaching students*			1	1
Technology Use in the Classroom	Technology Use in the Classroom				
	Student practices				
	•Collecting and analyzing data		1	1	2
	•*Creating something*	3			3
	•Joining online tutoring			1	1
	•*Learning efficient internet use*	3			3
	–Blogging	1			1
	•Making presentations using Google docs	1			1
	•Performing virtual labs		1		1
	•Searching information on the Web			3	3
	•Sharing data			2	2
	•Submitting assignments electronically		1	1	2
	•Writing online forums	1	2		3
	Teacher practices				
	•Assessing student learning			1	1
	•Catching students' prior knowledge and misconceptions	3		1	4
	•Collaborating with students	1			1
	•Displaying content information	2	2	8	**12**
	•Gathering student attention	3			3
	•Sharing course material		1		1
	•Teaching effective use of	2			2

	computers and the internet				
TPACK	TPACK				
	Knowledge and Beliefs about Curriculum Materials (Educational Technology)				
	•Active board-Interactive white board	1	3		4
	•Active expressions-Clickers	5			5
	•Class web site		1		1
	•Concept mapping			1	1
	•Digital microscope			1	1
	•Digital images	4	2		6
	•Google docs	1			1
	•Google Earth	1		2	3
	•Laptop computers	1			1
	–Online exam	1			1
	•Logger probe-Probe ware		2	4	6
	•Ning	1			1
	•Podcast	1			1
	•Short video clips	3			3
	•Simulations	3	5	1	**9**
	•Voice thread	1			1
	•Web assign (online tool)		1		1
	•What to use				
	–Pre- and in-service training	3	6	4	**13**
	–Self training	2	1	3	6
	Knowledge and Beliefs about Instructional Strategies for Science Teaching with Technology				
	•Activities				
	–Cook-book lab		1		1
	–Inquiry-based activity	2	2	2	6
	–Lecture with discussion	2	3	2	7
	–Process-skill lab			2	2
	–Student-led simulation		2		2
	–Students completing projects			2	2
	–Students completing test	2			2
	–Students completing worksheet	2	1		3

–Students writing lab reports		1		1
–Teacher-led demonstration	2	2		4
–Teacher-led discussion	1	2		3
–Teacher-led review previous day	3	2		5
•Balancing Science and the technology	2	1		3
•*Covering the standards*	1	2		3
•*Differentiating teaching style*	1	1		2
•*Giving specific instructions*		1	4	5
•Lesson planning	1	1	2	4
•Sticking to the schedule	1	1		2
•*Tailoring the technology to objectives*	1		1	2
•*Technology is just the way I teach*	2	1		3
•Trial and error	3	1	1	5
•Using representations	4	2	2	8
Knowledge and Beliefs about Purposes and Goals for Teaching Science with Technology				
•*Connecting science to everyday lives of students*	2		1	3
•*I am not the science guy*	4			4
•*It is hard to do a lab about plate tectonics*	1			1
•*Safe and economic experimentation*		3	1	4
•*Science and technology cannot be separated*	1		1	2
•*Science is a changing field*		2		2
•*Science is searching out the truth*			2	2
•*Technology fits my goals*	1		1	2
Knowledge and Beliefs about Student Learning with Technology				
•*Active participation*	5	1	8	**14**
•*Engaging*	4	1	5	**10**
•Enhance student learning		1	1	2
•*Hands-on science learning*	1	3	1	5

	•*I can see understanding*	2	2	2	6
	•*Kids love technology*	5	3	2	**10**
	•*Pictures tell more than words*	2	7		**9**
Free nodes	Background	1	1	1	3
	Memory		1		1
	PCK	2	16	3	21

Note: Italics represent emic codes and bold numbers represent frequent codes.

The frequently coded codes are: *available resources* – a subcategory of environment (school context), *collaborating with teachers, exploratory behavior,* and *determined* – subcategories of teacher identity, *simulations*, *active participation*, *engaging*, *kids love technology*, *pictures tell more than words,* and *pre- and in-service training* – subcategories of TPACK, *displaying content information* – a subcategory of teacher practices, and *reflection after the action* – a subcategory of the reflection. I attempted to do more than simply listing and sorting the codes. In addition to documenting their meaning I interpreted them. In the following section, I discuss the frequent codes.

Frequent Codes

Available Resources

During the interviews all teachers emphasized the importance of having easy access to the technology tools in their school – *available resources*. In the interviews teachers talked about the resources that they have in their classroom and school and how having access to the educational technology tools in the school setting affects their teaching. This is particularly important for Jeremy since he taught in a charter school when I did the follow up interview. Jeremy did not have easy access to the tools in that school and he largely discussed his frustration in the follow up interview.

On the other hand, Matt and Benson had various educational technology tools in their schools; however, they were also aware of the importance of having easy access to them and discussed about this issue many times in the interviews. In his follow up interview, Benson, for example, explained how he modified one of his lessons when he found that the laptop cart was not available during the time that he planed to use. In the case of Matt, access to various educational technology tools was very easy. He had five laptops dedicated to his classroom. Thus, he did not need to make plans to reserve a laptop cart or to go to the computer lab. However, in his previous school, access to the technology was a big issue and that was one of the main reasons for him to leave that school. Matt expressed that "if you do not have [technology] resources it is going to make a real challenge to try to integrate those things which is what I was at my old school."

Collaborating with Teachers

The second code that has high frequency is *collaborating with teachers*. Teachers in this study were found to collaborate frequently with their colleagues to decide what topics to teach, what technology tools to use and how to use them. They met with their colleagues either formally or informally to discuss their strategies. Also, they participated in online collaborations with teachers. Benson, especially, after becoming a Google certified teacher started to actively participate in online communities where teachers help each other to create innovative lessons that include technology. Jeremy attended several monthly meetings of a group of physics teachers in the state and also went to national conferences for physics teachers. Matt, since he was the newest science teacher in his department, closely worked with the experienced teachers. He also joined an online group to learn more about the effective ways of designing Moodle class site.

Exploratory Behavior

The next frequent code is *exploratory behavior* which shows how the teachers like experimenting with various technology tools in their teaching. They love to explore new technology tools and innovative practices. Teachers tried to "figure out best [technology tools] to use for students." Benson gave a project for students that required them to make a presentation about volcanoes with iMovie. Students worked in groups of 2-3 to complete their project. At the end of the project, Benson found that it was "too technical" for students meaning that they mainly focused on the transitions and sound effects of their iMovies not the science part of the project. Benson then decided to do the same project next time with Google presentation. The following school year, students used Google presentation to complete the project. They worked in groups and each group prepared two slides to present what they learned about volcanoes. Students added links and YouTube videos into their slides. According to Benson, Google presentation was easier for students than iMovie so that students could "do the science." After seeing students' high level of interest on Google presentation Benson decided to use the same tool for the next project that students did on storms. Matt also experimented with online discussions in order to find ways to increase student participation level. Jeremy used different simulations and digital images to determine the ones that most helpful for students to understand abstract Physics concepts.

Determined

Teachers were also found that they were very *determined* to find ways to use technology in the classroom. Even though this category represent all three teachers, almost all the codes came from Jeremy's follow up interview where he emphasized the strategies that he used to find the technology tools to be able to employ technology-rich classroom instruction. In the case of Jeremy, not having access to the technology tools did not hinder him; instead, he constantly searched for ways to find some tools to use in his classroom.

Simulations

Even though teachers were found to use various technology tools in their teaching, the codes showed that all of them used *simulations* in their teaching. Especially Jeremy while teaching about electricity employed many simulations to show students the electric flow. Also, Jeremy's students used the DC circuit builder simulation that allowed them "to build batteries, resistances, bulbs …and measure voltages and currents." Matt also used simulations when he was teaching about mitosis and meiosis. Benson used simulations in almost all his observed classes. Benson expressed that "the visual aspect of the simulations and images facilitate [student learning]…Being able to see it is important…I think with my content, visual is important more than other parts."

Displaying Content Information

Teachers in this study used educational technology tools in various ways; however, the codes showed that they all used them to *display content information* at one point. Most of the codes for this category came from the classroom observations. However, it is also important to note that while teachers display content information using the technology, students were not passive listeners. In these teachers' classrooms, there was always an interactive discussion even while teachers were showing a simulation or an image to teach a particular topic. Matt, for example, used two simulations while teaching about mitosis and meiosis. He stopped the simulations several times and asked students questions to find their understanding. He tried to connect the new information to students' every day life experiences. Thus, he opened up a discussion on human genetics.

Active Participation

Other frequently coded category is *active participation*. Teachers pointed out that students learn when they actively participate in their learning. They expressed that the use of technology in the classroom allows students to actively participate in their learning. All the three teachers also believed that students learn science better through hands-on activities and "hands-on with computers" is how Benson described his teaching in a technology rich classroom. Hands-on activities took place in various ways in each teacher's classroom. For example, Matt's students used Vernier probe ware, sensors, and calculator to collect and analyze data. They connected the Vernier probe ware to their computers to analyze the water samples that they collected from the Minnehaha creek. Students analyzed the pH level, temperature, and dissolved oxygen levels to find the water quality of the Minnehaha creek. Students went to the creek two different times to track down the change, if any, in the water quality of the creek. Jeremy's students, for example, used simulations to perform experiments with DC circuit builder. Benson's students participated in various online forums to discuss their understanding about environmental issues.

