Fall 2013

Investigating the Learning to Teach Process: Pedagogy, Innovation Adoption, Expertise Development, and Technology Integration

Sun Yan  
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Entitled
Investigating the learning to teach process: Pedagogy, innovation adoption, expertise development, and technology integration

For the degree of Doctor of Philosophy

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Head of the Graduate Program Date
INVESTIGATING THE LEARNING TO TEACH PROCESS: PEDAGOGY,
INNOVATION ADOPTION, EXPERTISE DEVELOPMENT, AND TECHNOLOGY INTEGRATION

A Dissertation
Submitted to the Faculty
of
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by
Yan Sun

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ABSTRACT


This dissertation reported three studies whose overarching purpose is to enhance our understanding about how teachers learn to teach by revealing the learning to teach process. Each of three studies revealed the learning to teach process from different perspectives. Guided by the Pedagogical Content Knowledge (PCK) framework, the first study revealed the learning process of elementary teachers’ development of engineering PCK through engineering teaching practices. Approaching elementary teachers’ learning to teach engineering from the perspectives of innovation adoption and expertise development, the second study revealed the learning to teach engineering process by constructing a framework depicting the stages and dimensions involved in the elementary engineering education (EEE) adoption process and the EEE expertise development process. A phenomenological approach was adopted in both the first and the second studies. The third study, using a two-phase explanatory sequential mixed methods research design, revealed the process of learning to teach with education technology during student teaching by showing how pre-service teachers’ progress in readiness for technology integration was affected by various contextual- and personal-level factors.
Each of the three studies contributes to our understanding of how teachers learn to teach through teaching practices. The learning to teach processes revealed in the three studies carry important implications for professional development and teacher preparation.
CHAPTER 1. THE LEARNING TO TEACH PROCESS: AN OVERVIEW

This dissertation consists of three studies. Centering on the lived classroom teaching experiences of in-service teachers and pre-service teachers, the three studies were intended to shed light on how teachers learn to teach by revealing the learning to teach process. One of the key assumptions about learning to teach proposed by Britzman (2003) in her critical study of learning to teach is that “there is no single story of learning to teach” (p. 20). The three studies provided evidence supporting this assumption: Guided by different theoretical perspectives, the three studies presented three learning to teach stories, each of which revealed a learning to teach process contributing to our understanding of how teachers learn to teach.

This chapter serves as an overview of the three studies. In addition to the “who”, “what”, “where”, and “when” about them, the overview also gives an introduction of the theoretical frameworks underpinning the three studies and the research methods adopted in these studies.

1.1 Understand the Learning to Teach Process: Theoretical Underpinnings

We need to understand how students learn in order to help them learn effectively. In a similar vein, we need to understand how teachers learn to teach in order to better prepare them for teaching. The overarching purpose of this dissertation is to enhance our
understanding of how teachers learn to teach by means of revealing the learning to teach process, and the three studies (referred hereafter as Study I, Study II, and Study III) in this dissertation were conducted to serve this purpose. While Study I and Study II focused on showing the learning to teach processes where elementary teachers learn to teach engineering to elementary students, Study III sought to unfold the learning to teach process where pre-service teachers learn to teach with educational technologies during student teaching.

1.1.1 Learning and Learning to Teach: Who, What, Where, and When

To look into teachers’ learning to teach and to understand it, the first question that needs to be answered is “what is learning?” Learning is defined by Alexander, Schallert, and Reynolds (2009) as follows:

Learning is a multidimensional process that results in a relatively enduring change in a person or persons, and consequently how that person or persons will perceive the world and reciprocally respond to its affordances physically, psychologically, and socially. The process of learning has as its foundation the systemic, dynamic, and interactive relation between the nature of the learner and the object of the learning as ecologically situated in a given time and place as well as over time. (p.186)

Learning, as explained in the definition, is a dynamic and multidimensional process that is content-related, learner-dependent, situation-bound, and context-specific. These characteristics have rendered learning a “comprehensive but elusive construct” (Alexander, Schallert, & Reynolds, 2009, p. 180) which does not easily lend itself to
empirical investigation unless the four elements—the learning content, learning context, the learner, and the learning situation—are clearly defined. These four elements correspond to the “what, where, who, and when” dimensions of learning which should be included in any comprehensive theoretical perspective of learning (Alexander, Schallert, & Reynolds, 2009). The learners (or the “who”) in Study I and Study II were in-service elementary teachers, and in Study III were pre-service teachers. For the in-service elementary teachers in Study I and Study II, the learning content (or the “what”) was learning to teach engineering to elementary students; for the pre-service teachers in Study III, it was learning to teach with educational technologies. The learning contexts (or the “where”) were the real world K-12 classrooms for all three studies, which means that the teachers in all three studies were learning to teach through real classroom teaching practices. The learning situations (or the “when”) were: for the in-service elementary teachers in Study I and Study II, the learning to teach took place after they finished an engineering professional development program, and for the pre-service teachers in Study III, the learning to teach took place when they were doing their student teaching.

The elementary teachers in Study I and Study II attended an engineering professional development program before starting real classroom engineering teaching, and the pre-service teachers took courses about or requiring educational technology uses. So, it is fair to say that learning to teach engineering and learning to teach with educational technology also took place respectively in professional development classrooms and in classrooms of teacher education programs. But, the three studies focused on the learning to teach process taking place in real K-12 classrooms. Such focus
originated from my constructivist view about learning and was determined by the nature of teaching.

From a constructivist point of view, learning is a dynamic internal process where learners actively “construct” knowledge by connecting new information to what they already know (Falk, 2009), and knowledge is constructed in the mind of the learner as a consequence of working through real-world situations (Falance, 2001). Adopting a constructivist view towards learning, the three studies sought to reveal the participating teachers’ learning to teach through real-world situations embedded in real classroom teaching practices. The decision of investigating teachers’ learning to teach process through real classroom practices was made also in view of the nature of teaching. As pointed out by Cohen (1988), “teaching is a practice of human improvement” (p. 55). On one hand, teaching is a profession deeply rooted in practice, justifying the relevance of studying teachers’ learning to teach process through real classroom practices. On the other hand, teaching as a practice of human improvement indicates that teaching “practitioners depend on their clients to achieve any results” (Cohen, 1988, p. 57). Labaree (2000) elaborated this idea when discussing the nature of teaching by comparing teachers with surgeons and lawyers: “A surgeon can fix the ailment of a patient who sleeps through the operation, and a lawyer can successfully defend a client who remains mute during the trial, but success for a teacher depends heavily on the active cooperation of the student” (p.228). Labaree quoted Dewey (1933) that “There is the same exact equation between teaching and learning that there is between selling and buying” (as quoted in Labaree, 2000, p. 228), and pointed out that there is a reciprocal relationship between teachers and students: “you can’t be a good salesperson unless someone is
buying, and you can’t be a good teacher unless someone is learning” (Labaree, 2000, p.228). The reciprocal relationship highlights the importance of including students in the landscape of research investigating teachers’ learning to teach, or in other words, the importance of focusing on teachers’ teaching practices where students are an essential part.

Embracing a constructivist view of learning and based on an understanding of the nature of teaching as discussed above, the three studies looked into teachers’ real classroom teaching practices, seeking to reveal different aspects of the learning to teach process. Given the uncertainty and constraints that are daily life in classrooms and schools, the learning to teach process will never be as static and direct as described in the idealized story of learning to teach which says that “classroom experience guarantees the teachers’ continuity and progress” (Britzman, 2003, p.4). The learning to teach process is evolving and dynamic. The three studies were intended to capture the dynamics of the learning to teach process where teachers confront the uncertainty and constraints in classrooms and schools, cope with the tensions between teaching and learning, and interact with the students, the classrooms and school contexts, and the instructional content, to make meaning about teaching and to turn meaning into insights.

1.1.2 Investigating the Learning to Teach Process: Theoretical Frameworks

As mentioned above, teaching is a complex multifaceted activity requiring a wide range of knowledge, skills, and personal attributes. This characteristic of teaching makes the learning to teach process even more complex. To ensure that the investigation of the learning to teach process remained focused and fruitful, each of the three studies was
As demonstrated in Figure 1, all three studies situated the investigation of the learning to teach process in the participating teachers’ real classrooms teaching practices and viewed the practices as a complex that synthesizes content, pedagogy, and factors related to students and classroom and school contexts. The three studies looked into the teachers’ teaching practices through specific theoretical lenses. Specifically, using the
Pedagogical Content Knowledge (PCK) framework (Shulman, 1986, 1987) as its theoretical framework, Study I investigated how elementary teachers constructed their PCK for teaching engineering to elementary students through their real classroom engineering teaching practices. Through the lenses furnished by Rogers’s (2003) diffusion of innovations model, the Concerns-Based Adoption Model (CBAM) (Hall & Hord, 1987, 2005; Hord, Rutherford, Huling-Austin, & Hall, 1987), and Dreyfus and Dreyfus’s skill acquisition model (Dreyfus, 2004; Dreyfus & Dreyfus, 1980), study II examined the participating elementary teachers’ engineering teaching practices to reveal the elementary engineering educational (EEE) adoption process and the EEE expertise development process. Study III investigated how student teaching practice influenced the participating pre-service teachers’ readiness for technology integration which was measured with the guidance from the Technological Pedagogical Content Knowledge (TPACK) framework and previous research findings of self-efficacy beliefs about technology integration (e.g., Albion, 1999; Lin & Lu, 2010; Mueller et al, 2008; Piper, 2003; Wang, Ertmer, and Newby, 2004).

1.2 Research Methods

I hold the view that research is not so much a matter of preference as a matter of positioning. Positioning, for me, means to critically examine where my research and my research questions stand in the literature, and then determine what would be the best possible method helping answer my research questions. In Study I, teaching engineering to elementary students is a new phenomenon (Cunningham, 2008) and there is little research on engineering PCK development among elementary teachers, which made the
research in Study I quite exploratory in nature. Given this exploratory nature and in view of the tacit nature of professional knowledge (Schön, 1983), a phenomenological approach was adopted in Study I, and face-to-face interview data and open-ended online survey data were collected, allowing the elementary teachers to lead me through their lived engineering teaching experience and to unravel the pedagogical reasoning behind their instructional decisions. The analysis of the qualitative interview and survey data was inductive, allowing the data to tell me how the elementary teachers constructed their PCK for teaching engineering through engineering teaching practices.

In Study II, although there have been innovation adoption models (e.g. Rogers’s diffusion of innovations model and CBAM) and expertise development models (e.g., Dreyfus and Dreyfus’s skill acquisition model) developed in previous innovation and expertise development research, these models are generic in nature and there are no models specifically addressing EEE adoption and EEE expertise development. So, similar to Study I, a phenomenological approach was adopted in study II, and face-to-face interview data and open-ended online survey data were used for constructing a framework depicting the EEE adoption process and the EEE expertise development process. The data analysis in Study II was different from Study I. Adopting an analytic induction approach (Patton, 2002), the analysis of the qualitative interview and survey data was first deductive and then inductive. In the deductive phase, the analysis was guided by the presumptions derived from Rogers’s diffusion of innovations model (Rogers, 2003), CBAM (Hall & Hord, 1987, 2005), and Dreyfus and Dreyfus’s skill acquisition model (Dreyfus, 2004) to construct a prototype of the EEE adoption and expertise development framework. Then, in the inductive phase, the analysis was to
identify themes and patterns from the data to revise the prototype and build it into a final framework.

In Study III, the literature is replete with research on technology integration, on the benefits of student teaching experience to pre-service teachers, and on the factors affecting pre-service teachers’ technology uses during student teaching. Previous research studies made it possible to quantify the impact of student teaching experience on pre-service teachers’ readiness for technology integration in Study III. A two-phase explanatory sequential mixed methods research design (Creswell, 2009) was adopted in study III with quantitative online survey data collected in phase I and face-to-face interview data collected in phase II. Growth curve modeling was used to analyze the quantitative online survey data. The analysis of the qualitative interview data was first deductive for the purpose of helping interpret the quantitative analysis results. Then, the analysis of the interview data was inductive for the purpose of identifying themes and patterns that could help further our understandings about the influence of student teaching experience on pre-service teachers’ readiness for technology integration.

Each of the following chapters presents a single study: chapter 2 for Study I, chapter 3 for Study II, and chapter 4 for Study III. The final chapter (chapter 5) is a conclusion chapter. All references are placed in a single bibliography section at the end.
CHAPTER 2. FROM KNOWING-ABOUT TO KNOWING-TO: DEVELOPMENT OF ENGINEERING PEDAGOGICAL CONTENT KNOWLEDGE BY ELEMENTARY TEACHERS THROUGH PERCEIVED LEARNING AND IMPLEMENTING DIFFICULTIES

2.1 Introduction

While the adequacy of supply and the quality of the workforce in the Science, Technology, Engineering, and Mathematics (STEM) fields have long been recognized as the long-term key to U.S. economic competitiveness and growth, there has been an increasing national concern about the shrinking STEM workforce pipeline (Jobs for the Future, 2007). Students are discouraged from entering the STEM pipeline due to either inadequate preparation in math and science or poor teacher quality in their K-12 education (ACT, 2006). Those who are academically qualified for postsecondary studies in STEM fields turn to other fields for various reasons such as high tuition and demanding curricula and courses of study (American Association of State Colleges and Universities, 2005). In the field of engineering, the trends in undergraduate and graduate enrollment in engineering science are troubling (U.S. Government Accountability office, 2005). The dramatic decrease in the number of engineers graduating from U.S. institutions has given rise to the warning by the Business Roundtable (2005) that if this

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trend continues, more than 90% of all scientists and engineers in the world will live in Asia.

With a strong emerging consensus among scientific, business, and education leaders that “America’s ability to innovate and compete in the global marketplace is directly tied to the ability of our public schools to adequately prepare all of our children in STEM” (NGA Reports, 2007, p. 4), efforts have been made to integrate engineering into K-12 education. Although experts agree that we must start in elementary schools to capture and maintain students in the STEM field, most outreach programs target high school students and “less attention has been paid to elementary and middle school students, where efforts would serve a ‘mainline’ function of promoting technological literacy and stimulating interests in mathematics and science” (National Academy of Engineering, 2008, p. 4).

Given the relatively small amount of attention paid to elementary engineering education, and the misalignment of STEM coursework and expectations between elementary, middle, and high schools (NGA, 2007), more efforts are necessary to target the elementary student population. One large step toward accomplishing this goal was the development of the Engineering is Elementary (EiE): Engineering and Technology Lessons for Children curriculum by the National Center for Technological Literacy (NCTL) and the NCTL’s Pre-College Engineering for Teachers (PCET) summer institutes introducing elementary teachers to engineering using the EiE curriculum. Research has shown that EiE greatly improved elementary students’ understanding about technology and engineering (Lachapelle, Cunningham & Oware, 2008; Lachapelle, Cunningham, John, Cannady & Keenan, 2010), had tremendous appeal among girls and
other underrepresented groups in STEM fields (Faux, 2006), and exerted significant
impact on students’ attitude toward engineering (Cunningham & Lachapelle, 2010).

Although research also showed that elementary teachers increased their knowledge
of engineering and technology through EiE training (Cunningham, Lachapelle & Keenan,
2010) and that EiE training had a strong positive impact on participating elementary
teachers’ instructional behaviors (Carson & Campbell, 2007), inadequate research
attention has been given to elementary teachers’ real world engineering teaching practice.
Also, little is known how, through engineering teaching practice, elementary teachers
construct their knowledge of engineering Pedagogical Content Knowledge (PCK), which
was defined in this study as specific engineering teaching strategies and methods making
engineering content comprehensible and teachable in elementary classrooms.