Engaging

In their interviews, all three teachers talked about how technology helps students to engage in the classroom activities over and over again. Even though this study did not aim to find teachers' reasons for technology integration, it was found that student engagement might play a critical role in teachers' decision about the use of technology. While talking about the interactive white board Benson reported that "it is very engaging…you just draw a simple line on the board and all the kids went wow! So the engagement fact is huge." Matt also expressed that most times his students argue over who is turn it is to write down the answer on the interactive white board. Jeremy pointed out that he has taught science without technology; however, he found that using technology in the instruction keeps student interest and increase engagement.

Kids love technology

Teachers expressed that their students love technology. Technology is an important part of students' every day lives and they love to use it in the classroom. Applying technology in the classroom practices makes science more interesting and enjoyable for students since they "love the technology." Seeing students enjoyment with technology in the classroom instruction influenced on teachers' decisions about technology integration. As in the case of Benson, he decided to continue to use Ning in his elective technology course since he found that his "students are so into it." For all the three teachers one reason for using interactive white board and simulations in classroom instruction is because they thought their students love them.

Pictures Tell more than Words

Teachers expressed that *pictures tell more than words*. Especially when they teach abstract concepts such Newton's law, mitosis and meiosis, and plate tectonics teachers preferred showing students visuals. Jeremy and Benson also specifically expressed that they are visual learners and believed that most of his students also visual learners. Thus, they thought that students can learn better by seeing. As Benson puts it,

> …That is where I fall in the learning category; I have to see it and I do not need anybody else say anything. I can figure it out if I can see it. So that is why I try with my teaching …with my content I think visual is important more than other parts.

Pre- and In-service Training

The category *pre- and in-service training* coded various times. Teachers took a content specific technology integration course in their pre-service teacher education program. They learned about the educational uses of the many technology tools in that course. In the case of Jeremy, he knew the basics of those before he took the course. Thus, in his post-licensure coursework he chose to take upper level classes on educational technology. Regarding the in-service training on educational technology, Jeremy and Matt constantly searched for professional development opportunities that help them improve their knowledge on the technology tools. Benson, on the other hand, became one of the professional development implementers for technology in his district. He helped teachers in his district to integrate technology into their teaching. It is important to note that in addition to learning about the technology tools in their teacher education program and in-service training programs, these teachers also learned about technology tools by themselves, in other words through self training. Technology changes so quickly and teachers need to update their knowledge of educational technology tools. Matt, for example, prefers to use online tutoring programs when he tries to learn a new technology tool. To be able to add new features in his class Moodle site, he completed the online tutor for Moodle and also joined the Moodle community to learn more about the applications of Moodle from other teachers. Benson and Jeremy also constantly continue to learn more about educational uses of the technologies. They follow the latest news regarding the educational uses of the technology through social networking sites and find what other teachers do with technology in their classrooms. Benson, blogs about the use of the technology in the classroom and also stated that reading other teachers' blogs about technology help him to spend less time on lesson planning.

Reflection after the Instruction

Finally, the category *reflection after the instruction* was coded several times. Teachers in this study were found to reflect on their practices. Each and every day, they looked back over their completed classroom practices to evaluate their teaching and student learning. Based on their reflection teachers made decisions on what technology tools to use in the curriculum and how to use them. This is a mental process that they complete everyday. It was found that reflection allowed the teachers to modify their classroom practices. In the case of Benson, moving away from iMovie was a decision that was made based on his reflection on his instruction. Matt in the following quote talked about his evaluation of the instruction included online forums.

> I was using them [online forums] without a specific goal in my mind and they became less useful... I was not framing good questions to frame a whole discussion around and as a result some of the discussions became sort of trivial

> and not very useful for the students either. They kind of felt like it is waste of their time.

Based on this reflection, Matt decided to frame more structured questions. In the following school year, Matt wrote questions that were more connected to what students were studying in the class. When teaching about water quality unit Matt asked his students to give responses to the following question on the online forum: “What action steps can we apply from our knowledge to make our world better?” 55 discussions occurred in the forum. Students not only responded to the question but also wrote responses to 2-3 of their classmates’ posts.

Common Codes

The analysis of the codes on NVivo 8.0 also showed that all the three teachers were references for some of the codes – common codes. The categories that were coded frequently represent all three teachers – the categories discussed above. In addition to those, the following are the codes that represent all the teachers: *kids are tech savvy* – a subcategory of environment (school context) and *lesson planning* – a subcategory of TPACK.

Kids are Technology Savvy

Kids are tech savvy is a dimension of the category *students* which is a subcategory of *environment*. The three teachers in this study explained that almost all their students are technology savvy. Students use technology everyday in their lives and they are comfortable using it in the classroom. As Matt expressed some of the students even teach him some computer “tricks” that he does not know. Benson pointed out an important issue in the interview to explain the misconception that many of the teachers have about students. He said that many teachers do not want to use technology since they do not want to deal with any unexpected problems that they usually face using technology in the classroom. Benson explained that since students are very technology savvy they know that computers, for example, do not work properly all the time. If he experiences any computer related problems students in his classroom behave calmly and wait for him to troubleshoot. As in the case of Jeremy and Mark, sometimes students offered to help to fix the problem. Seeing that students enjoyed using technology in the classroom also allowed teachers to feel satisfaction.

Lesson Planning

The code *lesson planning* shows that every teacher has different strategies for planning lessons. While planning a technology rich lesson Matt first defined his objectives of the lesson. Then he tried to find the educational technology tools that can help him to accomplish his goals. Finally he tried to connect the content that he is teaching to students' everyday life experiences. In the interview when I asked how he considered student prior knowledge and misconceptions, Matt explained how their pre-designed curriculum considered these factors. As mentioned previously, Matt followed a school mandated curriculum in his class. Jeremy on the other hand, expressed that he concentrated on what available tool he has got and the content that he teaches. Jeremy explained it:

> It depends first on what we got available. If I got all the Vernier stuff available what I have done so far is with the technology that we got available I try to create a situation for students where they can get these fundamental hands on concepts like the matching a motion graph with the motion probes or using video analysis to track a motion of a projectile to see what the x and y motion looks like so that was kind of fun. So just for them to be able see these formulas that are very

> confusing that we put on paper really in action where this formula come from, where these concepts come from and generally show them I am not lying these are really proved. You do not have to take my word any more and see it yourself so that is the one thing with the stuff available. As far as designing with other kinds of technology I really consider what kind of concept we are really talking about. Is it very confusing? Is it very theoretical concept like energy conservation? You cannot see energy, it is all theoretical very abstract which is the big reason for that simulation that since I have been using that for the last two years the students' understanding of energy conservation has increased. It has been awesome for them to see those graphs up and down as the skater goes up and down. If I am doing some sort of abstract concept like that it is imperative to use some sort of visual that gives them more of base to build their theories on.

In the interview, when I prompted about student misconceptions Jeremy expressed that he always searched for them and addressed them using "pictures or simulations." Through using these tools, Jeremy said, he can address students' misconceptions on the spot. In his class, Jeremy strongly encouraged students to ask questions regarding the concept that they are learning. Jeremy expressed that he can easily catch students' prior knowledge and misconceptions when they ask him questions. Benson, on the other hand, when designing a technology rich lesson he focused on the student engagement piece. Thus, he used "media rich or visual" applications at the beginning of his classes. Benson similar to Matt starts with defining the goal of the lesson which he aimed his students to be able to answer "the big question" of the day such as "what is a day?" "what is a season?". Benson also expressed that through asking the big question at the beginning of the class he found students' misconceptions and prior knowledge on that topic. After he defined the big question or defining what he wants his students to accomplish at the end of the lesson, he decided on which simulations, visuals, short video or audio clips to use in that lesson. Interestingly, he expressed that he did not try to integrate the technology into his existing lessons; instead he "focused on the use of the tools." For example, he did not plan how he can teach about volcanoes using Google Earth. Rather, he tried to figure out how he can use Google Earth in his class and which concept can be taught using Google Earth. So he tried to find how he can design his lesson around Google Earth. He did not aim to find how he can include Google Earth into his existing lesson on volcanoes. Benson also pointed out that "good lessons have more student activities"; thus, he tried to integrate various student activities in his classes. Since he teaches 90 minute block classes, for him, it is very important to keep student interest at high levels. He also expressed that students need to see the "defined breaks" between two different activities. Thus, using various visuals also help Benson to show students that they are moving to another activity or concept.

Rare Codes

The rest of the codes in the tree node do not represent all the tree teachers. Some represent only two teachers and a few of them represent only one teacher. Also these codes were coded rarely and classified as rare codes. *Digital microscope* – a subcategory of knowledge and beliefs about curriculum materials (educational technology) and *teachers' multiple role* – a subcategory of teacher identity are two examples of these codes.

Digital Microscope

Matt, for example, was observed using digital microscope various times in his teaching. So the classroom observation notes from those classes coded as digital microscope. It was found that teachers' content area highly influences their decisions on what tools to use in the classroom instruction and students' practices in the class. Benson, for example, taught an elective course on technology to teach students effective use of computers and internet. His students in that class heavily use online forums and discussions. They did not use digital microscope or collect and analyze data using probe ware like Matt's students did.