Preparing elementary teachers to teach engineering is challenging because most
elementary teachers lack preparation and confidence in teaching science (Lee et al., 2008),
and most of them regard teaching engineering as terrifying (Cunningham, 2008).
Previous INSPIRE research on professional development in elementary engineering
education indicated that many elementary teachers were afraid of attempting to teach
engineering topics and were uncomfortable about teaching engineering concepts because
of many preconceived opinions of engineering (Liu, Carr & Strobel, 2009). Given the
fact that elementary engineering education is a new phenomenon (Cunningham, 2008)
and that elementary teachers are not prepared for engineering education, an
understanding of how elementary teachers develop engineering PCK through engineering
teaching practice is critical for improving existing and future professional development
programs in elementary engineering education. The purpose of this study is to help attain
this understanding by investigating how the elementary teachers participating in the INSPIRE’s local Summer Academies at Arlington, TX, constructed their engineering PCK through their engineering teaching practice.

Adopting a phenomenological approach, the researchers of this study conducted in-depth face-to-face interviews and an on-line open-ended survey with the elementary teachers and explored their lived engineering teaching experience to find out “how they perceive it, describe it, feel about it, judge it, remember it, make sense of it, and talk about it with others” (Patton, 2002, p.104)—the “it” denoting engineering PCK. The lived engineering teaching experiences of these teachers were “bracketed, analyzed, and compared” (Patton, 2002, p. 106) to find answers to the research question of “How do elementary teachers construct their engineering PCK through engineering teaching practice?” Based on the ELC framework (explained in detail in the next section) developed by the researchers to guide this study, the above research question of this study has been subdivided into two questions: 1) How do elementary teachers construct engineering PCK in the area where engineering instruction interacts with the learners? 2) How do elementary teachers construct engineering PCK in the area where engineering instruction interacts with classroom and school contexts?

2.2 Theoretical Framework and Literature Review

2.2.1 PCK

PCK was first proposed by Shulman (1986, 1987) as an important framework of teacher knowledge. According to Schulman, PCK includes “an understanding of what makes the learning of specific topics easy or difficult” (1986, p.9) and PCK is “the
capacity of a teacher to transform the content knowledge he or she possesses into forms that are pedagogically powerful and yet adaptive to the variations in ability and background presented by the students” (1987, p. 15). Central to Shulman’s conceptualization of PCK is that PCK is learner-targeted or learner-oriented. This learner-oriented perspective runs through later research on PCK or PCK models (see, e.g. Ball, Thames & Phelps, 2008; Banks, Leach & Moon, 2005; Grossman, 1990; Koballa, Gräber, Coleman, & Kemp, 1999; Magnusson, Krajcik & Borko, 1999; Russell & Martin, 2007; van Driel, de Jong, & Verloop, 2002).

Knowledge of contexts has long been regarded as closely related to PCK (Cochran, King & DeRouiter, 1993; Fernández-Balboa & Stiehl, 1995; Shulman, 1987). In the Pedagogical Context Knowledge (PCxK) model (Barnet, 1999; Barnet & Hodson, 2001), the conception of PCK is linked to particular teaching contexts in classrooms. Grossman (1990) listed knowledge of context together with subject matter knowledge and general pedagogical knowledge as three domains influencing PCK. Teachers’ beliefs and perceptions of teaching and learning are strongly influenced by contextual parameters of the school culture and the educational system in general (Jimoyiannis, 2010; Siorenta & Jimoyiannis, 2008). What stands out here is the belief the PCK should always be approached and understood in specific contexts.

We hold the view that an essential part of PCK is a set of instructional methods and strategies used in teaching practice to transform subject matter knowledge (SMK) and to make it comprehensible and teachable in specific teaching situations. Based on this understanding and our constructivist view that knowledge is constructed through real life experiences, we defined engineering PCK in this study as engineering teaching methods
and strategies constructed through elementary teachers’ real classroom engineering instruction to make engineering content comprehensible and teachable in elementary classrooms.

As illustrated in the theoretical framework (see Figure 1), which we used to guide our investigation of elementary teachers’ engineering PCK development, “engineering instruction” stands in the center denoting the main focus of this study. However, instruction is not carried out in a vacuum but in interaction with specific target learners and specific contexts. Informed by previous PCK research literature regarding the learner-oriented perspective towards PCK and the influences of contexts on PCK, we included the “learners” and “contexts” dimensions into our ELC framework.

2.2.2 ELC Framework

The ELC framework constructed in this study was intended to guide our investigation of the elementary teachers’ practice-based engineering PCK development. As illustrated by the framework, we focused on the elementary teachers’ description of their real classroom engineering instruction and looked specifically into the areas where engineering instruction interacted with the “learners” dimension and the “contexts” dimension trying to present a holistic picture about how the elementary teachers constructed their engineering PCK through engineering teaching practice.
2.2.3 Elementary Teachers and Engineering Education

Most elementary teachers are not sufficiently prepared to teach science subject matter and lack the necessary scientific skill that would allow them to feel confident about teaching science on a regular basis (Lee et al., 2008; Raizen & Michelsohn, 1994). Elementary teachers’ lack of confidence in teaching science may stem from “a general disinterest in, lack of exposure to, or intimidation by science content” (Buczynski & Hansen, 2010). Yasar et al’s survey (2006) showed that, compared to middle school and high school teachers, elementary teachers were least interested in learning Design, Engineering, and Technology (DET) through in-service activities and workshops and scored the importance of DET the lowest. Also, according to the survey, middle and high
school teachers are likely to be science specialists more interested in content as opposed to elementary teachers who are generalists interested in children.

According to EiE engineering professional development research, the biggest challenges to integrating engineering into elementary classrooms were elementary teachers’ weak science knowledge, their anxiety or fear about engineering, their lack of previous experience with elementary engineering education, and their skepticism about including engineering in elementary classes (Cunningham, 2008). Similar mindsets about engineering and elementary engineering education were also found among the elementary teachers in previous research on INSPIRE Summer Academies (Liu, Carr & Strobel, 2009). Given elementary teachers’ unpreparedness for engineering teaching, it is reasonable to believe that there is much to be done by profession development providers to prepare elementary teachers for effective elementary engineering education.

What makes things harder for professional development providers is the fact that it is often difficult for teachers to translate knowledge gained through professional development in a way that meets their students’ needs (Duffy, 2004; Gordon, 2004). This knowledge transfer problem is reflected in the common lore among teachers: teaching as happening in classrooms and “talk about teaching” as happening in universities are incommensurable. Professional development providers need to think about how to help teachers translate their professional development learning into effective teaching practices. The present study, by investigating how the elementary teachers in INSPIRE Summer Academy developed their PCK in engineering after finishing their professional development learning, was intended to offer some insight into how teacher professional
development programs can be improved to better prepare elementary teachers for engineering teaching.

2.3 Methodology

A phenomenological research design was used to explore how engineering PCK was constructed the participating elementary teachers of INSPIRE Local Summer Academies. Data of this study were triangulated (Bogdan & Biklen, 2007) through transcripts of the face-to-face individual and group interviews and the answers to the online open-ended survey questions. The interviews were transcribed and analyzed together with the answers to the open-ended survey questions.

2.3.1 Participants

The interviews of the study involved 73 elementary teachers (see Table 1 for demographic information of these teachers). While these 73 teachers interviewed signed up for the summer academies voluntarily, they were recruited into this study by a mix of convenience sampling and purposeful sampling. Out of the total 101 interviews were 76 individual interviews (with 13 teachers interviewed both in 2008 and 2009) and 25 group interviews.
The elementary teachers of this study came from 13 elementary schools in Arlington, TX, teaching 2nd grade through 4th grade mostly in self-contained classrooms. Approximately half of the elementary teachers hold BA degree in fields such as English, Early Childhood Education, Interdisciplinary Study, and Government (See Figure 2). Twenty-eight out of twenty-nine BS degrees held by the teachers are in non-STEM fields like Education, Advertising, and Photography. Nine of these teachers have Masters Degrees, three of which are in STEM-related fields (one in Information Processing Technology and two in Math Education). One of the teachers has an EdD in Curriculum and Instruction with a focus on math education.

![Figure 3. Educational Background of the Teacher Participants (Study I)](image-url)
Thirty-one elementary teachers responded to our online open ended survey about their beliefs, motivations, and concerns about integrating engineering activities into their classrooms.

All participants of this study received one-week training of elementary engineering teaching from INSPIRE Summer Academy aimed at helping elementary teachers enhance their understanding of engineering concepts and pedagogies through various INSPIRE activities.

2.3.2 Data Collection Procedures and Instruments

A total number of 101 face-to-face interviews were conducted among the 73 teachers, including 76 individual interviews and 25 group interviews. The group interviews were conducted in June 2008, December 2008, and December 2009. The individual interviews took place in May 2009 and May 2010 respectively. The survey was posted online through SurveyMonkey in July 2009, and the survey data were collected in September 2009. The data were sorted in an Excel file after collection.

2.3.3 Data Analysis

This study included three sets of qualitative data: one from the group interviews, one from the individual interviews, and one from the answers to the open-ended online survey questions. According to the participating teachers’ profiles, the individual interview transcripts were first divided into “Title I Schools” group and “Non-Title I Schools” group, and were then further divided according to the teachers’ teaching experience into group 1 and group 5 of “0-2 years”, group 2 and group 6 of “3-5 years”, group 3 and
group 7 of “6-10 years”, and group 4 and group 8 of “over 11 years”. While group 1, 2, 3, and 4 belong to the “Title I Schools” group, group 5, 6, 7, and 8 belong to the “Non-Title I Schools” group. Three interview transcripts were randomly selected from each of the eight groups.

The 24 individual interview transcripts and the answers from the open-end online surveys were first analyzed. The data analysis was guided by the ELC framework and the operational definition of engineering PCK of the study. Also, the analysis strategy of inductive analysis and creative synthesis (Patton, 2002) were adopted to help the researchers to build patterns of meaning from the data.

Specifically, three rounds of data analysis were carried out during the whole process. In the first round, the elementary teachers’ responses to the online survey questions and the 24 interviews were read separately and independently by the researchers on a line-by-line basis. During the reading, the researchers took analytical memos about the patterns of difficulties and barriers perceived by the elementary teachers concerning integrating engineering into their classrooms. Comparing and discussing their analytical memos, the researchers reached an agreement on a list of themes with each theme overarching specific difficulty and barrier patterns emerged from the survey responses and the 24 interview transcripts.

In the second round of data analysis, each of the researchers read independently through the 24 interviews focusing on the specific engineering teaching strategies and methods the elementary teachers employed in their engineering instruction. While reading the interviews, the researchers took analytical memos about the patterns of how and why each of the instructional strategies and methods was used. Analyzing their
analytical memos, each researcher came up with a list of themes and patterns. In this inductive process (Strauss & Corbin, 1990), the original 24 interviews were reduced by each researcher into a list of themes, each of which captured and unified several patterns with corresponding instructional strategies and methods. Then, the researchers made comparisons across the themes and patterns they had respectively come up with and discussed about the differences they had on the themes and patterns, referring back to the original interviews whenever necessary. Based on their discussion, the researchers modified the themes and patterns to better categorize and present the instructional strategies and methods. A final single list of themes and patterns resulted.

In the third round of data analysis, the researchers tested the two lists of themes and patterns from the first and the second round of data analyses against new interviews outside of the initial 24 interviews. Each time, each of the researchers randomly selected five transcripts from the individual interviews and five from the focus group interviews. While reading these new interviews, the researchers looked for new patterns not yet captured in the first and second rounds and either revised the existing themes or added new themes to reflect those newly emerged patterns. The testing process went on until no new patterns emerged, and the themes were saturated (Strauss & Corbin, 1998). During the whole testing process, the two researchers met constantly and discussed their revisions of the themes and patterns to ensure the reliability and validity of the revisions. Two lists of core themes and patterns finally resulted: one on the difficulties and barriers of integrating engineering into elementary classrooms and one on the engineering instructional strategies and methods used by the elementary teachers in their engineering teaching practice. As the final step of the third round data analysis, the two researchers
revisited the two lists of themes and patterns with reference to the ELC framework to interpret and make sense of the elementary teachers’ construction of engineering PCK through engineering teaching practice.

2.4 Findings and Discussion

In this study, the interview questions and the open-ended online survey questions were intended to allow the elementary teachers to articulate and reflect on their experiences, problems, and associated solutions about teaching engineering to their elementary students. We present our findings about the practice-based construction of engineering PCK based on the analysis and interpretation of these articulated experiences, problems, and solutions. Excerpts from the interviews and online survey answers were integrated to illustrate and support the findings presented.

2.4.1 Learner Characteristics and Learning Difficulties: From Knowledge to Solutions

The elementary teachers’ engineering curriculum included four EiE lessons and a series of preparation activities to be done before and after the lessons. The preparation activities done before the lessons were: Active Listening, Teamwork, What’s Engineering, What’s Technology, Brainstorming about Technology, Critical Vocabulary, and Engineering Design Process. The Model Eliciting Activities were to be done after the EiE lessons. The elementary students in this study were second through fourth graders, representing an age group that is not typically exposed to engineering. Teaching engineering for the first time and teaching engineering to students of such an age group, the elementary teachers constructed their engineering PCK by gaining new knowledge
about engineering teaching and learning difficulties and by producing specific engineering teaching strategies and methods to deal with these difficulties in their engineering teaching practice.

**Misconceptions about engineering and technology.** One prominent characteristic the elementary teachers noticed of their students was that the whole notion of engineering “is just very foreign to” their young students. The idea that “an engineer did a car” or “he works on a car” were firmly established in the elementary students’ minds and even the “make vs. design” concept was hard for them to grasp. The elementary teachers tried giving textbook definitions like “an engineer is the person who designs, a craftsman is the person who makes it, and a technician is the person who uses it” and tried inculcating repeatedly to their students the ideas of “engineers don’t always make it”, “they design it” or “they’re not always the one that puts it all together”. But the elementary teachers realized that these just did not work. Then they tried something else. There were teachers who asked the students to “go home and talk with their family about ‘What is engineering?’” and “to get their family discussing it a little bit more, to find out if they had engineers in their family”, so that the students “came up with a student-centered definition first” before the concepts of engineering and engineer were discussed in class. One of the elementary teachers did a mini unit on the inventors her students were interested in, and together, they looked at the inventors as engineers to see how they made life easier. There were also elementary teachers who invited to class engineers they knew or some students’ parents who are engineers to talk to their students about what real engineers do.
When teaching about technology, the elementary teachers always began the “technology brainstorming” activity they learned in the INSPIRE summer academy. As was reported by the elementary teachers, this activity was not effective in correcting their students’ typical misconception that “technology was something that was robotic or required batteries”. To help their students understand what technology truly is, some elementary teachers developed their own instructional methods. There were teachers who brought in simple tools like paper clips and nut crackers, and discussed with their students “what was the function”, “what was the purpose”, “what was the design”, “how was it made”, “what was it made of”, and “how was it an improvement over previous inventions”. Some elementary teachers adopted demonstration teaching methods to teach the concept of technology to their students. A good example was a 3rd grade teacher who did the egg beater demonstration. According to this teacher, her students “tried the egg beater and saw how mechanically it was an improvement over the fork and how it made the job easier”. There were also some elementary teachers who adopted more hands-on methods and strategies. One 4th grade teacher brought in a little vacuum with automatic sensors. She picked the vacuum apart with her students and they talked about all the pieces in it. She also brought in Band-Aids and pencil sharpeners to allow her students to play with them and discuss in what ways they might be regarded similar to the vacuum.