Teachers' Multiple Roles

Interestingly, the code *teachers' multiple roles* show that teachers play different roles in their classroom. While Benson expressed that he is an "engager" in his class, Matt believed that his role is to "coach" his students, and Jeremy thought that he "guide[s]" his students. Their conceptualization of their roles in their classroom was found to closely reflect their classroom practices. For example, Matt was the teacher who wanted to draw a path for students to follow in their learning. He expressed that his students need "directions." He believed that he needed to give his students specific instructions before they start using the technology in a classroom activity. He did not want his students to get lost or focused on a different aspect of the activity that he planned. For example, in a class project where students searched for information about the urban water cycle, Matt gave the website that students needed to go and looked for information. Matt expressed that if he did not give clear instructions he might ended up "facilitating" a lot more than he would like to. Also, Matt did not want his students missing the science part of his lessons by focusing only on the technology aspect of the lesson. Benson and Jeremy gave some directions to their students to follow in a technology rich class; but not as much as Matt did. In the following quote, Benson talked about a class project that students completed using Google presentation.

> Students are doing two slides only on greenhouse effect and global warming and the differences so they made a double bubble map. What is about one and what is

> about the other? and What have they common and different? They are doing one slide on each. I tried to talk about it as making it more stylish and not doing power point like so there is rules like no bullet, no list, everything you talk about has to link. I talk about it some like futuristic magazine article. So it has to look good and then it has to act like Wikipedia. Everything that you talk about has to have a link to somewhere else and the links have to help build the knowledge of what you are talking about. So, they do not mention methane without linking it unless you just do not intent methane to be like a big deal.

Benson and Jeremy's main goal was to help students learn to enjoy science. They constantly tried to show students the interesting scientific facts and ideas to increase students' interest in science. In Benson' class, students listened a radio podcast about why shower curtain tends to billow inwards and stick to the body of the person who is showering. Benson used that podcast to teach students high and low pressure. In another class, he showed his students a video about Henry Kittenger who lifted off from Earth with a helium balloon and jumped from an air-thin height of 102,800 feet (31,334 meters). He used this video while he was teaching about the layers of the atmosphere. The concept of the video was extremely interesting for the students. It quickly captured student's interest and it was very engaging. Jeremy followed a similar path. He showed various interesting visuals while teaching about Newton's laws to make the topic more attractive and interesting for students. Jeremy and Benson tend to make their classrooms engaging environments. Jeremy put it,

> The students are very different now than I was in high school. They are expecting to see little bit more entertainment site and one way to do it is technology. If you stand up there and write on the white board or chalk board for 45 minutes or 60 minutes whatever they are not going to go for that. They think you are the driest person in the world directly. Whatever you can do put it [the technology] in there, you got to do it.

Matt wanted to build an entertaining environment, but he did more in a controlled and structured way. It was easy to predict during Matt's lessons what he was going to do next; however, especially in Benson's case, it was sometimes hard to predict what he was going to do, present, or ask students to do next especially if I did not have chance to talk to him regarding the lesson before the classroom observation.

In the previous paragraphs, I describe the codes and try to relate those codes to each other (open and axial coding). In the following section, I describe selective coding and cross-case comparisons while explaining main categories in detail and the relationships among those. The connections of the categories to the Deci's (1975) motivation theory will also be discussed.

The research question: How do science teachers' beliefs, knowledge, and identity contribute to their uses of technology in their instruction?

After creating the tree of the categories I started to think about the connections among the categories. I designed a thematic conceptual matrix (Miles & Huberman, 1994) to deepen understanding and explanation of the categories (see Table 9). This display allowed me to find how each category represents the cases and to make contrasts and comparisons among the cases. The matrix basically includes codes and direct quotations. It illustrates that all three teachers achieved some level of technology integration. They all intrinsically motivated to use technology in their teaching; they used variety of technology in their instruction while also allowing students to use them; and they posit a belief set in favor of technology. Benson, Jeremy, and Matt believed the use of technology in classroom instruction increase student engagement, interest in science, and science learning. The main differences were found in the technology tools that teachers used and in the ways that they applied them. Benson mainly used interactive white board, Google applications, online forums, and a variety of multimedia tools; Jack mostly used probe ware, interactive white board, and multimedia tools; Matt, on the other hand, generally applied probe ware, online forums, digital microscope, and various multimedia tools. While most of their classroom practices were found to be student-centered teachers were also observed using technology to present and display content information. Teachers in this study taught in different schools with different levels of technology infrastructure and school organization which seems to influence teachers' technology rich practices. When considering teachers' identity, the matrix shows that all the three teachers love using technology in their everyday lives and classroom instruction. They were determined and willing to learn the technology for personal use and classroom instruction. Reflection after the instruction was another commonality among them.

Table 9
Comparison of the Cases

	Benson	Matt	Jeremy
School Context	-Easy access to laptop carts, clickers, and interactive white board -Supportive colleagues and administrators -Mostly technology savvy students -No mandated tests or curriculum	-Easy access to various technology tools such as laptop computers, Vernier LabPro, digital microscope, interactive white board. -Extremely supportive colleagues and administrators -Almost all students are technology savvy -Mandated curriculum	-Easy access to laptop carts, computer lab, and Vernier LabPro at the first school -Access to the technology was challenging at the second school -Supportive colleagues and administrators in both schools -Mostly technology savvy students -Mandated tests at the first school
Teacher Identity	-Visual learner, very flexible in terms of classroom instruction, feels comfortable using technology, likes experimenting with technology in the classroom, make decisions on the fly, interdependent in the school, teacher-leader, collaborates with other teachers, exploratory behavior	- Feels comfortable using technology and also feels depended on the technology, collaborates with other teachers, willingness, very flexible in terms of classroom instruction	-Visual learner, risk taker, loves to know how things work, feels comfortable using technology, willing to find ways to integrate technology into his teaching, does not fear the technology, finds creative ways to be able to use the technology in his teaching, collaborates with other teachers, exploratory behavior
Intrinsic Motivation	-enjoys using the technology	-enjoys using the technology	-enjoys using the technology
Knowledge and Beliefs about Curriculum Materials (educational	-Interactive white board, multimedia tools - simulations/animations, short	-Interactive whiteboard, Vernier probe ware, multimedia-	-Interactive whiteboard, multimedia-simulations/animations and digital images-, Vernier probe

technology)	video clips, and podcasts-, online forums, Google docs, Google Earth, Voice Thread, Ning	simulations/animations-, digital microscope, online forums, Google Earth	ware, online forums
Knowledge and Beliefs about Instructional Strategies for Teaching Science with Technology	-Uses various activities and representations -Focuses on balancing science and the technology in his instruction -Experiments with educational technology	-Uses various activities -Tailors the technology to his objectives -Gives specific instructions to students before using the technology	-uses various activities
Knowledge and Beliefs about Purposes and Goals for Science Teaching with Technology	-"I am not the science guy" -Only loves to teach Earth Science -Connects Science to everyday lives of the students -"Science is fun"	-"Science is searching out for the truth" -Connects Science to everyday lives of the students	-"Science is an ever changing field of ideas and philosophies" -"Science is fun"
Knowledge and Beliefs about Student Learning with Technology	-Technology allows active learning -"Kids love technology" -Technology is very engaging	-Technology is very engaging -Technology use enhances student learning -"Kids love technology"	-Technology allows active learning -"Kids love technology" - Technology is very engaging -Technology use allows hands-on science -Technology use enhances student learning
The use of Technology in the Classroom – Teacher and Student Practices	Teacher practices: display content information, catch student prior knowledge and misconceptions, collaborate with students, share course material, teach effective uses of the internet, gather student attention Student practices: post blog	Teacher practices: display content information, catch student prior knowledge and misconceptions, share course material, assess student learning Student practices: collect and analyze data, present findings,	Teacher practices: display content information, catch student prior knowledge and misconceptions, share course material Student practices: collect and analyze data, submit assignments electronically, participate in online forums, perform virtual labs

	entries, join online forums, present information, learn efficient internet use	online forums, search information on the web	
Reflection	-Mental process of thinking and evaluating classroom practices and student learning	-Mental process of thinking and evaluating classroom practices and student learning	-Mental process of thinking and evaluating classroom practices and student learning - A part of technology integration process
Rewards/Satisfaction	“Kids love technology”	“Kids love technology”	“Kids love technology”

The selective coding includes understanding how teachers' beliefs, knowledge, and identity influence their technology rich practices through generating themes/assertions from the data. To do this, I revisited the working model of the conceptual framework of the study again. As emphasized earlier, the conceptual framework of this study emerged primarily from Deci's (1975) intrinsic motivation theory and the literature on technology integration. I found that various aspects of the model were supported by the data. However some parts such as emotions did not emerge from the data and the technical support under responsive environment as well. On the other hand a new concept, reflection, was added.

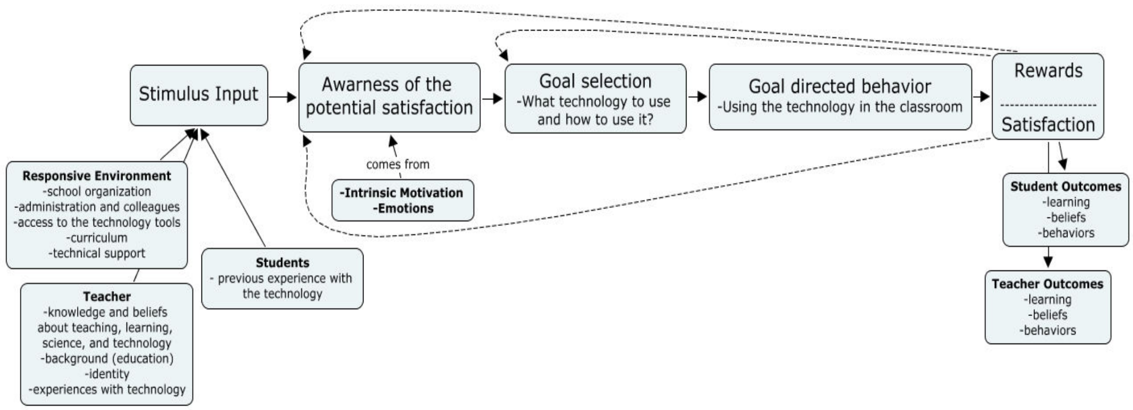

Figure 2: Conceptual framework of the study

The model was modified as below. In the following paragraphs, I explain the model and present data that support the model.