The elementary students’ misconceptions about technology and engineering unfolded to their teachers during the engineering learning and teaching process. In response to these misconceptions, the elementary teachers devised various strategies and methods to help their students correct these misconceptions. Though the strategies and methods were of different types, they were basically based on the understanding that
“isolated mental pictures and images” or “abstract definitions” were not useful in teaching their students engineering and technology-related concepts. The elementary teachers learned from their engineering teaching practice that what their elementary students needed were “hands-on”, “concrete and real-life examples”, and “opportunities to think, to experience, and to improve” in order to understand technology and engineering-related concepts.

**Lacking teamwork abilities.** Engineering is a social endeavor requiring extensive teamwork. For successful implementation of an engineering lesson, as one of the elementary teachers mentioned in the interview, the elementary students’ “being able to work together is the critical key”. However, the elementary teachers learned from their engineering teaching experiences that their young students lacked “basic teamwork knowledge and abilities” for engineering activities, especially for those design activities requiring teamwork for designing and producing a final product. The elementary teachers tried some methods they used in teaching other disciplines. They tried putting students with more leadership quality with those with less or they grouped their students according to friends-with-friends principle or the principle of putting in a group those who could get along together. However, those methods that worked well in activities of other disciplines failed to work in engineering design activities. The engineering design activities usually involved solution finding, decision making on design solution, and cooperation in producing and improving the final design product. Elementary teachers were able to see that, in such a complicated process, it was hard for their young students to get along. “A lot of arguments” and “my idea is the only idea or I don’t want to do
what you want to do” were reported as common among the elementary students in the engineering design activities.

To enable their students to work better in those engineering design activities, the elementary teachers developed different methods and applied these methods to their engineering teaching. Some of them adopted the visual modeling method by which they used Aisha story DVD or PBS shows like Design Squad to model engineering teamwork for their students. Some elementary teachers used the team-building method of creating flow maps and putting down important things for working as a team in engineering design activities, such as “how to work cohesively together”, “be open to new ideas and things”, “making contribution as team member”, and “be responsible and respectful”. They discussed with their students these important concepts, and referred the students back to those important concepts when the engineering design activities were on-going.

There were also elementary teachers who used a role-playing method for teamwork. Using this method, the elementary teachers assigned each team member a role, such as lead engineer, material handler or material manager, and facilitator, and defined and put down each role’s function and responsibilities before carrying out the engineering design activities with the elementary students.

In their engineering teaching practice, the elementary teachers realized their students’ inadequate teamwork abilities for engineering design activities. Instead of grouping the students into small groups and starting doing those activities or following those methods that worked for group activities in other disciplines, many elementary teachers created their own methods for eliciting better learning results from their students. These newly-created methods were strong evidence that teachers were “learning in and from practice”
(Ball & Cohen, 1999) about how to cultivate their students’ engineering teamwork skills and how to make engineering design activities workable and doable for elementary students. For the elementary teachers, this was a process from knowing about their students’ lack of teamwork abilities to knowing how to deal with it in the engineering teaching practice.

**Learning difficulties.** For the elementary teachers, teaching engineering to elementary students was a process of discovering their engineering-associated learning difficulties. Some difficulties were related to the fact that some engineering lessons and activities required mastery of some skills or concepts the elementary students had not yet mastered, such as measurement, fractions, and the concept of variables. As reported by the elementary teachers, their students “had a difficult time with measurement in the folder-making activity, like measuring one-fourth of an inch”, they “couldn’t get the fact that the measurement had to be exact”, they “just didn’t understand that when the bottom number gets bigger, that means it’s smaller”, or in the Play-Doh activity they “didn’t know one can only change one variable to actually figure out what’s working”. Some elementary teachers modified the engineering activity to make the measurement less difficult, brought in measuring cups to teach their students about fractions, or used flour and salt to demonstrate the concept of variables.

These learning difficulties informed the elementary teachers about what needed to be done to ensure those engineering lessons and activities were doable for and teachable to their students. More important than this was that these learning difficulties allowed the elementary teachers to see that engineering teaching and learning “was not isolated from the learning and teaching of other disciplines” and there were “many cross-curricular
connections that could be made between engineering and other disciplines”. For some elementary teachers, these understandings served as a starting point for their search of how to combine engineering with the teaching and learning of other disciplines they had been teaching. For some elementary teachers, the section in their social studies book about assembly lines became a good place where the teaching of the “assembly line process” was able to be tied in. While one elementary teacher extended her science lesson on filter into a filter design activity, another teacher “did a unit on the engineering design process to design and improve a telescope” after her lessons on solar system to show her students “how it is possible to see the solar system without traveling through space”.

Some elementary teachers even brought engineering into their teaching of language arts. One elementary teacher elaborated, during the interview, on how she integrated the pop-up card activity with the author-study activity on William Steig in language arts. Her students worked in groups doing research on William Steig’s books, “chose their own books from William Steig’s collection”, “chose their characters and elements of the story”, “made all the drawings”, and presented them on the pop-up cards they designed. This teacher understood “the key points of the engineering ideas and precepts as exploration and coming up with one’s own independent thinking”. So she did not impose on her students “any constraints whatsoever with how they were to do it [the pop-up cards: note by the authors]” and “did not give them any instructions on actually how to assemble it and design it themselves”. But she did tell her students to make their pop-up cards more animated and exciting to look at, “not just a flat two dimensional drawing”. This, to use the teacher’s own words, “brought in the math component as well” into the pop-up cards activity.
When this teacher reflected on this activity, she said only two groups were very successful with their pop-up cards and the quality of the work of other groups was not good. But she mentioned in her interview that “even now, several months after having done the pop-up cards, my kids are on their own, finding their own way of improving their little pop-up cards, to make sure they work better and things work nicer”. This, according to the teacher, was what really mattered. She understood from her engineering teaching experiences that teaching engineering in isolation sometimes interfered with the “flow of the teaching and learning of other disciplines” and undermined students’ ability to see the connections between engineering and other disciplines. However, integrating engineering into the learning of other disciplines not only made the learning of other disciplines much more fun but it also allowed the students to see relevant applications of engineering. This was regarded by this elementary teacher as a motivating force for her students’ continuous work on the improvement of their pop-up cards.

Another engineering learning difficulty the elementary teachers found common among their students was related to the engineering design process. The design process the elementary teachers introduced to their students was the EiE engineering design process (Cunningham, 2009; Hester & Cunningham, 2007), which included five phases (see Figure 3) forming a continuous circle around the design goal.
As was reported by the elementary teachers, the engineering design process, like the engineering concept, was very foreign to the elementary students. Showing the students the process graph or making bulletin board with the steps, and explaining what would happen at each step was the initial method used by many elementary teachers to introduce the engineering design process to their students. But this method in most cases only resulted in memorization of a few steps by a few students. In addition to their confusions about the steps, the elementary students kept asking question like “Is this important?”, or “Why are we doing this?”. The elementary teachers felt the need for an alternative method of teaching the design process. Many analogies arose as a result. Relying on their students’ prior knowledge about the writing process and the scientific process, some elementary teachers compared and contrasted the writing and scientific processes with the engineering design process to allow their students to build a working model of the engineering design process. Such analogies achieved better learning effects on the students: while they were doing their writing, they would see “That kinda goes with the
planning process”, or when they were doing their science experiments, they would see something similar to the engineering design process involved like “We need to test it, and if it doesn’t work, we’re going to need to improve it”.

For some elementary teachers, the best way to teach the engineering design process was through the “learning by doing” strategy. They either asked their students to work in groups or work as a class to brainstorm what they planned to do in each of the engineering design steps and create flow maps guiding their design and creation of the design products like paper tables and paper folders. The students referred back to their flow maps while designing and creating their products and reflected on the flow maps about the functions of the design process and what worked well and what did not. Some elementary teachers improved this “learning by doing” strategy by asking their students to design and create things they were interested in. Instead of doing the engineering design activities they brought back from the INSPIRE summer academies, these elementary teachers created such engineering design activities as “a bed for your doll”, “a chair for my mother”, and “a house for the three little pigs”. The teacher, who asked her students to build the house for the little pigs, recalled how her students manipulated with different materials, like marshmallows, craft sticks, and paper clips, and how much they were engaged in testing their houses with hair dryers or fans and in improving their houses based on the tests.

The elementary teachers developed their knowing about their students’ engineering learning difficulties through their engineering teaching practice. Again, knowing about these difficulties did not automatically result in the elementary teachers’ knowing of how to deal with them. Those strategies or methods used to help the students overcome their
learning difficulties were developed by the elementary teachers as a result of their trying-and-then-understanding about what would work better for their students in engineering lessons or activities.

*Engineering Learning Assessment.* Assessing student learning is what every teacher has to do. One of the elementary teachers said that in engineering teaching “the hardest thing for me is the assessment”. This was also the case for many elementary teachers. The teaching materials the elementary teachers received from the INSPIRE summer academy contained questions, rubrics, and assessments instruments that were intended to be used by the elementary teachers to assess their students’ engineering learning. However, after trying these ready-made assessment tools, some elementary teachers realized that some formal assessment methods or tools applicable to other disciplines like math and language arts were not readily workable for assessing their students’ engineering learning. Three main reasons, as reported by the elementary teachers, stood behind their practice-derived perception of the need for some informal assessment methods. First, young students at the age of 2nd-4th grade levels became stressed out easily by formal assessment or tests, and it was especially the case when they were facing a discipline like engineering which was very foreign to them. Second, it took more time for the elementary students to master those unfamiliar engineering-related concepts, so informal formative assessment would be desirable to ensure better learning outcomes. Third, there were wide spread and high level frustrations among the elementary students resulting from unsuccessful production of final engineering design products, and this called for assessment methods that could “turn the frustrations around” and could help develop the students’ “ability to go back, re-create, and improve”.
Based on the practical learning situations of their students, the elementary teachers employed different informal assessment methods in their engineering teaching. Some assessed their students by “doing a lot of questioning” and some checked their students’ understanding by looking at the examples of simple machines or technology they found in their houses. There were also some elementary teachers who got to know their students’ learning needs through things they wrote down in their notebooks or journals, by observing, listening and talking to them, or based on the students’ feedback about how they perceived and how they were able to make sense of those engineering concepts and activities. In those engineering design activities, “focusing on the exploration process not the final products” was a common feature of the informal assessment methods used by the elementary teachers. Some of the elementary teachers assessed their students’ design products by having them talk about why or why not they thought someone would want to buy their products, or about what “limitations and time or material constraints” had contributed to their failure of “getting their job finished”. One of the elementary teachers worked with her students to create flow maps of recipes and according the teacher, “a recipe is steps to make something”. She assessed her students based on their recipe maps, posing questions like “Did you follow the flow map you wrote?” and “You didn’t follow your flow map. Did you have any problems?” Some elementary teachers invited a group of parents or kindergarteners to their classrooms as the “consumer-group” giving the students feedback on their design, and the students re-designed their products based on the feedback.

Some elementary teachers even asked their students to come up with their own criteria for assessing their engineering design products. One elementary teacher’s
students decided to test their paper tables by seeing which groups’ table “could stack the most books” and one group said, “Well, we need to weigh their books. They may not be as heavy as our books”. Another elementary teacher talked about the creative testing methods her students used to test the quality of their play-doh such as the “stick to hands or desk test” and “the stamp test” of pressing erasers of various shapes down into the play-doh to see if it “kept the shape or closed back”. According to these teachers, having their students come up with their own criteria for testing their products would allow their students to have a clear picture about the goal of their design from the very beginning and would enable the students to focus on what needed to work on for improvement to reach the goal rather than being overwhelmed by possible frustrations associated with failure to reach the goal.

We were able to see that the assessment difficulties the elementary teachers encountered in their engineering teaching practice were closely related their students’ engineering learning difficulties. The assessment choices and decisions the elementary teachers made were based on their understanding of student learning difficulties and of ways to better meet student learning needs in engineering learning situations. And more importantly, these choices and decisions were based on their trials of what worked and what did not for their students in engineering learning situations. In search for assessment methods that worked for their students, the elementary teachers were constructing their situated knowledge about assessing engineering learning and about encouraging and improving engineering learning by assessing their students appropriately.
2.4.2 Contextual Constraints: From Knowing-about to Knowing-how

Teaching, like learning, happens in specific contexts. The elementary teachers in this study had no prior engineering teaching experiences in real classroom and real school settings. Their knowledge about the contexts of elementary engineering teaching came to them after they left INSPIRE summer academy to start their engineering teaching practice in their own elementary classrooms. Their knowledge of contexts included knowledge about the classroom contexts and about the school contexts and about how these contexts influenced their engineering teaching practice.

*Classroom-related contextual constraints.* Elementary classrooms were the immediate contexts within which the elementary teachers had to work to carry out their engineering instruction. The elementary teachers’ knowledge about classroom contexts unfolded to them in the form of a series of classroom-related contextual constraints that rendered negative impact on engineering instruction. A list of these classroom-related contextual constraints was identified from the interviews with the elementary teachers:

- Large class size but with no assistant
- Discipline issues
- High student turnover rate
- Learner diversity

In the teaching of non-engineering disciplines, the above classroom-related contextual constraints are also unavoidable. Although none of these contextual constraints were unique to engineering teaching, all of them made an impact on the elementary teachers’ engineering teaching. As was reported by many elementary teachers, the large size of their class and the discipline issues with some of their students held them
back in their engineering teaching and made it very difficult to plan the engineering
group projects. For those elementary teachers who had “very transient student
population”, they had to forgo some engineering activities because of “frequent turnover”
and “high transient rate” of their students.

The contextual constraints related to “learner diversity” manifested themselves in
different ways for different elementary teachers. For some elementary teachers, this
constraint was related to the diverse academic abilities among their students. For these
teachers, their elementary students in a single class ranged from those of “straight A” to
those who had to copy all stuff from others, from those mature to those extremely
immature and having “just recently stopped crying”, or from those good at critical
thinking to those have “no critical thinking skills whatsoever”. For many other
elementary teachers, the “learner diversity” constraint was associated with their student
body which consisted of both native-English-speaking students and a large number of
ESL students, who were diverse in their language and academic abilities.

Despite the fact that the meanings of “learner diversity” were teacher-dependent, the
elementary teachers found it always a big challenge to strike a balance between the
diverse learning needs of their students during their engineering teaching practice.
Sometimes they had to modify their engineering teaching by “cutting steps”, “cutting
directions”, “rewording everything”, and “making it simpler and playful”. These
modifications were intended, as one of the teachers put it, to ensure those students at the
lower end of the continuum to “at least be able to take something away” from their
engineering learning. Some of the elementary teachers talked about “how important
dialogue was” and used a lot of conversations to prepare their less capable students for the engineering lessons.