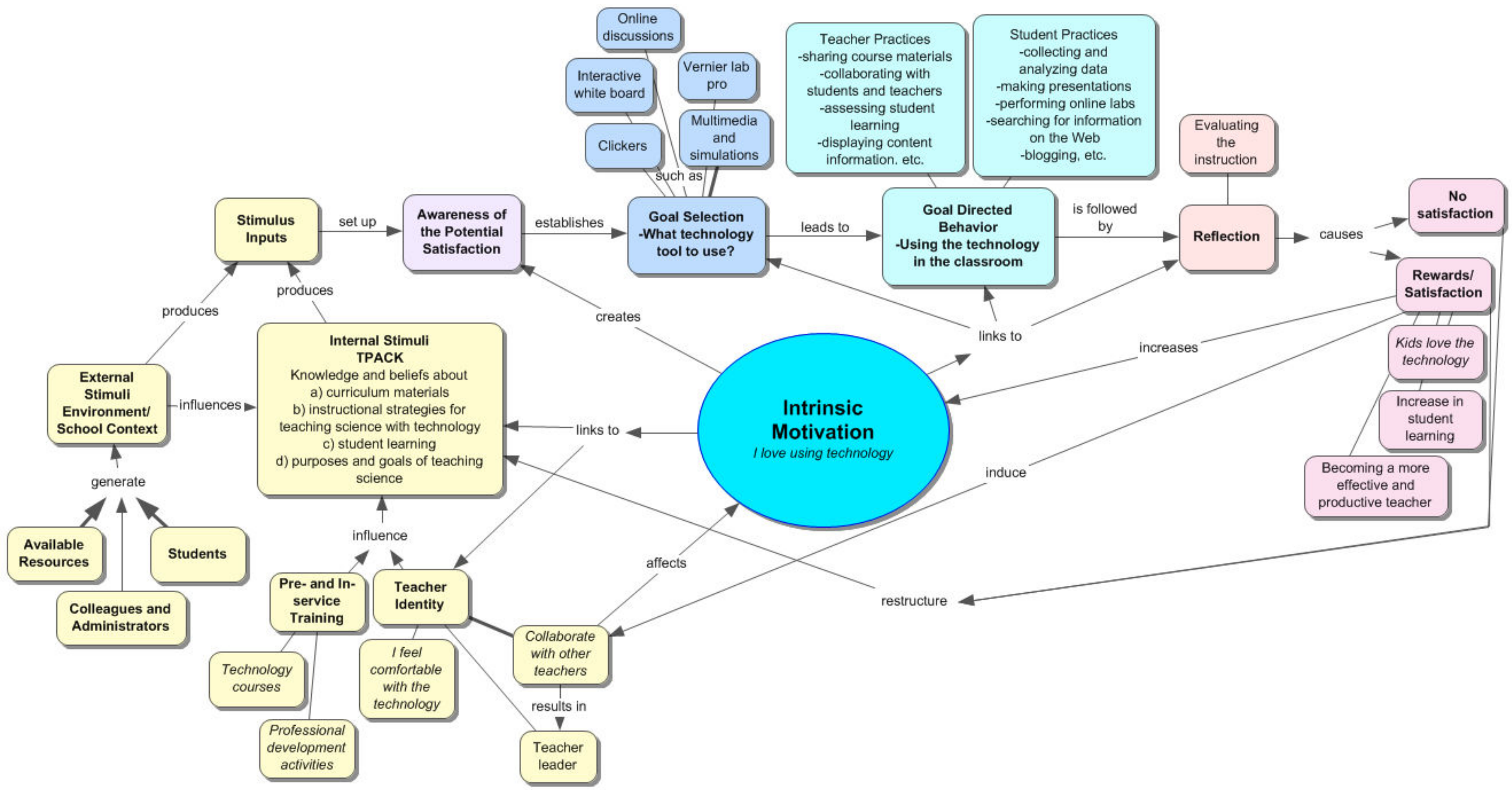

Figure 20. Conceptual model of successful technology integration

The diagram shows the cognitive view of technology integration into classroom instruction. It also shows the interacting components that are critical to the use of technology. The bold arrows represent strong interactions and were defined based on the frequency of the codes. The first element in the model is stimulus inputs. The stimuli can come from the environment and/or the teacher. The teacher and the external stimuli play vital roles in the model; however it was found that the role of the external stimuli is moderate. Three categories form external stimuli: Available resources, students, and colleagues and administration. Having easy access to the educational technology tools heavily influences teachers' decision on what technology to use and how to use it. Students' experiences with technology are also an indicator for teacher's decisions. Even though most of their students are technology savvy, teachers explained that they have also non-tech savvy students in their classrooms; thus, they differentiate their teaching. The influence of available tools and students was found to have bigger impact on teachers' decision than the influence of the colleagues and administration. Teachers mostly focused on what is available for them and if it is appropriate to use the available tools for their students while making decisions about the use of the technology in their classes. In Benson's case, supportive administration had a negative influence on him. His successful practices were appreciated by his administrator and he was asked to participate in several committees in the school. As a result of this, Benson felt pressure on him. Benson expressed that he was working on too many things and he did not want to add another thing on his list.

The internal stimulus in the model is TPACK which is influenced by teachers' pre and in-service training and their identity. Technology savvy teachers were found to look for ways to use technology in their classrooms. They experiment with the technology tools that they have used in their everyday lives to include them into their teaching. Using the technology in everyday life makes it easier or "natural" for the teachers to use the technology for the educational purposes. As Benson puts it, "I think I used the technology a lot in my personal life so it comes in naturally to my teaching life." He continued,

> I use Ning for professional development stuff. I use Facebook for personal stuff. I use Twitter for both. So I see it is very natural for me to extend it to the classroom because it is part of my life so it is not a stretch! I do not have to think a lot about how I am going to facilitate it because I have used it.

Teachers consider their own learning styles while teaching a concept. For example, if they are a visual learner, they think that their students learn science better "by seeing." Thus, they use visuals to display content information. Teachers' own learning style, their comfort level with technology and other personal traits such as collaboration with other teachers to create innovative practices influence their knowledge and beliefs about educational uses of technology and their practices. Those characteristics motivate teachers to learn more about the educational uses of the technology and impact on teachers' beliefs about the effectiveness of the technology on student learning.

In the model, TPACK represents teachers' knowledge and beliefs about curriculum materials particularly educational technology tools, knowledge and beliefs about instructional strategies for science teaching with technology, knowledge and beliefs about purposes and goals of teaching science with technology, and knowledge and beliefs about student learning with technology. The four domains of the TPACK were found to work collaboratively. Here, it is important to note that evaluating teachers' domains of TPACK is not the aim of this study. It was found that the teachers had the four domains of TPACK and the domains function as a part of a whole. Regarding teachers' knowledge and beliefs about curriculum materials particularly educational technology tools it was found that teachers used various technologies in their teaching. Their content area might influence the tools that they choose to use. For example, Benson did not employ probe ware while teaching earth science. On the other hand, Matt and Jeremy both used probe ware in their life science and physics classes. Teachers were found to fully integrate several technologies such as interactive white board and simulations into their teaching. Thus, the use of educational technology has become a part of their everyday teaching. Regarding the knowledge and beliefs about instructional strategies and representations, teachers used various instructional strategies and representations. Teachers were found to mostly employ student-centered activities while applying educational technologies. Depending on their objectives and the tools that they used they employed variety of activities (e.g., from cook-book labs to open-inquiry projects). Considering the knowledge and beliefs about student learning with technology, they all want their students to use technology while developing their content knowledge. Teachers believe that the use of technology in classroom instruction could support students in understanding the science concepts. Finally, regarding the knowledge and beliefs about purposes and goals for science teaching with technology, it was found that teachers recognize the interplay of science and technology and transform their ideas into their teaching.

Teachers apply TPACK to decide what technology tools to use, when and how to use them, and then what might happen in terms of student learning when the technology is used. Before the instruction, they consider their own content knowledge to decide what facts and theories to present to students, they think about the possible technology tools to use and their students' previous experiences with that particular technology tool(s) and their prior knowledge and misconceptions about the content.

Teachers' identity was found to influence their TPACK. Teachers' experiences as students and their interests and abilities seem to contribute to their TPACK. Their purposes for teaching science with technology closely related to their personality. It seems that external factors might also influence on teachers' TPACK particularly development of TPACK. Availability of the resources, students' characteristics, and supportive environment might impact on teachers' knowledge and beliefs.

Pre- and in-service training is another stimulus input and it was found to influence on teachers' TPACK. The educational uses of technology tools that they learned in their pre- and in-service education programs influenced their TPACK development. In this study, all the three teachers were found to be willing to improve their knowledge through attending professional development opportunities and/or self training. For example, Matt explained that:

> I think I have got a fairly significant knowledge about technology and technological tools that I try and keep up by reading new things and seeking out opportunities for further training in different technologies… I think that knowledge helps me be more comfortable and confident as I try out new technologies and technological tools and helps to support my learning and ideas in that regard.