In their engineering teaching practice, the elementary teachers became acquainted with those classroom related contextual constraints and had to adopt specific instructional measures to counteract the negative impact of these contextual constraints. Not uniquely specific to engineering teaching, these contextual constraints and instructional measures were generic in nature. However, knowledge about these contextual constraints and how to deal with them appropriately is definitely a valuable part of the elementary teachers’ understanding about elementary engineering education. More importantly, since most of these contextual constraints offered different perspectives allowing the elementary teachers to see the engineering learning difficulties of their students, knowledge about these contextual constraints and how to deal with them would contribute to the elementary teachers’ abilities of making engineering content teachable.

**School-related contextual constraints.** Analysis of the results of the online survey from the elementary teachers revealed the difficulties and barriers they perceived concerning integrating engineering into their classrooms:

- Time issue (Lack of time for engineering teaching)
- Lack of administrative support
- Accountability issues (e.g. state-mandated tests, meeting standards, and instructional objectives)
- Personal unpreparedness (e.g. lack of engineering content knowledge, unfamiliarity with engineering design process, and lack of engineering teaching experience)
• Student-related issues (e.g. age-appropriateness, academic preparedness, and learning interests)

The first three in the list corresponded with the school related contextual constraints perceived by the elementary teacher in their engineering teaching practice. Engineering was not a discipline the elementary teachers were required to teach. Integrating engineering into their classrooms meant that they had to find time for engineering from their already packed teaching schedule. This was not easy for these elementary teachers because most of them taught in self-contained classrooms and were responsible for teaching all subjects to their students. One of the elementary teachers said in her interview that “my curriculum sadly consists of a lot of teaching, testing and re-teaching of specific objectives in those subject areas. I have TAKS [Texas Assessment of Knowledge Skills: note by the authors] for every subject area including Computer Science. I have to learn how to balance and incorporate it all”. Similar things were mentioned by another elementary teacher: “We have not only academic things that we are responsible for as far as testing is concerned, but wherever there are learning gaps with our students, we are then commended with closing those gaps; and the bigger the gap is, the more intensive and the more time that we are forced to spend with a student outside of our regular teaching time. So I think it’s a really hard balance to try to make”. What these two teachers said was the typical situation most elementary teachers in this study were in and the “time issues” were therefore perceived by them as the biggest barrier to integrating engineering into their classrooms. Also, it was not hard to see that the “time issues” were inseparable from what they were held accountable for as elementary teachers.
These time and accountability issues had great impact on the elementary teachers’ engineering teaching practice. Many elementary teachers reported in the interviews that they found it hard for them to carry out engineering teaching on regular basis. They sometimes had to leave engineering aside to prepare their students for the benchmarks, the TAKS, or the end-of-year testing and it was not uncommon when some of the elementary teachers picked up engineering where they left off last time, their students had long forgotten what had been covered. Knowing about these time and accountability issues and the constraints these issues set upon their engineering teaching, some elementary teachers began to search for ways that would help fight against these constraints. One good example of this came from one elementary teacher who did the “The Great Egg Drop” activity with her students.

Instead of doing the EiE Packaging Plants activity which was totally new for her students, the elementary teacher did the “The Great Egg Drop” activity which involved packaging design for raw eggs to protect the eggs in a six-foot drop. She had done this activity with her students before she attended the INSPIRE summer academy and the students had been asked to design their packages at home and tested them at the school. She modified the activity and did it in a new way:

The way I did it this year was, rather than have them package it at home, I let them go home and gather materials; I told them the constraints . . . Then they went home and they had a specific date they had to bring materials back… So anyway, they had their materials, they built their package here. Before doing that, though, they had to sketch what they wanted their package to look like and diagram it. Then they wrote a procedure down of how they put their packaging together and how the egg was
going to be secure, and then we took it outside and did a six-foot drop. I let them
come back in, if their egg didn’t make it, they had to improve their package, and then
we took it to the roof. After that, they wrote up their findings.

According to this teacher, it was time-efficient to adapt such a science activity in
physics with which her students had prior experience with into an engineering design
activity. Since there was no need to prepare the students from scratch for what they were
to do, the students would be able to have a more focused experience with the engineering
design process and to accomplish more in less time.

Different from this “more with less time” strategy was the strategy adopted by a 4th
grade teacher. Since electricity and magnetism are in the 4th grade TAKS, this 4th grade
teacher created a “circuit design” engineering activity and combined this activity with her
teaching of electricity and magnetism. This teacher’s “test-alignment” strategy was based
her belief that “if you would align with what you had to do versus trying to wiggle room
for it, that would be helpful”. There was another teacher who also adopted this “test-
alignment” strategy. But she used this strategy in a different way. Instead of creating
some engineering activities that were in alignment with the TAKS, she used the
engineering teaching materials preparing her students for the TAKS. For example, she
used the engineering stories to prepare their students for TAKS language arts and TAKS
social studies. As this teacher said, “the Texas Essential Knowledge and Skills are in the
stories, so you can practice: Who are the main characters? What are their feelings?
What’s the setting?... I didn’t mind that it took me two extra days to do the activities. I
did not cover all the social studies in that six weeks that I was supposed to cover. But I
didn’t feel like I didn’t get my practice for the TAKS test with it”.

In addition to those contextual constraints associated with time and accountability issues, the elementary teachers voiced in the interviews the issues related to lacking administrative support they perceived in their engineering teaching practice. According to the elementary teachers, engineering teaching “still sounds appended to the main business of school” because “it’s not state mandated”, “it’s not included in the TAKS tests” and “the EiE stuff doesn’t look at all like the state tests”. One of the elementary teachers talked about the lack of support from administration and board members. Her comments were a good summary of the status quo of administrative attitudes toward elementary engineering integration as perceived by many other teachers:

There is a push to concentrate on ‘teaching to the test’. There is a very strong insistence to worry about test scores and not developing the whole student. I am afraid that I may be told to cut back on this area of instruction [engineering instruction: note by the authors].

To realize integration of engineering into elementary classrooms, as one of the elementary teachers commented, “The whole school would have to get onboard. It would take a whole-school push, starting with the principal, and the principal would have to really mandate it, and be willing to manage it and revisit it and visit it in the classrooms and expect to see it in the classrooms”. Some of the elementary teachers talked about the need to get buy-in not from the principals but from other teachers in their schools and the parents by allowing them to “see the payoffs”. Some suggested holding “Engineering Open House” to “have the kids showing what they’ve learned”. There were also teachers who thought it would be a neat idea to publicize what they were doing about engineering in their classrooms through TV or the internet. According to them, this would be a great
educational push for integrating engineering into elementary classrooms. One of the teachers took pictures of her students when they were working on the engineering power station activity and put the pictures on the school district web page. As she said, “the first thing you see are those pictures that pop up”.

The above plans and thoughts from the elementary teachers were intended to improve the school environment so as to make it more conducive for engineering integration. These plans and thoughts were evidence that the elementary teachers gleaned from their engineering teaching practice knowledge about those school contexts constraining elementary engineering education. Such knowledge would provide the elementary teacher with valuable guidance of how to adapting their engineering teaching practices to the contextual constraints to ensure more successful and sustainable integration of engineering into their classrooms.

2.4.3 Discussion

The findings of this study revealed that the elementary teachers developed two types of knowledge through their engineering teaching practice: 1) Knowledge about engineering teaching and learning difficulties and various classroom- and school-related contextual constraints on elementary engineering integration; 2) Knowledge about engineering teaching strategies and methods dealing with the above difficulties and contextual constraints. These two types of knowledge covered both the “L” dimension and the “C” dimension in the ELC framework of this study, but they were of quite different nature. Based on their review of previous literature, Mason and Spence (1999) distinguished two types of knowledge: knowing-about which includes “knowing-that
(factual), knowing-how (technique and skill) and knowing-why (having a story in order to structure actions)” (p. 135), and knowing-to which is the active knowledge that enables one to act and respond to specific new situations. Of the two aforementioned types of knowledge the elementary teachers developed through their engineering teaching practice, the former one would be classified as knowing-about while the latter as knowing-to. And the elementary teachers’ knowing-to was the engineering PCK as defined in this study.

According to Mason and Spence (1999), knowing-about, albeit important, is not sufficient to enable teachers to handle particular learning and teaching situations. To be able to do so, teachers need to develop their knowing-to. But knowing-about does not necessarily entail the development of knowing-to. The elementary teachers started their engineering teaching practice with existing knowing-about. Such knowing-about included the “knowing-that”, “knowing-how”, and “knowing-why” they accumulated from their prior experience in teaching non-engineering disciplines and also included the “knowing-that”, “knowing-how”, and “knowing-why” they learned through the training in the INSPIRE summer academy. In their engineering teaching practice, they developed their knowing-about of engineering teaching and learning difficulties and various classroom- and school-related contextual constraints. Does this newly developed knowing-about together with their pre-existing knowing-about automatically allow them to know how to act and respond to the specific engineering learning situations in their classrooms?

The inert knowledge problem prevents us from applying existing knowledge to new situations (Gambro & Switzky, 1996; Mandl, Gruber & Renkle, 1994; Miller & Gildea, 1987; Renkl, Mandl, and Gruber, 1996). This inert knowledge problem may help explain the knowledge transfer problem in professional development and the common lore
among teachers that were mentioned earlier in this paper. Of the three types of explanations (i.e. metaprocess explanations, structure deficit explanations, and situatedness explanations) identified by Renkl et al (1996) for the causes of the inert knowledge problem, situatedness explanations are based on the perspective that “knowledge is fundamentally situated and, therefore, context-bound” (p. 115) and attribute the causes of the inert knowledge problem to the differences between new situations and previous situations from which prior knowledge was built. Teachers’ knowledge about teaching is deeply situated in classroom practices (Shulman, 1987) and is deeply dependent on particular times, places, and contexts (Orton, 1993). The elementary teachers in this study had no prior engineering teaching experience before participating in this study and engineering was a discipline seldom taught at the elementary level. So, the new engineering teaching and learning situations would possibly render the elementary teachers’ knowing-about, whether pre-existing or newly-acquired, inert and consequently made them unable to deal with the new engineering teaching and learning situations. However, the knowing-to the elementary teachers developed through their engineering teaching practice provided strong evidence that this was not the case.

Findings from this study revealed those “trials and failures” the elementary teachers experienced before they arrived at their knowing-to. In face of the teaching and learning difficulties and contextual constraints encountered in their engineering teaching practice, the elementary teachers tried the instructional strategies and methods which they used and were effective in teaching other non-engineering disciplines but found these strategies and methods did not work for the engineering learning situations at hand. The
elementary teachers initially carried out the engineering lessons and activities as they had learned in the INSPIRE summer academy but later realized that these lessons and activities needed to be done differently to make engineering teaching workable under the contextual constraints. Such trials and failures allowed the elementary teachers to see what did not work for their students in the new elementary engineering teaching contexts, which finally led the teachers to become successful in finding the teaching strategies and methods that worked. This “trial-failure-success” process empowered and situated the elementary teachers’ knowing-about, turning it into knowing-to that were responsive to particular engineering learning needs and engineering teaching contexts.

Describing themselves as “radical constructivists”, Cochran et al. (1993) adopted the term PCKg (Pedagogical Content Knowing) to refer to PCK based on the belief that the word “knowledge” is too static to capture the dynamic process where teachers construct their PCK. Findings from this study presented an engineering PCK development process (illustrated in Figure 4) which is not only dynamic but evolving. During this process, the elementary teachers first developed their knowing about engineering teaching and learning difficulties and classroom- and school-related contextual constraints. And then they engaged themselves in a trial-failure-success process which empowered and situated their newly-developed and pre-existing knowing about. It was in this process that the elementary teachers constructed their engineering PCK or knowing-to in the form of instructional strategies and methods overcoming those difficulties and constraints uncovered by their knowing-about.
The elementary teachers in this study received one week of INSPIRE engineering teaching training and were provided with engineering curriculum and teaching materials to be used for classroom implementation. The INSPIRE training, their prior non-engineering teaching experience, and their newly developed knowledge about engineering teaching and learning difficulties and contextual constraints served as knowing-about based on which the elementary teachers constructed their engineering PCK. However, indispensible for their constructing of engineering PCK was the trial-failure-success process the elementary teachers engaged themselves in during their engineering teaching practice. This dynamic process was a sense-making process empowering and situating the elementary teachers’ knowing-about and transforming their knowing-about into engineering PCK.
The importance of this sense-making process carries valuable messages to professional development programs: 1) Elementary teachers’ engineering PCK development should be approached from a dynamic and evolving stance rather than a possessive and static one; 2) The sense-making process rooted in real classroom and school settings is essential for elementary teachers’ construction of engineering PCK; 3) Absence of this sense-making process may result in the inertia of elementary teachers’ knowing-about and consequently block elementary teachers from responding effectively to student engineering learning needs and contextual constraints.

The elementary teachers’ situated and practice-based knowing-about and knowing-to concerning engineering teaching in elementary classrooms are valuable resources that can be used for the improvement of future INSPIRE elementary engineering training programs. The findings of the study suggest that a “returning, sharing, and improving” mechanism can be adopted by INSPIRE and other similar professional development programs to improve engineering professional development for both in-service and pre-service elementary teachers. The mechanism can work like this: Invite previous teacher learners who have practiced engineering teaching in real elementary classrooms to return and share their knowing-about and knowing-to with new participating teachers. This will help new teacher learners enrich their knowing about engineering teaching and learning, facilitate their sense-making process, and promote their engineering PCK construction once they leave professional development programs to start their engineering teaching practice. Professional development faculty and organizers can improve instruction and training materials for their future participating elementary teachers based on the knowing-about and knowing-to gathered from their previous teacher learners.
The *knowing-about* and the *knowing-to* related to the “contexts” dimension would be especially important for professional development programs if they aim to permeate engineering into elementary classrooms. The *knowing-about* and *the knowing-to* related to the “contexts” dimension, for example, would help professional development programs to ensure that the elementary engineering lessons or activities they develop are aligning with what elementary teachers have to do as mandated by state or school curriculum. The “kill-two-birds-with-one-stone” effects achieved through such engineering lessons or activities will definitely promote the permeation of engineering into elementary classroom.

The permeation of engineering into elementary classrooms also relies on including pre-service teachers into professional development of engineering education. The “returning, sharing, and improving” sessions would be helpful to pre-service teachers as well. Those sessions can facilitate their future development of engineering PCK and can prepare them for possible difficulties and issues they may encounter in their future elementary engineering teaching practice.
CHAPTER 3. ELEMENTARY ENGINEERING EDUCATION (EEE) ADOPTION AND EXPERTISE DEVELOPMENT FRAMEWORK: AN INDUCTIVE AND DEDUCTIVE STUDY

3.1 Introduction

Integrating engineering into elementary classrooms is an innovative educational practice that promotes technological literacy (Cunningham, Lachapelle, & Lindgren-Streicher, 2006) and addresses the national concern about the shrinking Science, Technology, Engineering, and Mathematics (STEM) workforce (Nugent, Kunz, Rillet & Jones, 2010). However, engineering is not a discipline traditionally taught at the elementary level, and elementary teachers, in comparison to middle and high school teachers, are the least prepared for and least interested in teaching design, engineering, and technology (DET) (Yasar et al., 2006). There is an urgent need to prepare elementary teachers to teach engineering. This need is even more pressing given that a significantly large number of states (currently 41) contain explicit engineering components in their existing standards for science, math, vocational, and technological education (Carr, Bennett & Strobel, 2012), and that the new national science education framework contains for the first time engineering as explicit content (Committee on Conceptual Framework for the New K–12 Science Education Standards, 2011). An ever-increasing

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number of professional development programs are currently offering training to elementary teachers to prepare them for engineering teaching (e.g., CIESE PD workshops in CIESE, 2010; EiE workshops in Cunningham, 2008; INSPIRE summer academies in Strobel & Sun, 2013).