The second element of the model is awareness of the potential satisfaction or the "energy source or the motive" (Deci, 1975, p. 96). This can explain the desire for the use of technology in the instruction. The awareness of satisfaction comes from intrinsic motivation, the desire to use the technology which is the most important part of the model. As Deci (1975) pointed out “the awareness has nothing to do whether or not will the environment will allow satisfaction” (p. 96). The person has the potential to achieve the goal which is using technology and aware that the future stage is going to be more satisfying than the current stage. For example in Jeremy’s case, the environment, his second school, had negative effects on his technology integration efforts; however, his motivation to use technology was not really influenced by not having access to the tools in his school. His motivation, energy, leads him to find ways to keep using technology in his instruction. Feeling satisfaction with the technology enhanced classroom practices also helps teachers to continue to use technology in their instruction. Seeing that the use of technology in the classroom enhance student engagement and interest in science and help students to learn science increase teachers’ motivation to use technology consequently their awareness of the potential satisfaction. For example, in Benson’s case, for the first time he used Ning in his elective technology course he found that his “students love it.” Thus, he decided to keep using it in his elective class and possibly in his environmental science classes.

The third element in the model is goal selection. It is choosing the appropriate tools to present a particular science concept in the classroom. Teachers choose a tool among the set of alternative technology tools. All three teachers were found to use interactive white board, a variety of multimedia tools such as simulations/animations and digital images, and online forums in their teaching. Benson also applied Ning and several Google applications. Jack and Matt, on the other hand, used Vernier probe ware. Matt was also the only teacher who used digital microscope. In his unit on organisms, Matt frequently used the digital microscope. It can be said that teachers choose tools by considering their knowledge, beliefs, content area, students, and availability of the tools since the goal selection happens as a result of processing stimulus inputs.

The fourth element in the model is goal directed behavior – the use of technology in the classroom. In the case of effective technology integration, teachers are expected to allow their students to use the technology tools in their instruction. So technology integration does not just involve in the teachers who use technology to deliver the content information. Thus, in the model the goal directed behavior includes both teacher and student practices. Student practices includes data collection and analysis, joining online discussions, performing virtual labs, searching content information on the internet, and designing class projects. Teacher practices, like student practices, vary. Teachers might use the technology tools to present content information, share class material, to assess student learning, or to catch students' prior knowledge and misconceptions. Various student and teacher practices were observed in classroom observations. As emphasized previously, each teacher was found to achieve some level of technology integration based on what educational technology tools they used and how they used them.

The fifth element in the model is reflection. This element does not occur in Deci's (1975) cognitive model of behavior. This element emerged from teachers' drawings of technology integration and interview data. Jeremy particularly used the word "reflection" in his model of technology integration and emphasized the importance of it. Matt and Benson did not use the word reflection in their model; however, while they were explaining their model and their lesson planning strategies they talked about how they analyze the effectiveness of their lessons and the ways to modify them for next years. Reflection can be very simple, meaning just evaluating the lesson that recently taught, thinking about what went well or wrong, and considering possible ways for modifications. Evaluating students' outcomes such as achievement and motivation and personal outcomes such as knowledge, beliefs, and motivation allow teachers to assess their technology rich classroom practices. Through reflection teachers keep experimenting with the educational technology tools to select most appropriate tools for teaching a particular topic for their students.

Finally, the last element in the model is rewards and satisfaction. Feeling satisfaction after completing an intrinsically motivated behavior allows the person to set up another goal. Rewards can be intrinsic or extrinsic. However, as emphasized earlier, the teachers in this study use technology in their teaching without expecting any external rewards. Conversely, as Benson expressed external rewards such as the appreciation of the principal for Benson's effective practices and subsequent expectations from his principal for Benson to join several faculty committees caused Benson to feel some pressure on him. He simply does not want or need to be rewarded for his successful uses of technology in his teaching by his principal. Interestingly, he applied for the Google academy to be certified as a Google teacher. In this case, he might not expect an external reward; instead, he wanted to be certified as a Google teacher to increase his intrinsic motivation and to achieve his bigger goal – collaboration with other technology enthusiast teachers. Feeling satisfaction or dissatisfaction might cause a readjustment of the beliefs on teaching, learning, and technology tools. Since beliefs links to knowledge and both set up TPACK there exists a feedback loop in the model. This can be called as internalization. In his model, Deci (1975) argues that there are direct feedbacks from satisfaction to the awareness of the potential satisfaction; however, those feedback loops did not emerge from the data.

Assertion*: The major assertion generated from data analyses was that teachers' use of technology in classroom instruction was constructed jointly by their identity, TPACK, and the resources that are available to them and that the internalization of the technology use came from reflection.*

As emphasized earlier, the participants of this study were chosen purposefully since they already had a high motivation to use technology in their classrooms. Teacher identity was found to have critical influences on teachers' decision about the use of technology in their instruction. By teacher identity I mean the *self*. Teacher identity is very complex and multi-faceted. However, in this study I attempted to understand *who they are as teachers* who implement technology-rich lessons. I did not aim to compare their identity with teachers who do not use technology. Instead I tried to find the commonalities regarding their personal and professional identities. It was found that teaching is in fact closely related to identity of the teachers. They weave their identity into their teaching. They have enthusiasm for teaching their subject with using technology and this enthusiasm and motivation are linked to personal identity. Their identity in turn tied directly to their knowledge and beliefs about science, technology, and teaching and learning.

Teacher knowledge of technology tools and beliefs influence their technology rich practices. In the model, knowledge and beliefs placed as stimulus inputs since those are the requirements for teachers for technology integration. Matt and Jeremy continually stressed the importance of their knowledge about students' needs, technology, and pedagogy, and their constructivist beliefs on student learning as important factors on their decision on what tools to use and how to use them. On the other hand, Benson did not explicitly emphasize the importance of his knowledge and beliefs on his technology rich classroom practices. He emphasized that "this is just the way that I teach… I just believe that technology is just the another way of best practice." However, it was found that like Jeremy and Matt, Benson hold constructivist beliefs. This study shows that teachers' practices reflect their beliefs. For successful technology integration teachers should hold constructivist beliefs about student learning. For example, in the following quote Matt expressed how his knowledge and beliefs impact on his teaching.

> I think my knowledge around student learning and my beliefs around student learning through constructivism and through student centered classroom focus me on using tools that allow that experimentation and try and error and looking at the way that knowledge fits together with other pieces of knowledge in unique and hopefully interesting ways.

Jeremy in the following quote explained how the development of his knowledge play a role in his technology-rich classroom practices.

> As I learn more and more about what is available and I learn more about what the students actually do and know in yearly a base, that is changing all the time, that is going to have to change the way that I do with the technology. Plus just the more new things I am able to use, like forum, that I have never able to use before, might be able to look all those responses, the quality of the responses most like I won't be totally satisfied with them, I'll probably want to teach some aspect of it, maybe put a little more restrictions on what they can and cannot post on the forum, little things like that. So they spend less time just chatting and having fun of it and more time doing with what they suppose to be doing.

Benson, like Jeremy and Matt, expressed that he knows the uses of most technology tools. He also expressed that he focused on the tools and worked toward innovative ways to teach Earth Science with those tools. He pointed out that he does not use technology in his teaching just for the sake of technology. His knowledge about technology tools allow him “to see what [he] wants to do and what would be the outcome.”

The school context was found to have a critical influence on teachers’ technology rich practices. Teachers seem to more easily implement their technology supported instruction when they have easy access to the tools. However, it was found that the teachers in this study tried to find ways to use technology in their teaching even when they did not have access to the technology tool in their school. For example, Jeremy, while he was teaching in his second school did not have access to many technology tools. However, he constantly searched for ways to use technology in his teaching. He was searching to buy cheap and old probe ware for his classroom or borrowing some tools from the Science House at the Science Museum. In the case of Benson and Matt, if they did not have access to a particular tool that they planned to use in a specific class, they simply rearranged their lesson plans to be able to teach the preplanned lesson with using technology on a different day. In the following quote Benson gave an example,

> I am doing [the class project] now because the computers are available. Last year, I did differently. We learned more about the atmosphere and then we talked about these two things [green house gasses and global warming] and this year I am doing at these two things way ahead and then we are going to back and talk about the atmosphere. So I will be able to tie in more…I think I do that every year to see if there is a better way to present it and this year I do not… right now I do not think I am going to like it more. If I had my chance I would do these. I was going to do this presentation next week but it just did not fit.

Having access to technology is very important for the teachers; however, for technology enthusiasts not having access to technology is not used as a reason for them for not to use technology in the instruction.

Reflection played a critical role in effective teaching. In this study, it was found that teachers' reflections about the outcomes of technology-rich classroom practices on student learning and themselves allowed them to restructure their knowledge and beliefs about technology. Through reflecting on their practices, they learned the effectiveness of the technology tools on student learning. They also drove decisions about possible ways to use the technology tools in their classes. For Jeremy, reflection allowed him to modify his technology rich classroom practices. He described that action as a cycle: Implementation, reflection, change/implementation (see figure 14 in chapter IV). As shown in figure 14, the implementation after reflection also depends on the teachers' content knowledge, experiences with technology, resources that are available to the teacher, and the teacher's knowledge and beliefs about student learning. So the reflection might push the teacher to learn more about the educational uses of a particular technology tool or his/her beliefs about the effectiveness of that tool. Through reflection, teachers can improve their practices. Jeremy expressed that:

> I think that what I am always reaching for students is never going to be really accomplished. They are both going to keep going up. That is why I keep building more and more tools, keep looking for newer ways, whether it is simulations or technology wise to reach what I want. So as far as I know right now probably never be finished looking for that stuff. But I think the tools for them getting the things that I am finding now are I am able to use them much more effectively than I may have been in the past just because of the seen the student reactions to this and that situation or piece of technology, I am able to learn from that maybe more find tune myself to where they might be interested.

Benson and Matt also draw conclusions every day from their classroom practices. Through reflecting on what and how students learn, how they interact, how technology tools influence on students' learning, how the lesson might be modified they evaluate their teaching. In the interviews, they explained possible ways to modify their lessons based on their evaluations of their teaching and student learning. Through reflecting on practices, for example, Matt decided to change the card sorting activity that he followed at the beginning of his organism unit, Benson decided to use Google presentation instead of iMovie for the volcano project, and Jeremy decided to use online forums more frequently. It is important to note that, none of the teachers used any particular tool to reflect on their teaching. As Benson expressed reflection is simply a part of teaching. Reflecting on classroom instruction allows teachers to sustain their technology-enhanced practices.

Chapter VI: Conclusion, Implications, and Suggestions for Further Research

In the following pages, I summarize the findings of this study while making connections to the results of previous studies. I then discuss some of the implications for principals, teachers, and teacher educators. I conclude by discussing the potential areas of the future research.

Conclusion

The current study aimed to explore teacher-level factors that influence on classroom technology integration. Teachers' beliefs, knowledge, and identity were examined to find how they contribute to teachers' uses of technology in the classroom. The data also provided some insights on 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 were depicted in the model (see Figure 20).

In the model, teacher identity, beliefs, and knowledge were presented as internal stimuli that serve as critical inputs and conditions for technology integration. With respect to teacher identity, it was found that successful technology integration closely related to teachers' identity. As explained earlier in this study teachers' identities were explored while paying considerable attention to their personality and personal characteristics. Unlike most previous research studies, the effects of teacher identity on technology integration have not been investigated through analyzing only teacher demographics data of survey studies (e.g., Becker, 2000, Hadley & Sheingold, 1993). The descriptive methodology that those studies used unfortunately only provides information about commonalities among the technology using teachers; thus, they are limited in providing depth information about teachers' identities. In this qualitative study, a closer, in-depth look at the participating teachers who are motivated to use technology in their classroom practices led into the conclusion that all three teachers in this study are more similar than dissimilar in their characteristics. First of all, they all expressed their desire to teach with technology. Teachers' willingness to learn how to use technology is very critical in the technology integration process (Sheingold & Hadley, 1990). Teachers in this study were found to devote an extensive amount of time and effort to learn the use of educational technology tools. They self teach various applications on their own time to grow professionally and personally.

Exploring new educational technology tools and searching for ways to integrate them into classroom instruction seems to be a common characteristic among these teachers. This exploration allows teachers to see more benefits of technology. They are risk-takers - in other words, they are willing to explore new tools and ways to include them into their teaching to expand their uses of technology. Another pattern is that teachers in this study also feel competent and comfortable in using various technologies; they all expressed that they do not "fear the technology." When a technology related problem occurs during the classroom instruction, they behave calm and make decisions on the fly. They do not fear that they may lose the control over students or have a chaos in the classroom when having a technology crash.

One interesting finding regarding teachers' identity is that these teachers are not fully dependent on others (e.g., colleagues) in terms of technology use. In contrast, they are the teachers whose help is needed by other teachers. Benson, for example, is the technology integration specialist in his school and district, other teachers search for his support and help in using educational technology tools particularly interactive white board. It is also important to note that these teachers are highly successful in collaborating with other teachers. They participate in online discussion forums and social networking sites. They stated that through online discussions with other teachers they found useful resources and lesson planning ideas. Communicating with colleagues who have similar interests in technology and desire to find innovative ways to use technology in the classroom instruction seems to be critical. Thus, the presence of collaboration among other teachers can be seen as a positive factor for technology integration. This finding is consistent with findings from other studies (e.g., Zhao, Pugh, Sheldon, & Byers, 2002).

In addition to using the technology in the classroom, all three teachers emphasized that they use technology in their everyday lives for different purposes. There appeared to be a relationship between teachers' uses of technology in their personal lives and in their classroom instruction. It seems that it is easier to integrate the technology into teaching if teachers are familiar with the technology.

In regards to the demographics of the teachers, they are male and they are in their early thirties. This fact seems to indicate that young age profile and gender might be a determining factor for technology integration. However, earlier studies showed mixed results. Law and Chow (2008), for example, found that age and gender are not direct determining factors for pedagogical adaptation of technology. Sheingold and Hadley (1990) also did not find gender difference in computer use in their survey study. On the other hand, Becker's (1994) survey of teachers who integrated computers into their teaching indicated that males were overrepresented among the computer using teachers who teach science and English. Another pattern is that teachers in this study have high academic qualifications. Both Jeremy and Benson have a M.Ed. degree while Matt was taking courses to complete his M.Ed. during the time of the study. This might explain teachers' competence in both general and pedagogical uses of technology. Becker (1994) also found strong educational credentials as a factor in the positive relationship to computer-using teaching. The author showed that taking more credits and degrees than the other teachers may allow computer-using teachers to have more experience in using computers.

Well-developed TPACK was found to be necessary for successful technology integration. This finding was also supported by previous research (Guzey& Roehrig, 2008; Koehler & Mishra 2008; McCrory, 2008; Niess, 2005). Teachers must draw upon both their knowledge and beliefs about teaching, learning, science, and technology to select appropriate educational technology tools to teach particular topic to their specific group of students. Each teacher was found to have similar beliefs about teaching and learning but differences were found in knowledge about technology and reasons for teaching science. Their knowledge about the educational technology tools reflect the tools that they use in their instruction. Benson, for example, has well-developed knowledge about educational uses of online tools, Google applications, interactive whiteboards, and simulations and animations. Jeremy, on the other hand, knows how to use probe ware, interactive whiteboard, and multimedia. Matt also has well-developed knowledge about probe ware and multimedia. Regarding the reason for teaching science, while Benson wants his students to understand the world around them and appreciate for it, Jeremy wants his students to see that science is a changing field and it is enjoyable and interesting. Matt, on the other hand, wants students to see that science is searching out for the truth and what they learn in their science classes are actually connected to their everyday lives.

In this study it was also found that teachers possessed constructivist, student-centered beliefs regarding teaching and learning. It seems that teachers were aware of the importance of student-centered instruction and allowed students to use technology in the classroom instruction. Teachers see technology as a necessary tool to enhance student learning and to improve their instruction. For them technology rich instruction is very effective in helping students to learn science better. They reported that their students learn best when they are able to "see" things such as visual applications of science concepts. They all overwhelmingly believe that the use of technology in the classroom increases students' interest and motivation. Regarding their own performance, teachers, particularly Benson, believe that technology help them become a more productive teacher. Teachers' beliefs were found to be an indicator of teachers' use of technology in their classrooms (Ertmer, 1999; Ertmer, Paul, Lane, Ross, & Woods, 1999; Honey, M. & Moeller, B., 1990; Levin & Wadmany, 2006; Windschitl & Sahl, 2002).

Teachers' beliefs about student learning and the value of the technology in teaching and learning portray their classroom practices. As emphasized earlier, teachers in this study hold student-centered beliefs. Holding constructivist, student-centered beliefs enable technology using teachers implement constructivist instruction (Windschitl & Sahl, 2002). Teachers in this study mostly employed student-centered classroom practices (e.g., inquiry-based activities, process-skill laboratory activities); however, they also applied teacher-centered classroom practices (e.g., lecture w/o discussion, cookbook laboratory activities). One possible explanation for their use of different activities and techniques in their teaching is that while beliefs play an evident role in teaching they are not the only indicator of teachers' teaching strategies. It was found that availability of the technology resources and teachers' knowledge about those resources, and the science content that is presented to students also impact on teachers' classroom practices.

Although originally this study did not aim to answer the question of whether school-related factors influence technology integration, the findings indicated that the school-related factors are important predictors for technology integration. Various school-based factors interact with teachers' use of technology (Brickner, 1995; Sandholtz, Ringstaff, & Dwyer, 1997; Zhao, Pugh, Sheldon, & Byers, 2002). School-related factors such as 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. Unlike most previous studies (e.g., Law, 2008), technical support was not found to be the main factor that impact the teachers' technology-rich practices. The availability of the technology is a necessary condition; however, in this study it was found that not having available resources at the school is not an excuse for teachers for not using technology in the classroom. In the case of Jeremy, he did not have access to technology tools in his second school but he searched for ways to use technology in his classroom and he was able to employ a couple technology-rich lessons. This finding suggests that teachers need to make efforts to be able to integrate technology into their teaching if the school technology infrastructure does not offer easy access to the technology. Regarding the availability of the tools, previous studies also showed that having available technology tools does not necessarily lead teachers to use technology (e.g., OTA, 1995) or to apply constructivist instruction (e.g., Windschitl & Sahl, 2002). These findings demonstrate the vital role of teacher-level factors on technology integration.