Previous research on professional development in elementary engineering education (EEE) reported the positive impact of professional development on both elementary teachers’ engineering content knowledge and their teaching practices (Cunningham, Lachapelle & Keenan, 2010; Hsu, Cardella & Purzer, 2010). However, findings from previous research also revealed elementary teachers’ misconceptions about engineering and technology (Cunningham, Lachapelle, & Lindgren-Streicher, 2006); their varying degrees of unfamiliarity with Design, Engineering and Technology (DET) (Hsu, Cardella, Purzer & Diaz 2010); and their perceived barriers to integrating engineering into elementary classrooms (Lee & Strobel, 2010). These misconceptions, unfamiliarity with DET, and perceived barriers have contributed to elementary teachers’ fear of teaching engineering and skepticism about integrating engineering into their classrooms (Cunningham, 2008; Liu, Carr & Strobel, 2009).

What we can learn from the above referenced research is that, given the innovative nature of EEE and elementary teachers’ unpreparedness for engineering teaching, both elementary teachers’ EEE adoption and EEE expertise development will be a process over time. To improve the effectiveness of engineering professional development for elementary teachers, we need to have a systematic and comprehensive understanding about the EEE adoption and EEE expertise development process. But unfortunately, such an understanding is missing in the literature. The present study was intended to fill up the
gap by investigating elementary teachers’ EEE adoption and EEE expertise development and by constructing an EEE adoption and expertise development framework.

Adopting theoretical perspectives furnished by (1) Rogers’s (2003) diffusion of innovation model, (2) the Concerns-Based Adoption Model (CBAM) (Hall and Hord 1987; 2005; Hord, Rutherford, Huling-Austin, and Hall 1987), and (3) Dreyfus and Dreyfus’s skill acquisition model (Dreyfus, 2004; Dreyfus & Dreyfus, 1980), the researchers of this study constructed an EEE adoption and expertise development framework. The construction of the framework was based on analyses of interview and survey data collected from 2nd – 4th grade elementary teachers who participated in the elementary engineering education summer academies offered by INSPIRE.

3.2 Purpose and Research Questions

The purpose of this study was to construct an EEE adoption and expertise development framework by investigating elementary teachers’ adoption and implementation of engineering teaching. This framework is intended to capture the developmental process of elementary teachers’ EEE adoption and EEE expertise development diachronically, and to reflect individual differences and personal experiences synchronically at a given time during the EEE adoption and EEE expertise development process.

The construction of this framework was guided by two research questions: 1) What are the stages of EEE adoption and what are the descriptive characterizations associated with each stage? 2) What are the stages of EEE expertise development and what are the descriptive characterizations associated with each stage?
The EEE adoption and expertise development framework construction in this study includes two diagnostic dimensions: the EEE adoption dimension and the EEE expertise development dimension. This two-dimensional framework is proposed to help professional development programs conceptualize, assess, and track elementary-teachers’ EEE adoption and EEE expertise development so as to provide the learners with appropriate needs-based instruction and support that promotes sustainable integration of engineering into elementary classrooms.

3.3 Literature Review

3.3.1 Preparing Elementary Teachers for Teaching Engineering

Integrating engineering into elementary classrooms is innovative both in the sense that it requires modifications of existing teaching practice to include engineering (Cunningham, 2008) and that engineering is a discipline not taught or learned in the majority of schools in the United States (Cunningham, Lachapelle, & Lindgren-Streicher, 2006). This level of innovation entails great challenges in preparing elementary teachers because “the education of the vast majority of elementary school teachers (like the bulk of our population) did not include engineering or technology activities or information” (Cunningham, Lachapelle, & Lindgren-Streicher, 2006, p.1). The challenge of preparing elementary teachers for engineering teaching also lies in the fact that elementary teachers are generally disinterested in and intimidated by science content (Buczynski & Hansen, 2010) and by DET (Yasar et al., 2006). In addition, it has been shown that engineering teaching has it idiosyncratic properties rendering generic teaching strategies ineffective.
(Strobel & Yan, 2013). This presents another challenge for preparing elementary teachers for engineering teaching.

Elementary teachers are not prepared for engineering teaching. Their unpreparedness can be seen in their misconceptions and overly broad ideas about engineering and technology (Cunningham, Lachapelle, & Lindgren-Streicher, 2006), their unfamiliarity with DET (Hsu, Cardella, Purzer & Diaz 2010), and their hesitance to teach engineering as reflected in their concerns such as meeting state standards, lack of time, resources, and administrative support (Hsu, Cardella, Purzer & Diaz 2010; Strobel & Sun, 2011). Moreover, in their engineering teaching practice, elementary teachers demonstrated individual differences in terms of comfort levels with teaching engineering and decisions about implementing engineering teaching: not only did the amount of engineering teaching implemented vary from teacher to teacher, but also elementary teachers’ decisions about future implementation were quite different. Some indicated that they would include more engineering into their classrooms, some expressed their inclination not to do so, and some were not sure about their decision for want of enough information and knowledge about engineering (Carson & Campbell, 2007). Individual elementary teachers also differed in their perceptions of the importance of DET, and these differences were reported to be related to previous full-time teaching experience in general and science teaching experience in particular (Hsu, Cardella, Purzer, & Diaz 2010).

Two overarching themes identified from previous research are: 1) given elementary teachers’ unpreparedness for engineering and engineering teaching, it will be a process for elementary teachers to become prepared for teaching engineering; 2) there exist
individual differences among elementary teachers in their perceptions and attitudes toward, and their capabilities in, teaching engineering. These two overarching themes highlight the importance for professional development programs to develop both a diachronic and a synchronic view of integrating engineering into elementary classrooms. While a diachronic view will enable professional development programs to understand strategically the changes elementary teachers have to go through to ensure the sustainable integration of elementary engineering, a synchronic view will allow professional development programs to make tactical planning aimed to deal effectively with individual elementary teachers’ differences in adopting and implementing engineering teaching.

Reviewing previous literature, the researchers of this study found Rogers’s innovation diffusion model, the CBAM, and the Dreyfus skill acquisition model relevant and enlightening for the construction of the EEE adoption and expertise development framework. Therefore, these models are review below.

3.3.2 Diffusion of Innovation Models (Rogers’s and CBAM)

Rogers’s diffusion of innovations model. Rogers’s diffusion of innovations model describes how, why, and at what rate innovations become diffused into widespread practice among members of a social system. Rogers (2003) defines innovation as “an idea, practice, or object that is perceived as new by an individual or other unit of adoption” (p.12) and diffusion as “the process in which an innovation is communicated through certain channels over time among the members of a social system” (p.5).
In his model, Rogers (2003) describes the innovation-decision process as “an information-seeking and information-processing activity, where an individual is motivated to reduce uncertainty about the advantages and disadvantages of an innovation” (p. 172). According to Rogers (2003), the innovation-decision process (shown in Table 2) involves the following five stages:

Table 2

*The Innovation-decision Process of Rogers’ Diffusion of Innovation Model*

<table>
<thead>
<tr>
<th>The knowledge stage</th>
<th>An individual learns about the existence of an innovation and seeks information about it.</th>
</tr>
</thead>
<tbody>
<tr>
<td>The persuasion stage</td>
<td>The individual develops a positive or negative attitude toward the innovation.</td>
</tr>
<tr>
<td>The decision stage</td>
<td>The individual makes a decision to adopt or reject the innovation.</td>
</tr>
<tr>
<td>The implementation stage</td>
<td>The individual puts the innovation into practice and reinvention of the innovation may take place.</td>
</tr>
<tr>
<td>The confirmation stage</td>
<td>The individual stays away from “conflicting messages about the innovation” (p. 189), seeking confirmatory information supporting his/her decision, but discontinuance may still occur.</td>
</tr>
</tbody>
</table>

According to Rogers (2003), five characteristics (shown in Table 3) of an innovation are notably relevant to decisions to adopt:

Table 3

*The Five Characteristics of an Innovation*

<table>
<thead>
<tr>
<th>Relative advantage</th>
<th>“The degree to which an innovation is perceived as being better than the idea it supersedes” (p. 229).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compatibility</td>
<td>“The degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters” (p. 15).</td>
</tr>
<tr>
<td>Complexity</td>
<td>“The degree to which an innovation is perceived as relatively difficult to understand and use” (p. 15).</td>
</tr>
<tr>
<td>Triability</td>
<td>“The degree to which an innovation may be experimented with on a limited basis” (p. 16).</td>
</tr>
<tr>
<td>Observability</td>
<td>“The degree to which the results of an innovation are visible to others” (p. 16).</td>
</tr>
</tbody>
</table>
In addition, Rogers (2003) recognizes individual differences in innovativeness—
“the degree to which an individual or other unit of adoption is relatively earlier in
adopting new ideas than other members of a system” (p. 22). Based on their
innovativeness, individuals can be classified into five adopter categories: innovators
(2.5%), early adopters (13.5%), early majority (34%), late majority (34%), and laggards
(16%).

The Concern-Based Adoption Model (CBAM). Unlike Rogers, who argues for and
was committed to the development of a general diffusion model across various
disciplines (Rogers, 2004), the CBAM team roots the development of CBAM in school
contexts and specifically focuses on describing and explaining the process of attitudinal
and behavioral changes experienced by teachers when adopting educational innovations
and the effects of interventions from external change agents on adoption.

CBAM (Hall & Hord, 1987) consists of three diagnostic frameworks for
conceptualizing and measuring individual teachers’ engagement with and implementation
of proposed educational innovations: stages of concern, levels of use, and innovation
configuration. This research study only utilizes the first two frames of stages of concern
and levels of use due to the fact that our framework is not based on classroom
observation—a requirement for the third framework.

The stages of concern framework (Hall & Hord, 1987) identifies the seven
developmental stages of concern (shown in Table 4) that teachers go through in adopting
and implementing an educational innovation:
Table 4

The Stage of the Concern Framework of CBAM

<table>
<thead>
<tr>
<th>Stage</th>
<th>Concern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 0: Awareness</td>
<td>Little interest in or concern with the innovation.</td>
</tr>
<tr>
<td>Stage 1: Informational</td>
<td>Interest in learning more about the innovation (without worry about self in relation to the innovation).</td>
</tr>
<tr>
<td>Stage 2: Personal</td>
<td>Uncertainty about the demands of the innovation, personal ability to implement it, and personal costs of getting involved.</td>
</tr>
<tr>
<td>Stage 3: Management</td>
<td>Focus on implementation issues of efficiency, organization, management, scheduling, and time demands related to the innovation.</td>
</tr>
<tr>
<td>Stage 4: Consequence</td>
<td>Focus on the impact of the innovation on students and the possibility of modifying the innovation to improve learning outcomes.</td>
</tr>
<tr>
<td>Stage 5: Collaboration</td>
<td>Interest in coordinating and cooperating with other teachers regarding the innovation.</td>
</tr>
<tr>
<td>Stage 6: Refocusing</td>
<td>Focus on exploring more benefits of the innovation, including the possibility of making changes in it or replacing it with an alternative innovation.</td>
</tr>
</tbody>
</table>

While the stages of concern framework presents the affective dimension of change experienced by teachers in the adoption and implementation process of an educational innovation, the levels of use framework (Hall & Hord, 1987) focuses on teachers’ behavioral patterns as they prepare to use, begin to use, and gain experience in implementing an educational innovation. An individual teacher’s behavior in the change process can be identified as belonging to one of the seven levels (which include both non-users and users of the new program) (shown in Table 5), with seven corresponding decision points at which a positive decision signals a subsequent increase in the teacher’s commitment to and utilization of the innovation (Hall & Hord, 1987):
### Table 5

*The Level of Use Framework of CBAM*

<table>
<thead>
<tr>
<th>Level of Use</th>
<th>Description of levels and decision points</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nonuser</strong></td>
<td></td>
</tr>
<tr>
<td>Level 0: Nonuse/Unaware</td>
<td>The teacher has no knowledge of the new program and no involvement in it, and is doing nothing to become involved.</td>
</tr>
</tbody>
</table>
| Level 1: Orientation | The teacher has acquired or is acquiring information about the new program and is exploring its value orientation.  
*Decision point A: The teacher decides to take action to seek more detailed information about the new program.* |
| Level 2: Preparation | The teacher is preparing for first use of the innovation.  
*Decision point B: The teacher decides to use the innovation.* |
| **User**           |                                           |
| Level 3: Mechanical Use | The teacher begins to implement the innovation but is struggling with following the stepwise procedures required of the innovation implementation with little time for reflection.  
*Decision point C: Decisions about changes (if any) and use (e.g., making the innovation more manageable and easy to implement) are teacher-centered rather than student-centered.* |
| Level 4a: Routine Use | The teacher establishes a routine pattern of innovation use.  
*Decision point D1: The teacher makes a few attempts to improve the innovation practice or its consequences.* |
| Level 4b: Refinement | The teacher assesses the impact of the innovation on his/her students and initiates corresponding changes in innovation use to improve student outcomes.  
*Decision point D2: The teacher makes changes in the use of the innovation to improve student outcomes.* |
| Level 5: Integration | The teacher collaborates with other teachers to extend the impact of the innovation beyond his/her individual classroom.  
*Decision point E: The teacher makes changes based on input of peer teachers and in coordination with what they are doing.* |
| Level 6: Renewal    | The teacher re-evaluates the quality of innovation implementation and seeks to make major modifications in the innovation and/or explore alternative innovations.  
*Decision point F: The teacher begins making major modifications to the innovation and/or exploring alternative, better innovations.* |
CBAM makes it explicit that the adoption and implementation of educational innovations is a process that is developmental in nature and a highly personal experience for each teacher, involving developmental growth in feeling and skills (Anderson, 1997; Hall, Loucks, Rutherford, & Newlove, 1975). The CBAM framework furnished the researchers of this study with new lenses to approach the adoption and implementation of EEE by elementary teachers.

3.3.3 Dreyfus Skill Acquisition Model

Studies of change in adopting and implementing an innovation should focus on individuals—their change first in attitudes and then in knowledge and skills (Casey, Harris & Rakes, 2004). So, when investigating elementary teachers’ EEE expertise development, the researchers of this study included the Dreyfus skill acquisition model (Dreyfus, 2004; Dreyfus & Dreyfus, 1980) as one of the theoretical frameworks.

The Dreyfus skill acquisition model (Dreyfus, 1982, 2004; Dreyfus & Dreyfus, 1980, 1986) consists of five stages of skill acquisition (Dreyfus, 2004): Stage 1, novice; stage 2, advanced beginner; stage 3, competence; stage 4, proficiency; and stage 5, expert.

In stage 1, a novice learner has no previous experience in the task he/she is learning, and is therefore dependent on context-free rules and invariably follows these rules without heeding specific external circumstances. After experiencing a sufficient number of examples of the task, a novice learner becomes an advanced beginner and begins to develop context-specific knowledge about the task. But according to Dreyfus (2004), “Still, at this stage, learning can be carried on in a detached, analytic frame of mind” (p.177).
Learners at the stage of “competence” are learning to deal with performance overload by developing a plan or choosing a perspective that helps them to focus on a few of the vast body of possible relevant elements and aspects, and to consequently make understanding and decision making easier. Characteristic of this stage is that the detached stance of the novice and the advanced beginner is replaced by the learner’s emotional involvement in the chosen actions and in responsibility for the outcomes, successful or unsuccessful, of his/her choices.