In regards to the stimulus inputs discussed in above paragraphs, the priority and importance of those factors are different for each teacher. For example, for Benson having enough time to design and implement technology rich lesson is very important. Collaboration with "like minded people" is very critical for him since it is one way to decrease the amount of time to create new technology rich lessons. Having access to the computers in the school and supportive school environment are other necessities. On the other hand, for Matt his beliefs, knowledge, and students are most important factors that influence his technology rich instruction. He expressed that teachers have to hold "constructivist beliefs" and have enough "experience with technology" in order to include technology into classroom teaching. Supportive administration and colleagues and access to technology were also critical for him. For Jeremy, applying technology in his teaching is a cyclical process. His knowledge about students, content, and pedagogy and the available resources influence his practices. He reflected on his practices and gave decisions for further implementation. For the teachers, their knowledge and beliefs about technology, students, and content, the school environment are all stimulus inputs. For each teacher, each factor has different level of importance.

In addition to the teacher identity, knowledge, and beliefs that are presented as stimulus inputs in the model, teacher motivation is another critical component of the model. It is important to note that all three teachers use technology in their instruction without expecting any rewards from their colleagues or administrators. None of them are pushed to use technology in the classroom. Using technology in the classroom is their choice. Hadley and Sheingold's (1993) findings of a nationwide survey of around 600 technology using teachers also demonstrated that teacher motivation is one of the main factors for teachers to accomplish technology integration. The authors found that teachers who integrate technology successfully into their teaching have high motivation in and commitment to using technology for instruction.

Considering the technology integration, one very important point is sustainability. This study suggests that sustained technology integration involved in reflecting 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 sustained technology use in the classroom instruction. Reflection is a vital component of the model.

The importance of reflection in technology-rich teaching has also been emphasized in previous literature (Ertmer, 1999). Reflection can take place in variety of forms. Teachers, for example, can engage with other teachers to discuss and evaluate their technology-enhanced practices, conduct self-study, or use specific tools (e.g., online journals) that are aimed to help them to reflect on their practices. It is important to note that, in this study, it was found that for the participating teachers reflection is a way of thinking; it is a step by step process for them where they first look at their classroom instruction during and after the instruction, evaluate student learning, create alternative methods, and then try those methods in their instruction. Thus, reflective teaching is a part of their everyday teaching.

Interaction among the Factors

Thus far, teacher-level factors, school-level factors and the critical elements of the model were discussed. Each of them was described separately; however, the interaction among those also needed to be discussed. In this study, teachers' identity was found to contribute to teachers' knowledge and practices. The findings of this study show that teachers rely on their identity to shape their knowledge and beliefs. While teacher identity seems to contribute to TPACK, pre-and in-service training also contributes to teachers' TPACK. In this study, teachers had already known various educational technologies when they started their teaching. They took a subject specific technology course in their teacher education program. After receiving their licensure they kept learning new tools and new ways of using educational technologies through self training and through participating in professional development opportunities. Teachers were found to be willing to update their knowledge about technology. While it was found that the factors related to the teacher play a more significant role than the school-based factors, the effects of school related factors on technology integration cannot be underestimate. A weak relationship was discovered among the school-based factors and teachers' TPACK. However, more data is needed to show the influence of school-based factors on teachers' development of TPACK.

In conclusion, from the above-given discussion of the findings, it can be argued that the findings represent the model (see Chapter 2) that was created through modifying Deci's (1975) cognitive approach to behavior shed new light on teachers' technology integration efforts. Various models of successful technology integration have been created (e.g., Zhao & Franks, 2003; Zhao, Pugh, Sheldon, Byers, 2002; Tong & Trinidad, 2005); however, since most of these models (e.g., Tong & Trinidad, 2005) attempt to include all the teacher-level, school-level, and national-level factors and treat those as independent variables they fail to explain some factors and also relationships among those factors. The model that was developed from the findings of this study provides a much deeper understanding of the teacher-level factors, the complex relationship among them and the effects of school-level factors on them.

The model of the current study allowed seeing the technology integration process and the relationship among teacher-level factors and also school-level factors. The model demonstrates that the teachers' use of technology in classroom instruction was constructed jointly by their identity, TPACK, and the resources that have available for them and the sustained technology use comes from reflection. It also shows how complex the technology integration is. Even though the model is created for science teachers it can be used to understand the technology integration efforts of teachers of different subject areas.

Implications

There are several implications of the current study. First, in a school organization technology should be considered as a useful tool so that teachers can successfully integrate technology into their teaching. Teachers with the goal of using technology in classroom instruction could not achieve technology integration in schools if technology were treated as an unnecessary tool. As in the case of Matt, he could not achieve technology integration in his previous school since the school administrators did not pay enough attention to technology use in classroom instruction.

Second, this study implies that the administration should allow enough flexibility for teachers to make decisions regarding the use of technology in the classroom instruction. All three teachers in this study closely worked with their colleagues to decide what topics to cover; however, they all had enough flexibility to follow their own instructional strategies. They made their own decisions while planning lessons; they chose what technology tool to use in their lessons. Neither administrators nor colleagues forced them to use a particular tool in a certain way in classroom instruction. Teachers in this study used particular technology tools in their teaching based on their own judgment and insights.

Third, the presence of professional collaboration seems to be crucial to the technology integration. All three teachers expressed that designing technology-rich lesson plans takes time. Collaboration with other teachers through online or face-to-face discussions help teachers decrease the amount of time that they need to spend in designing technology enrich lesson plans. Thus, administrators might allow teachers time to design lesson plans that incorporate technology. It also seems important that teachers need to attend professional development opportunities to learn innovative lesson plans and to update their knowledge of technology. Thus, administrators should also provide teachers high-quality professional development.

Fourth, this study implies that having access to the technology outside the school seems impact teachers' technology integration efforts. In this study, all the three teachers used technology in their personal lives. It is easier for them to use some of those tools in their classroom since they do not need to spend extra time to learn about those tools for classroom instruction.

Finally, teacher education programs would influence teachers on adopting technology use when teaching. Teachers in this study graduated from a teacher education program that focuses on reform-based teaching. They were required to take content 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. It would be beneficial if teachers are required to take technology courses in their teacher education program. In these courses, teachers might also see the effectiveness of the use of technology on learning and might decrease their fear of technology. It is important to provide teachers with opportunities to explore and practice with various technology tools in technology courses. As in the case of the teachers in this study, while they use some common educational technology tools each also uses tools that are more appropriate to teach their content area. Another critical aspect is that teachers should be allowed to check out educational technology tools that they practice within their technology courses to explore them more on their own time. More practice and self exploration might help them increase their comfort level with the technology tools. Finally, providing model lessons that include technology applications is vital. Most beginning teachers do not have enough time to create new technology-rich lessons. During the early years of teaching, it would be easier for them to follow the existing plans with some modifications to meet their own students' needs.

Suggestions for Further Research

The findings and implications of this study lead to some questions that need to be answered in further investigations. They are as follows:

1. A necessary next step would be to conduct a comparative study between teachers who have achieved technology integration and teachers who could not. There have been conducted various survey studies to find the factors that influence on technology use; however, a few qualitative studies have been conducted to investigate the impact of factors on adopting technology in classroom technology (e.g., Zhao, Pugh, Sheldon, & Byers, 2002). A comparison study might help to find further connections among the teacher-level and school-level factors and how these affect the pedagogical uses of technology.

2. Another study would be to examine the teachers who teach the same subject in different school settings using educational technologies. Teachers previously discussed in this study taught different science subjects. Jeremy

taught Physics, Benson taught Earth Science, and Matt taught Life Science. A study with only Earth Science teachers or Physics teachers or Biology teachers might shed new light on the pedagogical practices of teachers using technology.

3. Finally, a study that includes students and teachers would examine the effects of various pedagogical practices using technology on student learning. This further research could uncover the relationship between student progress and learning outcomes and teachers' uses of technology.

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Appendix A

Observation Protocol

I. Background Information

Teacher Name		**School**			
Subject observed		**Grade level**			
Observation is (circle or bold one)	In-field		Out- of-field		
Date		**Start time**		**End time**	
Traditional/Block		**Meet 5 days or 3-4 days**			
Observer		**Observation#**			
Number of students in class:					

*Protocol regarding the observational coding

- The first priority should be to take notes about the lesson. This will be recorded under III. Description of events over time.
- Record the most salient event during the 5 minute data collection periods. For example, students may work individually and the may work in groups. If they spend more time individually, then code the 5 minute segment as individual.
- Under cognitive activity, code what happens and not the intent of the lesson.
- At the end of the lesson code the 10 items for "quality" of instruction

Try to observe a variety of classes that represent the content areas that are taught.

II. Contextual Background and Activities

A. Objective for lesson (ask teacher before observing):

B. How does the lesson fit in the current context of instruction (e.g. connection to previous or other lessons)?

C. Classroom setting: (space, seating arrangements, etc. Include a diagram, if possible).

D. Any relevant details about the time, day, students, or teacher that you think are important? (i.e.: teacher bad day, day before spring break, pep rally previous hour, etc.)

III. Detail log/transcript of the classroom observation (indicate time when the activity changes)

Elapse Time Start time:	**Observation Notes** (Note: *=Critical Incident)
End time:	

IV. Evaluation of the class in 5-minute increments.

Time in minutes	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60
Instruction												
Organization												
Student												
Cognitive												

Time in minutes	60-65	65-70	70-75	75-80	80-85	85-90	90-95	95-100	100-105	105-110	110-115
Instruction											
Organization											
Student											
Cognitive											

Key ---*Note:* Type of Instruction - requires two codes: type of activity and organization (Ind, Group etc.)