Learners at the stage of “proficiency” assimilate experience into the ability to discriminate important aspects from unimportant aspects among a variety of situations and the ability to act accordingly. But a proficient learner still has to make decisions about the best course of action consciously in a specific situation. With enough experience in a wide variety of situations, a proficient leaner gradually develops the ability to make more subtle and refined discriminations and enters the stage of “expertise”. In this stage, the individual possesses the expertise that allows him/her to make intuitive decisions about the best action without calculating or comparing alternatives.

The Dreyfus skill acquisition model has been adopted by researchers to study expertise development in areas like nursing (e.g., Benner, 2004; Benner, Hooper-Kyriakidis, & Stannard, 1999) and teaching (e.g., Berliner, 1988a, 1988b; Crawford, 2003). Based on the Dreyfus skill acquisition model, Berliner’s research (1988a, 1988b) pointed out that teachers at various levels of experience and expertise differed in their ability to interpret classroom phenomena, discern the importance of events, use routines, predict classroom phenomena, judge typical and atypical events, and evaluate teaching
performance. Empirical data in Berliner’s studies revealed that “developmental differences are real” (1988a, p.33) among teachers in teaching-expertise development and that these differences “have important implications for the policies we adopt for the education of teachers” (p.33). Findings from Berliner’s studies help justify the appropriateness of adopting the Dreyfus skill acquisition model as a theoretical framework for studying teaching expertise.

3.4 Theoretical and Methodological Framework

This study used Rogers’s innovation diffusion model, the CBAM, and Dreyfus’s skill acquisition model as the theoretical frameworks for the construction of the EEE adoption and expertise development framework. Four presumptions about the EEE adoption and expertise development framework were derived from these theoretical frameworks: 1) The adoption and implementation of EEE as an innovation is a process; 2) During the process, there exist different EEE adoption stages along a continuum, with identifiable traits and qualities associated with each stage; 3) During the process, there exist different EEE expertise development stages along a continuum, with identifiable traits and qualities associated with each stage; 4) Synchronically, individual elementary teachers stand in different EEE adoption and EEE expertise development stages, and diachronically, individual elementary teachers progress along the stages. To construct the EEE adoption and expertise development framework, researchers of this study adopted an analytic induction approach, which is first deductive and then inductive (Patton, 2002). Specifically, the researchers began examining the data of the study in terms of the theory-
derived presumptions and then looked at the data afresh for “undiscovered patterns and emergent understandings” (Patton, 2002, p.454).

The four theory-derived presumptions served as guidance for the construction of a prototype framework and as sensitizing concepts (Blumer, 1969) which provided the researchers “a general sense of reference” and “directions along which to look” (p. 148) when examining the data in the deductive phase to verify the assumptions and to refine the prototype. In the inductive phase, the researchers identified themes and patterns through inductive analysis and put these themes and patterns into categories. The researchers developed terms to describe these inductively-generated categories (Pattorn, 2002), and then used them to create analyst-constructed typologies (Marshall & Rossman, 2010; Patton, 2002). The typologies are explanatory in nature, assuming both the classificatory and descriptive roles (Elman, 2005). The classificatory role functions to divide elementary teachers’ EEE adoption and expertise development into “parts along a continuum” (Pattern, 2002, p.457), while the descriptive role functions to provide a description of these parts based on an inductive analysis of the patterns that emerged from the data.

The theoretical and methodological framework of this study is illustrated in Figure 6.
3.5 Research Design

Data for this study were collected from the participating teachers of INSPIRE’s local summer academies using face-to-face interviews and online open-ended surveys. Transcriptions of the interviews were analyzed together with the answers to the online open-ended survey questions for the purpose of constructing the EEE adoption and expertise development framework.

3.5.1 INSPIRE Local Summer Academies (Project Context)

INSPIRE was established in 2006 and is dedicated to the integration of engineering into K–12 education and the improvement of engineering education in K–12 school settings. INSPIRE provides elementary teachers with professional development in...
engineering education through national summer academies at the university where INSPIRE is located, local summer academies at the locations of partnering schools, and online professional development programs. The summer academy is a week-long, face-to-face workshop for elementary teachers interested in integrating engineering into their classrooms. Since 2006, INSPIRE has organized four national summer academies for over 120 elementary teachers from 16 states, and local summer academies in Arlington, TX with funding from a private foundation. The summer academy uses EiE (Engineering is Elementary®) curriculum\(^3\) materials such as Storybooks, Lesson Plans, and Student assessments and models the teaching of two of the twenty EiE units to elementary teachers to familiarize them with the structure of EiE curriculum and some elementary engineering teaching pedagogy.

3.5.2 Participants

The INSPIRE summer academies were held among elementary teachers from 13 elementary schools in a school district in Arlington, TX. While the 73 participating teachers interviewed were recruited by a mix of convenience sampling and purposeful sampling, all of them signed up for the summer academies voluntarily. These teachers taught grades 2 through 4, mostly in self-contained classrooms. A total number of 101 interviews were conducted with them, including 75 individual interviews and 26 group interviews. The demographic information of these teachers is given in Figure 7.

\(^3\) The EiE curriculum is authored by Engineering is Elementary®, an elementary engineering curriculum development project primarily funded by the National Science Foundation (NSF).
Figure 7. Demographic information of teacher participants (Study II)

Approximately half of the elementary teachers interviewed hold B. A. degrees in fields such as English, Early Childhood Education, Interdisciplinary Studies, and Government (see Figure 8). Twenty-eight out of twenty-nine B.S. degrees held by the teachers are in non-STEM fields like Education, Advertising, and Photography. Nine of these teachers have Masters Degrees, three of which are in STEM-related fields. One of the teachers holds an Ed.D. in Curriculum and Instruction with a focus on math education.

Figure 8. Educational background of teacher participants
Two open-ended online surveys were conducted among the participating elementary teachers of the INSPIRE Arlington local summer academy. Sixty-eight elementary teachers responded to the survey, answering questions about their beliefs, motivations, concerns, and plans for incorporating engineering into their classrooms.

3.5.3 Data Collection

The face-to-face group interviews were conducted in June 2008, December 2008, and December 2009. In the group interviews, the elementary teachers were selected into groups of three to six based on their individual schedules and each group was interviewed by a member of the research team. Fifty-eight teachers were included in group interviews. Two rounds of individual interviews with 62 different elementary teachers took place in May 2009 and May 2010. The 33 teachers interviewed in 2009 were Cohort I, who attended the 2008 summer academy. Although it was planned to interview all these 33 teachers again in 2010, only 13 of them were available during the time of 2010 interview. So, among the 42 teachers interviewed in 2010, 29 were Cohort II, who attended the 2009 summer academy and the remaining 13 teachers were Cohort I, who were interviewed both in 2009 and 2010. All interviews were audio-taped and then transcribed. The two open-ended surveys were posted online in July 2009 and July 2010, and survey data were collected in September 2009 and September 2010 respectively. The data were sorted in an Excel file after collection and prepared for analysis.
3.5.4 Data Analysis

Three sets of data sources were included in this study: the individual interviews, the group interviews, and the answers to the online open-ended survey questions. Three rounds of data analyses (summarized in Figure 9) were conducted on these data.

![Figure 9. Three rounds of data analysis (Study II)](image)

In the first round of data analysis, the individual interviews in 2009 and 2010 were respectively arranged into 4 groups according to the elementary teachers’ years of teaching experience: the “0-2 years” group, the “3-5 years” group, the “6-10 years” group, and the “over 11 years”.

There were in total eight groups of individual interviews, and two individual interviews were randomly selected from each of the eight groups. The 16 individual interviews were put together with 12 randomly selected group interviews (four from June...
2008, four from December 2008, and four from December 2009) and the answers to the open-ended survey questions.

The researchers of this study read through these interviews and the answers carefully first for verifying the four presumptions and for developing the prototype framework of EEE adoption and expertise development. Then the researchers read through these data for the second time on a line-by-line basis, independently taking analytical memos of the themes and patterns either supporting or challenging the stages of EEE adoption and expertise development in the prototype. The prototype framework was modified and refined based on the comparisons and discussions of the analytical memos to ensure reliability and validity. The modified and refined framework was then tested against new randomly selected interview data. Each time, five new interviews were selected and the researchers read through the interviews, independently taking analytical memos of newly emerged themes and patterns. Whenever finishing five newly selected interviews, the researchers joined together to compare and discuss their analytical memos and made revisions of the framework to reflect the newly emerged themes and patterns. The testing continued until no new themes and patterns emerged, agreement was reached, and the themes and patterns became saturated (Strauss & Corbin, 1998). All themes and patterns thus yielded were collected and compared to organize into appropriate EEE adoption and EEE expertise development classificatory categories and stages. Analyzing the themes and patterns at each stage, the researchers developed terms to name each of the stages. A two-dimensional, multiple-staged EEE adoption and EEE expertise development framework was finally constructed.
In the second round of data analysis, the researchers of the study checked the reliability and validity of the EEE adoption and expertise development framework. During the framework check process, each time the researchers randomly selected two individual interviews and rated the two interviewed teachers into specific EEE adoption and EEE expertise development stages while taking notes of evidence supporting their ratings. After finishing the ratings, the two researchers compared their ratings and discussed the differences in their ratings with reference to their notes. Researchers modified or clarified particular themes and patterns in the framework. A total of three rounds of framework check were conducted, and the results are as follows: in the first round, the two researchers reached 57% agreement (4 categories out of 7); in the second round, the researchers reached 71% agreement (5 categories out of 7); and in the last round, the researchers reached 100% agreement (7 categories out of 7).

For the third round of data analysis, the researchers analyzed the individual interviews of those elementary teachers who were interviewed both in May 2009 and May 2010. There were in total 13 elementary teachers who were interviewed individually in both these two years, but only 12 teachers’ interviews (24 interviews in total) were analyzed because one elementary teacher acted as engineering teaching facilitator for the other 12 teachers and did not actually implement engineering in her classroom. Each of the researchers first independently read the 24 individual interviews and rated the 12 teachers’ 2009 and 2010 standings in the EEE adoption and expertise development stages. While reading and doing the rating, the researchers took notes of evidence supporting their ratings and of the differences the teachers demonstrated between the two years. Then the researchers met to compare their ratings and resolve the differences by referring
to their notes and the original interviews. A final list of the 12 teachers’ 2009 and 2010 standings in the EEE adoption and expertise development stages was agreed upon by the researchers. This list is reported in the next section to show the elementary teachers’ progress over the two years of 2009 and 2010.

3.6 Findings and Discussion: the EEE Adoption and Expertise Development Framework

Data analysis results of this study verified the four theory-derived presumptions. The final EEE adoption and expertise development framework includes the EEE adoption dimension and the EEE expertise development dimension. We present the two dimensions in this section, specifying the classificatory categories included in each dimension and elaborating upon the descriptive characterizations of each classificatory category that distinguish the elementary teachers into different EEE adoption and EEE expertise development stages.

3.6.1 The EEE Adoption Dimension

Findings from this study indicated that one important characteristic of EEE adoption among the elementary teachers was synchronic differences, that is, synchronically, individual elementary teachers stood at different EEE adoption stages although receiving the same EEE training and practicing engineering teaching for the same amount of time. Four themes emerged from the data analyses as factors that influenced elementary teachers’ EEE adoption process: 1) perception of practicality and sustainability of EEE; 2) comfort level with engineering teaching; 3) perception of EEE benefits to elementary students; 4) degree of engineering integration. These four themes are the overarching
classificatory categories, and the specific data-derived patterns falling under these four
categories serve as descriptive characterizations that classify the elementary teachers into
the four stages of EEE adoption: attempter, adopter, ameliorator, and advocator. The
following table (Table 6) lists the four different EEE adoption stages and the descriptive
classifications of each stage.
### Table 6

#### Stages of EEE Adoption

<table>
<thead>
<tr>
<th>Stages of EEE Adoption</th>
<th>Perception of Practicality and Sustainability of EEE</th>
<th>Comfort Level with Engineering Teaching</th>
<th>Perceptions of EEE Benefits to Elementary Students</th>
<th>Degree of Engineering Integration</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stage I: Attempter</strong></td>
<td>I-1: Overwhelmed by the perceived barriers to EEE and regarding EEE as impractical and unsustainable because of the perceived barriers</td>
<td>I-2: Feeling uncomfortable with teaching engineering as indicated by unwillingness to teach engineering and by the mish-mash of engineering content when teaching</td>
<td>I-3: Holding an “engineering as anti-literacy” view about EEE benefits (i.e., learning engineering helps understand some engineering-related concepts)</td>
<td>I-4: Teaching engineering continuously and sporadically and treating engineering teaching as isolated and as an add-on</td>
</tr>
<tr>
<td><strong>Stage II: Adopter</strong></td>
<td>II-1: Fully aware of the perceived barriers of EEE but viewing engineering as practical in elementary classrooms</td>
<td>II-2: Feeling more comfortable with teaching engineering as indicated by covering expected amount of engineering content and allowing more time elaborating engineering content and answering student questions</td>
<td>II-3: Hold an “engineering as an excursion” view about EEE benefits (i.e., learning engineering helps review knowledge and skills learned in other disciplines)</td>
<td>II-4: Devoicing more time for engineering teaching and wanting to make occasional attempts to integrate engineering into the teaching and learning of other non-engineering disciplines</td>
</tr>
<tr>
<td><strong>Stage III: Ameliorator</strong></td>
<td>III-1: Proving EEE practicality though engineering teaching practice and becoming conscious of the need to make EEE sustainable</td>
<td>III-2: Feeling quite comfortable with teaching engineering as indicated by regular engineering teaching practice and expanding engineering learning with additional engineering teaching materials</td>
<td>III-3: Hold an “engineering as application and enrichment” view about EEE benefits (i.e., learning engineering helps broaden students’ horizon and enrich their skill sets)</td>
<td>III-4: Practicing engineering teaching on regular basis and being more frequent in integrating engineering into the teaching and learning of some of other non-engineering disciplines</td>
</tr>
<tr>
<td><strong>Stage IV: Advocate</strong></td>
<td>IV-1: Convincing of EEE practicality based on successful personal engineering teaching experiences and starting to make efforts to make EEE sustainable</td>
<td>IV-2: Feeling fully comfortable with teaching engineering as indicated by confidence gained through successful engineering teaching experiences and willingness to make the successful engineering teaching stories known to others</td>
<td>IV-3: Holding an “engineering as empowerment” view about EEE benefits (i.e., learning engineering promotes students’ development as real-life problem solvers and their understanding of the career potentials in engineering)</td>
<td>IV-4: Making engineering teaching an integral part of teaching practice as a result of being able to integrating engineering into all other non-engineering disciplines all the time</td>
</tr>
</tbody>
</table>
**Attempter**

**I-1: perception of practicality and sustainability of EEE.** Elementary teachers in this study voiced their perceived barriers to integrating engineering into their classrooms in their responses to the online open-ended survey. Some major perceived barriers included time issues, lack of administrative support, lack of resources, personal unpreparedness, accountability issues, and student learning-related issues. Typical of the elementary teachers in the attempter stage was that their perception of the practicality and sustainability of EEE was teacher-oriented rather than student-oriented. So barriers related to time issues, administrative support, and accountability issues like high-stakes tests drew most of their attention. These elementary teachers became rather overwhelmed by these barriers and regarded EEE as impractical and unsustainable because, as some mentioned in the interview, “I need to prepare the students for the state-tests”, or “I’m required to teach certain objectives throughout the year, and I don’t have enough time to teach it [engineering]”. For some attempters, these barriers all came back to time, but when asked what they planned to do to move past the issue of time, the typical answers they gave were “I don’t know” or “It’s really a tough question”.

**I-2: comfort level with engineering teaching.** Elementary teachers at the attempter stage felt unprepared for engineering teaching or not comfortable with it. The comment from a fourth grade teacher that “I don’t feel the same comfort with it [engineering] as I do with math” was common among attempters and was indicative of their low comfort level with engineering teaching.

**I-3: perception of EEE benefits to elementary students.** Elementary teachers at the attempter stage demonstrated low levels of understanding of the benefits of EEE to
elementary students. As indicated by some elementary teachers in the interview, engineering teaching and learning for elementary students was “having fun” or allowing them to know “what the word engineering means and be familiar with some terms”. Such a view toward the benefits of EEE was referred to by the researchers of the study using the code of engineering-as-anti-illiteracy emerging from the coding process of the interview data. This engineering-as-anti-illiteracy view toward the benefits of EEE denoted the attempters’ limited understandings of the benefits for elementary students of learning engineering, it was not surprising to see a limited degree of engineering integration at the attempter stage.

*I-4: degree of engineering integration.* For the elementary teachers in the attempter stage, engineering teaching was treated as an isolated activity or an add-on to what they had been teaching. A consequence of this was that these elementary teachers were very inflexible about their plans for teaching engineering. A good example of this came from an elementary teacher who told the researchers in the interview that “Another thing that was hard was I needed to get the EiE [Elementary is Engineering] unit done before I had taught capacity, so they [the elementary students] didn’t quite know some of the measuring techniques and things like that”. In fact, integrating the EiE unit with the teaching and learning of capacity would have solved the problem. But unfortunately, with the notion that engineering teaching and learning was isolated from the teaching and learning of other disciplines, these elementary teachers demonstrated limited degrees of integrating engineering with the rest of the curriculum. Treating engineering as an add-on, these elementary teachers taught it only when they could squeeze time out of their required teaching tasks for engineering. There were also some attempters who postponed
engineering teaching until the end of the year and had to rush through it. The adoption of EEE by the elementary teachers at this stage is characterized by passivity, sporadicity, and discontinuity.

**Adopter**

II-1: perception of practicality and sustainability of EEE. Like those in the *attempter* stage, the elementary teachers in the *adopter* stage were fully aware of numerous barriers to EEE. But the *adopters* saw EEE as practical despite these barriers, and they became conscious of their students in their perception of EEE practicality. One of the elementary teachers talked about her experience of teaching the concept of *What is Engineering* to her students: “We talked about what is engineering throughout the year, we have talked about, ‘Oh, we’re being engineers because we’re asking what the problem is, how can we find a solution; we’re coming up with restraints, we’re asking questions, we’re talking about a plan and coming up with solutions.’ So, engineering can be built in a lot through the classroom, not just through engineering”. Like this elementary teacher, those in the *adopter* stage began to realize that the practicality of EEE lies in the fact that engineering is not just something to be done for its own sake and in isolation, but rather something “can be built in a lot through the classroom”.

II-2: comfort level with engineering teaching. According to the *adopters*, there was no need to rush through the engineering content or activities because they felt comfortable with teaching engineering to their students. Also indicative of the adopters’ comfort with teaching engineering is that fact that they began to allow their students to pose questions and to argue with each other in engineering class.
**II-3: perception of EEE benefits to elementary students.** Representative of the elementary teachers was the view voiced in the interview that the benefits of learning engineering lay in its serving as a review or an extension of what their students had learned in other disciplines, such as helping them review a lot of math or supporting some of their existing skills or vocabulary. The researchers of this study labeled this as an *engineering-as-an-extension* view toward the benefits of EEE to elementary students.

**II-4: degree of engineering integration.** Another change that came to the elementary teachers at the *adopter* stage is that they devoted more time to EEE. Not only did the *adopters* allow more time for engineering teaching and learning and cover more engineering content, but they also allowed their students to go back and forth with various engineering concepts to enable a deeper understanding of these concepts. The *engineering-as-an-extension* view held by the *adopters* enabled them to find some opportunities to connect engineering with the teaching and learning of other disciplines. Although such connections were occasional and engineering was still appended to other disciplines, certain amounts of initiative, absent among the *attempters*, could be indentified among those at the *adopter* stage in finding ways to integrate engineering into their classrooms. Being able to link engineering with those disciplines they had been teaching for many years also made these elementary teachers feel more comfortable with and confident in teaching engineering.

**Ameliorator**

**III-1: perception of practicality and sustainability of EEE.** The elementary teachers in the *ameliorator* stage proved the practicality of EEE by practicing engineering teaching on a regular basis. In addition, the *ameliorators* began to think about the
The ameliorators told the researchers in the interview that they were alone or with only a few colleagues in their schools implementing engineering teaching and, to use their own words, “engineering teaching still sounds appended to the main business of school” because “it’s not state mandate” and “it’s not included in the TAKS (Texas Assessment of Knowledge and Skills)”. In face of such status quo of engineering teaching at their schools, the ameliorators expressed their concerns about the sustainability of integrating engineering into elementary classrooms. However, although the ameliorators became aware of the need and the importance of make EEE sustainable, they had no specific ideas about how to do it. This is an important characteristic distinguishing the ameliorators from the advocates in the next EEE adoption stage.

**III-2: comfort level with engineering teaching.** The above mentioned concern about the sustainability of EEE reflects that the elementary teachers in the ameliorator stage have moved out of the confinement of their immediate classroom environments to think about the larger educational environment making EEE more widely accepted and sustainable. The breakthrough of such a confinement was a strong indicator of the ameliorators’ confidence in teaching engineering in their classrooms. Teaching engineering on regular basis and searching for additional engineering teaching materials were evidence that ameliorators’ comfort level with engineering teaching has greatly improved. The interview data indicated that the ameliorators’ became more confident in teaching engineering because of their regular engineering teaching practices.

**III-3: perception of EEE benefits to elementary students.** Compared to the elementary teachers in the attempter and adopter stages, the ameliorators held a considerably broadened view about the benefits of EEE to elementary students. As some
Ameliorators mentioned in the interview, learning engineering “opened the students’ minds to other things”, enhanced their hands-on skills and abilities that would “help in all areas”, and enabled them to see that engineering was “not something that they have learned but something people use in the real world”. The comment made by one of the ameliorators that “the benefits outweigh the time it takes” gives a good summary of the reason why ameliorators made engineering teaching a regular practice.

At the ameliorator stage, the elementary teachers went beyond the engineering-as-an-extension view to embrace engineering teaching and learning as an application and enrichment. The code “engineering as application and enrichment” was used in this study to represent the ameliorators’ view of the benefits of EEE to elementary students. As indicated by the interview data, this engineering as application and enrichment view drove the ameliorators to learn more about engineering and to expand more on their engineering teaching.

III-4: degree of engineering integration. The ameliorators taught engineering on regular basis. Some of them chose to do engineering on every Friday, and named the day “Engineering Friday” or “Freaky Friday”. One of the attempters told the researchers in the interview that she had covered only four out of ten engineering lessons she had planned to do, and this was quite typical of the attempters. The following is an example of what an ameliorator did about engineering. This example shows the stark contrast between a typical ameliorator and a typical attempter:

There is also a tremendous amount of activities online. We got through what you [the interviewing researcher] taught us last summer [at the summer academy], but we thought, “Well, gosh, we still have three weeks, four weeks of school left. If we do one every Friday,
we’ve got to work this in, you know, we need some extra lessons”. And so I went online to
look at, you know, like power tower and other things that the kids can do. There are
tremendous resources out there for engineering.

This elementary teacher’s students kept asking her: “Are we doing Freaky Friday?”
and the teacher responded to her students’ love and enthusiasm to engineering by doing
engineering regularly and by actively searching for supplemental activities and lesson
plans.

In addition to implementing engineering on regular basis, the ameliorators explored
more resources to help their students, to use one of the ameliorators’ own words, “see
that engineering goes into many, many, many different areas and components and parts
of the world”, and they intertwined engineering more closely with the teaching and
learning of other disciplines. Being more active and taking more initiative in integrating
engineering into elementary classrooms became a landmark separating the ameliorators
from those in the two previous EEE adoption stages.

Advocator

IV-1: perception of practicality and sustainability of EEE. The data analysis results
of this study indicated that the elementary teachers at the advocator stage were convinced
of the practicality of EEE because of their successful engineering teaching experiences.
More important than this is that the advocators became aware of the persuasive power of
their successful practice-based engineering teaching experience in winning sustainable
integration of engineering into elementary classrooms. One of the advocators said in the
interview, “What I also think would help is just letting the teachers who had done the EiE
units, to say, ‘listen, this really does work’, and to be an advocate for the units”. Many
elementary teachers in the *advocator* stage, like the one quoted, expressed their intention of becoming an advocator of EEE and drawing other elementary teachers onboard by using personal teaching success stories.

Compared with those in the *ameliorator* stage, the elementary teachers in the *advocator* stage came up with specific plans of how to win support for EEE and how to make it sustainable. There were such plans quoted from the interview data as holding an “Engineering Open House” to showcase what the elementary students had learned or achieved through EEE, and using TV or the internet to publicize what the elementary students and their teachers were doing with engineering in the classrooms. For some advocators, making EEE sustainable required the whole school to become engaged or a whole-school push starting with the principal. One of the elementary teachers at the *advocators* stage suggested in the interview that we “put the principals through the training…make them come to an after-school thing so they can kind of get a feel for what engineering is about”. Interview data from the study showed that one of the advocators actually put her advocacy plan into practice. What this elementary teacher did was take pictures of her students doing engineering activities and make them first image to be seen on the school webpage.

*IV-2: comfort level with engineering teaching*. The elementary teachers at the *advocator* stage had practice-based success in engineering teaching. According to the *advocators*, such success enabled them to be fully confident in teaching engineering to their students. The *advocators* indicated in the interview that they were fully comfortable with teaching engineering. Great confidence in and high comfort level with engineering teaching explained why the *advocators* not only implemented engineering teaching
extensively but also wanted to make their success in engineering teaching known to others to ensure sustainable integration of EEE into elementary classrooms.

IV-3: perception of EEE benefits to elementary students. The *advocators* were able to understand the benefits of EEE to elementary students from broader and more comprehensive perspectives than teachers at earlier stages. The following is a good example of those broader and more comprehensive perspectives:

I think they’re learning more about a profession that they can choose when they grow up, but they’re also learning that engineering is all around us, and that is what’s important … I think that they’ve learned a lot this year. You know, I have a lot of girls who think that they want to become engineers, and that’s important because, you know, like you said, it’s not a girl-driven or a woman-driven field, and so we’ve at least opened the doors for them to see what’s out there for them.

As exemplified by the quote above, the elementary teachers at the *advocator* stage viewed EEE not only as something about making real-life connections, but also as something that can promote elementary students’ development as real-life problem solvers and as something that would enable elementary students to see the career potential in engineering-related fields. There were also some *advocators* who viewed EEE as something that would allow elementary students to see the contributions that they are able to make to society and even the huge impact of what they can do on another culture. The code *engineering-as-empowerment* was used by the researchers to refer to the advocates’ view about the benefits of EEE to elementary students. This *engineering-as-empowerment* view toward EEE was behind the advocates’ extended integration of engineering in their classrooms and their efforts to make EEE sustainable.
**IV-4: degree of engineering integration.** For the elementary teachers at the *advocator* stage, engineering became an integral part of their teaching practice like other disciplines. The advocators made extensive integration of engineering into their teaching. To use one of the advocators’ own words, engineering “permeated the teaching and learning of all other disciplines”. The connections the advocators made between engineering and other disciplines were not only extensive but systematic. The analysis of the interview data showed that the connections were systematic in two senses. Firstly, the connections were carefully planned ahead of time by taking the engineering content and the content of other discipline into comprehensive consideration. Secondly, the connections were made for specific purposes. Such purposes might be “to promote the understanding of science and math concepts through engineering” or “to allow the students to see through engineering relevant applications of what’s learned in school”, just to mention a few comments made by the advocators in the interviews.

3.6.2 The EEE Expertise Development Dimension

Findings from this study indicated that synchronic differences were also apparent in the elementary teachers’ EEE expertise development. Three themes regarding the elementary teachers’ EEE expertise development emerged from the data analysis: 1) contextualization of engineering learning; 2) development of engineering teaching pedagogy; and 3) making interdisciplinary connections. These three themes are the overarching classificatory categories, and specific data-derived patterns falling under these three categories serve as the descriptive characterizations classifying the elementary
teachers into the five stages of EEE expertise development: *mechanical imitator, skillful imitator, adaptor, improver,* and *creator* (see Table 7).
Table 7

Stages of EEE Expertise Development

<table>
<thead>
<tr>
<th>Stages of EEE Expertise Development</th>
<th>Contextualization of Engineering Learning</th>
<th>Development of Engineering Teaching Pedagogy</th>
<th>Making Interdisciplinary Connections</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage I: Mechanical Imitator</td>
<td>I-1: Contextualizing engineering teaching by adding some daily life engineering examples into engineering teaching but still unaware of students' learning needs</td>
<td>I-2: Sticking to the engineering teaching procedures and steps as learned in professional development but becoming able to apply some generic teaching strategies and methods to address engineering learning problems and issues</td>
<td>I-3: Having no idea how engineering can be integrated into the teaching and learning of other disciplines</td>
</tr>
<tr>
<td>Stage II: Skilled Imitator</td>
<td>II-1: Contextualizing engineering teaching by adding some daily life engineering examples into engineering teaching but still unaware of students' learning needs</td>
<td>II-2: Relying mostly on the engineering teaching procedures and steps learned in professional development but becoming able to apply some generic teaching strategies and methods to address engineering learning problems and issues</td>
<td>II-3: Becoming aware of some potential opportunities to integrate engineering into the teaching and learning of other disciplines but with no attempts to make actual interdisciplinary connections</td>
</tr>
<tr>
<td>Stage III: Adaptor</td>
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**Mechanical Imitator**

**I-1: contextualization of engineering learning.** It was illuminated by the data of this study that typical of the elementary teachers at the mechanical imitator stage is that they transferred what they learned in the INSPIRE summer academies into their lesson plans and really followed the lesson plans pretty closely without paying much attention to the
particular contexts where engineering learning took place. An example of this is a 2nd grade teacher who used one of the EiE lesson plans provided by the summer academy as it was and did not realize that this lesson was too long for her seven- or eight-year-olds. This teacher told the researchers that she noticed her students “getting antsy” and “keeping looking around”. Despite this, she followed the lesson plan strictly and, as she mentioned in the interview, “did the book all in one sitting”. She attributed her students’ responses to the lesson to her poor planning. But perhaps such responses were due more to her lack of understanding of elementary students’ learning needs and of what would work better for them when learning engineering.