Activity codes			
B	bellwork	RP	research project
Lec	teacher led lecture w/o discussion	SR	student reading assigned material
LWD	teacher-led class discussion	SP	student presentations
Dir	teacher directions	TB	students working from textbook
Dem	teacher-led demonstration	WK	students completing worksheet
Sim	teacher-led simulation	V	video/film/DVD
RT	teacher-led review-tes	HA	homework assigned
RH	teacher-led review-homework/previous day	HC	homework collected
RI	teacher-led-in class assignment	FT	out-of-class experience (field trip)
LI	inquiry lab/activity	AD	administrative task
LG	guided inquiry lab/activity	Q	quiz
LD	directed inquiry lab/activity	I	interruption
LV	verification lab/activity	NS	non-science instruction
LP	process/skills lab/activity	O	other ________________________ (please specify)

Organization Codes		Student Attention to Lesson	
WG	whole group	LE	low attention, 80% or more of the students off-task. Most students are obviously off-task – heads on desks, staring out of the window, chatting with neighbors, etc.
SG	small group	ME	medium attention, 50% of students are attending to the lesson.
CL	cooperative learning	HE	high attention, 80% or more of the students are attending to the lesson. Most students are engaged with the activity at hand – taking notes or looking at the teacher during lecture, writing on the worksheet, most students are volunteering ideas during a discussion, all student are engaged in small group discussions even without the presence of the teacher.
Ind	students working individually on assignments		

Cognitive Activity

1 Receipt of Knowledge--(i.e., lecture, reading textbook, etc.) Students are getting the information from either a teacher or book. This generally includes listening to a lecture, going over homework or watching the teacher verify a concept through a demonstration or working problems at the board. The critical feature is that students are not doing anything with the information.

2 Application of Procedural Knowledge-Students apply their knowledge (from Bloom's taxonomy: Use a concept in a new situation or unprompted use of an abstraction. Applies what was learned in the classroom into novel situations in

the work place.). This typically involves students using what they have learned, doing worksheets, practicing problems, or building skills. The critical feature is simple application of information or practicing a skill.

3 Knowledge Representation-organizing, describing, categorizing. Students manipulate information. This is a step beyond application. Students are re-organizing, categorizing, or attempting to represent what they have learned in a different way – for example, generating a chart or graph from their data, drawing diagrams to represent molecular behavior, concept mapping.

4 Knowledge Construction-higher order thinking, generating, inventing, revising, etc. Students create new meaning. Students might be generating ideas, or solving novel problems. For example generating patterns across three different data sets, drawing their own conclusions, articulating an opinion in a discussion or debate.

5 Other-e.g. classroom disruption

Appendix B

Interview Protocols

First Interview:

1. Tell me about your teaching career

2. How would you describe your school?

   -What is it like to teach in this school?

   -Are there any contextual factors that influence your teaching?

   -Do you have a curriculum that you are expected to use? In your view, is it a good curriculum? Does this curriculum provide you some freedom?

   -Are there any tests that you are required to give to your students?

3. I want you to think about what knowledge a science teacher need to teach with technology.

   -Now can you draw a representation of what knowledge a science teacher need to teach with technology? OR can you draw me a concept map that represents what knowledge a science teacher needs to teach science with technology?

   -Can you give me an explanation of this drawing?

4. Tell me about your personal experiences with technology.

5. My understanding is that you incorporate technology into your teaching. In what routines do you use technology? What technology tools do you mostly use? Why do you use those particular technology tools? How do you decide when and how to use technology tools in your classroom?

6. Why do you think it is important to teach science with technology? OR What it means to you to teach science with technology?

7. What is your role as a teacher in a technology rich classroom? What is your students' role?

8. How do your students learn science best in a technology enhanced learning environment? What strategies do you use to scaffold student learning in your classroom? How does technology tools support student learning?

9. How do you decide what to teach and what not to teach?

10. How do you design technology rich lesson plans? OR What do you consider while you are planning a lesson?

    -Do you consider students' prior knowledge? Can you give an example?

    -Do you consider students' misconceptions? Can you give an example?

    -Do you consider variations in student understanding? Can you give me an example?

11. How do you assess student learning in your classroom?

    (If time allows)

1. What it means to you to teach science as inquiry?

2. How often do you use inquiry in your classroom? Can you give me an example of your inquiry activity? Did this activity include any technology tools?

3. Do you think technology can support and enhance inquiry? If so how?

4. What are the difficulties and limitations connected with teaching science as inquiry? What strategies do you use to overcome these difficulties?

Second Interview:

1. How are things going since we last talked?

2. Tell me about the unit that you are teaching.

3. Tell me about a lesson in your current teaching unit that you were pleased with.

    - You mentioned that you used technology tools in this lesson. How did you decide what tools to use in this lesson? How is that fit with how you teach? Can you think of other tools that might be used to teach this lesson? If yes, how do you decide what to use?

    - You did not mention that you used technology tools in this lesson. Do you think technology might have been useful in this lesson? Probe: Why not?

4. Tell me about a technology-rich lesson in your current teaching unit that you were not pleased with. How would you modify that lesson?

5. I understand that you have used (the names of the tools) in your current teaching unit and I saw you using the (the names of the tools). What are the other technology tools that you use in your teaching? Can you tell me when you used them and how you used them in your teaching?

6. I understand that you have integrated technology into your teaching. How would you describe yourself as a technology-using teacher? Can you think of anything about your personality or characteristic that you think affect your use of technology?

7. In the last interview, we did not talk much about your students. Can you tell me how technology might influence student learning? Any examples? How the technology works with students? OR Could you tell me how do you see your beliefs about student learning match or mismatch your use of technology

8. So far, we have talked about technology, students, and science. Could you tell me how do you see your knowledge about technology, students, and science might affect your use of technology?

9. What is your advice to other science teachers who try to incorporate technology into their teaching?

10. Knowing that my research is aiming to understand personal factors that shape teachers' uses of technology, is there any additional information that you would like to share regarding your beliefs, knowledge, and teaching that we have not talked about, that would be helpful for me to know?

Appendix C

NVivo Codes

Tree Nodes

Name

- Environment (School Context)
  - Available resources
  - Colleagues and administration
    - School politics
  - Curriculum
  - Mandated school tests
  - Students
    - Kids are tech savvy
      - Students are more flexible than we are
      - Students feel comfortable
    - Non-tech-savvy students
    - Student characteristics
- Intrinsic Motivation
  - I enjoy using technology
- Reflection
  - Reflection during and after the instruction
- Rewards and Satisfaction
  - Increase in student understanding
  - Kids love technology
  - Saving time and being more efficient
- Teacher Identity
  - Collaborating with teachers
  - Determined
  - Exploratory behavior
  - I am a visual learner
  - I am flexible
  - I become dependent on technology
  - I do not fear the technology
  - I feel comfortable with the technology
  - I like knowing how things work
  - Interdependent
  - Make decisions on the fly
  - Risk taker
  - Teacher-leader
    - Frustration with non-tech-savvy teachers
    - Technology integration specialist
  - Teacher's multiple roles

Name

- I am an engager
- I am coaching students

- Technology Use in the Classroom
  - Student Practices
    - Collecting and analyzing data
    - Creating something
    - Joining online tutoring
    - Learning efficient internet use
      - Blogging
    - Making presentations using Google docs
    - Performing virtual labs
    - Searching information on the Web
    - Sharing data
    - Submitting assignments electronically
    - Writing online forums
  - Teacher Practices
    - Assessing student learning
    - Catching students' prior knowledge and misconceptions
    - Collaborating with students
    - Displaying content information
    - Gathering student attention
    - Sharing course material
    - Teaching effective use of computers and the internet
- TPACK
  - Knowledge and Beliefs about Curriculum Materials (Educational Technology)
    - Active board-Interactive white board
    - Active expressions-Clickers
    - Class web site
    - Concept mapping
    - Digital images
    - Digital microscope
    - Google docs
    - Google Earth
    - Laptop computers
      - Online exam
    - Logger probe-Probeware
    - Ning
    - Podcast

Name

- Short video clips
- Simulations
- Voice thread
- Web assign (online tool)
- What to use
  - Pre- and in-service training
  - Self training
- Knowledge and Beliefs about Instructional Strategies for Teaching Science with Technology
  - Activities
    - Cook-book lab
    - Inquiry-based activity
    - Lecture with discussion
    - Process-skill lab
    - Student-led simulation
    - Students completing projects
    - Students completing test
    - Students completing worksheet
    - Students writing lab reports
    - Teacher-led demonstration
    - Teacher-led discussion
    - Teacher-led review previous day
  - Balancing Science and the technology
  - Covering the standards
  - Differentiating teaching style
  - Giving specific instructions
  - Lesson planning
  - Sticking to the schedule
  - Tailoring the technology to objectives
  - Technology is just the way I teach
  - Trial and error
  - Using representations
- Knowledge and Beliefs about Purposes and Goals for Science teaching with Technology
  - Connecting science to everyday lives of students
  - I am not the science guy
  - It is hard to do a lab about plate tectonics
  - Safe and economic experimentation
  - Science and technology cannot be separated
  - Science is a changing field
  - Science is searching out the truth
  - Technology fits my goals

Name
Knowledge and Beliefs about Student Learning with Technology
Active participation
Engaging
Enhance student learning
Hands-on science learning
I can see understanding
Kids love technology
Pictures tell more than words