Some of the elementary teachers at the mechanical imitator stage introduced engineering concepts (e.g., what technology is, what engineering is, and what an engineer is) to their students by giving definitions learned at the INSPIRE summer academy such as the definitions mentioned by a mechanical imitator in the interview that “an engineer is the person who designs, a craftsman is the person who makes it, and a technician is the person who uses it”. Some elementary teachers at the mechanical imitator stage told the researchers in the interview that they taught engineering concepts “by pulling out the notebook used in the INSPIRE summer academies and using the notebook a lot”, or “by asking the students to work on the exercises in the book”. These mechanical imitators seemed to have no better ideas about how these concepts could be taught to their students, and there was no evidence that they taught these concepts by relating them to real-life experience. So it is not surprising that when the question “Do you think your lessons changed your students’ perceptions of engineering?” was asked, the typical answer heard
was “I don’t know because I don’t know if they had a perception of engineering in the first place”.

I-2: development of engineering teaching pedagogy. Numerous learning problems and issues were reported by the elementary teachers of this study. The following are some examples of such problems or issues quoted from the interview data: the problem that the elementary students “just did not cooperate”, they “just cannot handle anything in a group”, they “had hard times understanding the engineering design process”, the engineering activities were messy because of “a lot of arguments” or “clowning around”, there were frustrations resulting from unsuccessful production of engineering final products, etc. In the face of these problems and issues, the mechanical imitators did not know how to respond except to hope things would be better next year or when there was more time for planning, or just to attribute these problems or issues to engineering’s being “a little too difficult for this age group”, to use the exact words of a mechanical imitator.

I-3: making interdisciplinary connections. Also characteristic of the elementary teachers in the mechanical imitator stage is that they made few interdisciplinary connections in their engineering teaching and seemed to have no idea how to integrate engineering into the teaching and learning of other disciplines. Some of these elementary teachers told the researchers frankly in the interviews that they did not do a good job in this, or they just expressed the intention of looking at the curricula of other disciplines to see how engineering could possibly be tied in.
Skillful Imitator

II-1: contextualization of engineering learning. The elementary teachers at the skillful imitator stage, though mostly still taught engineering in a de-contextualized manner paying little attention to students’ learning needs, began to realize the need to allow the students to realize “the penetration of engineering in all parts of life” or “there is engineering everywhere”, just to quote two of the skillful imitators from the interview. They responded to such a need by adding some daily life engineering examples outside the EiE teaching materials provided by the INSPIRE summer academy into their engineering teaching. Although the skillful imitators still relied on the EiE teaching materials provided by the summer academies and what they learned there as their main engineering teaching resources, the idea of opening up their students’ eyes for engineering around them had already begun to burgeon.

II-2: development of engineering teaching pedagogy. When it came to the pedagogy of engineering, the skillful imitators had begun to take some initial steps to deal with the problems and issues they encountered during their engineering teaching. For example, they employed some realia like maps and pictures to help students with language problems in understanding the engineering content, they used model student groups who behave well as a group to demonstrate how to work in groups, or they physically arranged the seats and guided the students to the seat arrangements to make engineering activity groups work better. The teaching methods used by skillful imitators were not specifically aimed to engineering learning problems. Rather, such methods were generic in nature and could possibly be used to in any other disciplines to address some general
learning issues. However, we were able see in these methods the progress the *skillful imitators* were making in engineering teaching.

**II-3: making interdisciplinary connections.** While the elementary teachers at the *mechanical imitator* stage taught engineering completely in isolation, those at the *skillful imitator* stage became aware of some potential opportunities to integrate engineering with the teaching and learning of other disciplines. For example, some elementary teachers mentioned that fractions and measurements in math were necessary for the paper folder activity\(^4\), a science unit about matter was helpful for the Play-Dough activity\(^5\), and an understanding of the writing process and scientific process would facilitate the learning of the engineering design process. With their practice-derived understanding that some knowledge and skills from other disciplines were necessary or conducive for their students’ engineering learning, the *skillful imitators* saw potential opportunities for interdisciplinary connections between engineering and other disciplines. Although this could be regarded as an improvement over the *mechanical imitator* stage, there was little evidence from the interview data that these elementary teachers had more specific ideas about how interdisciplinary connections could be made in their engineering teaching practice, or that they actually made some interdisciplinary connections in their engineering teaching.

\(^4\) Paper folder activity (Taylor, 2007) is an elementary engineering design activity in which students are required to design and create paper folders based on a specific engineering design process model.

\(^5\) Play-Dough activity (Cunningham, DeCristofano, Hester, Higgins, Knight, Lachapelle, ... Yocom de Romero, 2007) is an elementary engineering activity in which elementary students are asked to improve their play dough recipe and to prepare quality play dough by exploring the properties of solids and liquids, and by experiencing the sequenced process of mixing the two.
Adaptor

III-1: contextualization of engineering learning. An important characteristic that distinguished adaptors from skillful imitators is that adaptors became aware of students’ learning needs during the engineering teaching process and began to make efforts to accommodate the learning needs. For example, some adaptors paid attention to elementary students’ inadequate teamwork abilities and learned to prepare the students better for engineering teamwork rather than simply putting them into small groups and having them begin group engineering activities right away. Another example came from a third grade teacher who told the researchers in the interview that “kids in contemporary society are being very visual, with everything geared to them visually”. He, therefore, accommodated such learning need by integrating some pictures or video clips in his engineering teaching.

As illustrated in the above examples, those learning needs that caught the adaptors’ attention were generic in nature rather than specifically related to engineering learning, rendering the adaptors unable to contextualize engineering teaching based on students’ real engineering learning needs. Compared with skillful imitators, adaptors did a better job in contextualizing engineering learning by relating engineering to real life. Unlike skillful imitator, who simply placed some daily life engineering examples before their students, adaptors found ways to place engineering lessons like what is engineering and what is technology into real life contexts. There were some elementary teachers at the adaptor stage asking parents or acquaintances who were engineers to speak with their students and talk about what real engineers do. Some adaptors asked their students to look for examples of technology in their houses and to explain why these examples were
identified as technology. Giving students opportunities to see or find out by themselves how close engineering was to them characterized adaptors’ way of contextualizing engineering learning.

**III-2: development of engineering teaching pedagogy.** Compared with the elementary teachers in the previous two stages, the elementary teachers in the *adaptor* stage demonstrated understandings of the nature of engineering activities and important things elementary students need to learn from these activities. Such understandings are well demonstrated in what two of the *adaptors* told the researchers in the interviews: “It didn’t really matter to me whether they failed or they succeeded in the book staying on top [in the paper table activity*6], but did they carry out their design with all members contributing?” And: “We needed to make sure that they [the students] knew when they would try to make something and it wouldn’t work, that, in and of itself, was being an engineer”. With understandings as such, elementary teachers at the *adaptor* stage were able to employ teaching strategies and methods that were more specifically aimed to engineering learning problems as compared to those strategies and methods used by *skillful imitators*.

Examples of some of such strategies and methods from the interview include (those with quotation mark were direct quotes from the interview): creating flow maps of a recipe to guide elementary students’ design and improvement of engineering products; asking students to brainstorm what could be done to improve the products; having students discuss what “limitations and time constraints and material constraints” had

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*6* Paper table activity (Design Squad, 2008) is an elementary engineering design activity in which students are required to design and create paper tables based on a specific engineering design process model.
contributed to their failure to “get their job finished”; and guiding and improving student learning through questioning: “Did you work together to the end?”; “Did you give up?”; “What were the problems?”, and “Do we have any suggestions?”. These examples showed that elementary teachers in the _adaptor_ stage began to adapt engineering teaching in ways that, from their perspective, would better meet their students’ engineering learning needs and to improve engineering learning outcomes.  

**III-3: making interdisciplinary connections.** As compared to _skillful imitators_, who made no attempts to make interdisciplinary connections, adaptors began to make some attempts to connect engineering with the teaching and learning of other disciplines. These attempts included combining the engineering assembly line activity with the topic of the assembly line in social studies, and adding the engineering pop-up card activity as part of the author study activity in language arts. Although the elementary teachers at the adaptor stage were able to find some opportunities to connect engineering with the teaching and learning of other disciplines, these connections were superficial and in these connections engineering remained its own separate entity, appended to but not truly integrated with other disciplines.

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7 The claim that the adaptations made by the adaptors would improve student learning outcome is reported here totally based the _adaptors_’ perspective. This study did not provide evidence to support this claim, and it was not the focus of this study to do so. Future research is needed to furnish such evidence.

8 Engineering assembly line activity (see lesson 2 in National Center for Technological Literacy, 2005) is an elementary design activity in which students are asked to address questions of scale-up in the production of different prototypes designed in previously projects.

9 Pop-up card activity (Whiting, 2001) is an elementary engineering design activity in which students are required to design and create pop-up greetings cards following a specific engineering design process model.
**Improve**

IV-1: contextualization of engineering learning. The elementary teachers in the *improver* stage practiced their engineering teaching in a more student-oriented way than those in the *adaptor* stage. The *improvers* went beyond adapting what they had learned in the summer academies to their students’ learning needs. They actually made changes to the learned teaching procedures and steps with an intention to improve the engineering learning outcomes.  

A 4th grade teacher told the researchers in the interview that she realized “the 4th grade is really important for packaging engineering”, so she “found a great book out of our basal that talked about packaging, and used that, and used it throughout the year…” (The basal was the elementary students’ reader, and to use the elementary teacher’s words, “it is called a basal because it’s not novels, it’s either snippets of long books or it’s a compilation of a lot of books”). According to this elementary teacher’s own words from the interview, she “decided to use the story out of the basal for packaging engineering and talking about it” because “it was more suited toward kids’ lingo”. When this elementary teacher went deeper into her story, it became more obvious how her ideas about engineering teaching and learning were different from those of the elementary teachers in previous stages:

…the book [the EiE story book meant to be used by INSPIRE summer academy elementary teachers] was not bad by any means, but I was worried that the kids would not have been interested in it, and so I did change the story, I read the story out of the basal instead. It’s about a little boy who decides to—he goes to the

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10 The changes made by the improvers were intended by them to improve student learning outcome. This study did not provide evidence to show this was the case, and it was not the focus of this study to do so. Future research is needed to furnish such evidence.
grocery store for his mother, she needs toothpaste, and it’s $1.50. He was like, “Why
does it cost $1.50?” So he comes up with his way to package his toothpaste, and he
ends up being a millionaire. It’s a play, so the kids just really enjoyed it, but I got to
use the same lingo as packaging engineers and talked about how they help even with
income and gross income, and also talked about money… So I thought it was a
better fit.

This elementary teacher presented us an example of how the *improvers* thought
would improve student learning experiences by making appropriate changes to
engineering teaching procedures and materials based on situated engineering teaching
and learning needs. This elementary teacher told the researchers in the interview that it
was also her intention to enable her students to see from this engineering packaging story
that “engineering is for solving real life problems” and thus feel motivated to learn
engineering. Such intention was also expressed by a 2nd grade *improver* who compared
and contrasted a candle, a flashlight, and a light bulb with her students. From such an
intention that was typical among *improvers* we can see that improvers were
contextualizing engineering learning by showing her students engineering is for solving
real life problems.

**IV-2: development of engineering teaching pedagogy.** One elementary teacher at the
*improver* stage made an impressive comment about assessing engineering learning: “That
[assessing engineering learning] is a difficult piece because kids think outside the box,
and you, as grading them, have to also think very outside of the box. It’s hard to give a
student that tries hard a bad grade, because they’re using all that they have. If they
haven’t been shown a world, it’s hard for them to think”. This comment is impressive not
so much in the sense that it reflects the teacher’s heightened understanding of assessment of learning as in the sense that it gives a good summary of the principle *improvers* used to guide their engineering teaching—the principle of teaching engineering by “showing the students a world of engineering”.

The *improvers* showed their students a world of engineering by giving them opportunities to explore the world around them to see what engineering is and what engineering is about. To these elementary teachers, engineering teaching was not giving students “isolated mental pictures and images”, as mentioned by an *improver* in the interview, but giving students hands-on, concrete, and real-life examples, and opportunities to think, to experience, and to improve. One elementary teacher found that it had stuck in her students’ heads “that technology was something that was robotic or required batteries”. Here is her approach for correcting the misconception:

I brought in things like one of those little vacuums that it’s—it has automatic sensors and when something’s dropped or spilled—it’ll move. And we picked it apart and we talked about all the little pieces in it. I brought in band-aids. I brought in nut crackers and pencil sharpeners and they were able to just play with it and talk about it, and I think that really helped.

This approach is a great example of bringing in hands-on, concrete, and real-life examples to meet learning needs and to promote engineering learning. Another elementary teacher at the *improver* stage decided, instead of doing the paper folder activity she learned in the INSPIRE academy to teach the engineering design process, to do an activity her students wanted—design a bed for a doll—using materials they could find around them. She worked with her students on discussing the components of the bed,
designing and drawing the components in the journals, and exploring the possibilities of using materials they found around them, like Styrofoam cups and strings, for the components.

In other improvers’ engineering classes, window shades in the classroom became good realia for the students to learn gear machines and levers, while rulers and “just various items in the classroom”, as one improver said in the interview, were utilized in teaching engineering and engineering concepts. Guiding their students to interact with their physical environment was a way the improvers showed their students a world of engineering, or perhaps more accurately, an engineering world for elementary students.

IV-3: making interdisciplinary connections. Compared with the adaptors who were limited in their abilities to see the opportunities of making interdisciplinary connections and who made only occasional and sporadic interdisciplinary connections, the improvers were be able to make more comprehensive interdisciplinary connections. Not only did the improvers found opportunities to connect engineering with all other disciplines they taught but they also were becoming able to show through the connections the relevance and usefulness of engineering. In the interdisciplinary connections made by the improvers, engineering was not an add-on. Rather, engineering and other disciplines were tied together in such a way allowing students to see engineering requires knowledge and skills in other disciplines, and these knowledge and skills found real world applications through engineering.

An example came from an improver who combined writing in language arts and the learning of measuring and fraction with the paper folder activity. In making these interdisciplinary connections, this improver made conscious efforts to allow her students
to see that writing skill facilitated the documentation of their design solutions and their
design improvement plans, and that skills in measuring and knowledge of fraction were
indispensable for the success of creating the paper table. As this improver mentioned in
the interview, it was her hope that her students’ interests in learning engineering and
motivation in learning other disciplines would increase as a result of seeing through
engineering the applications of what they were learning or had learned in other
disciplines. This improver’s hope served as a good summary of what the improvers tried
to achieve in their efforts to connect engineering with the teaching and learning of other
disciplines. And this hope also helped explain the progress the improvers make in making
connections between engineering and other disciplines.

Creator

V-1: contextualization of engineering learning. The creator stage is aptly named, for
“creative” and “creating” are perfect descriptors for the elementary teachers who had
progressed past the improver stage. The elementary teachers at the creator stage
contextualized engineering learning by creating real life contexts to allow their students
to experience engineering and its relevance. One of the elementary teachers at the creator
stage came up with a new way for her kids to experience the engineering design and re-
resign process:

I had some kindergarteners come down. They were our consumer group and the kids
made their design. And they told the kids whether it was a really nice picture, was it
colorful enough, was it easy to put together, and the kids took that information and
started redesign.
Among the elementary teachers participating in this study, there were three elementary teachers who did the egg-drop activity instead of the EiE plant packaging activity\(^\text{11}\) introduced in the INSPIRE summer academy. The following teacher is the one among the three who did this activity differently:

I thought it really went along well with the kids because it was springtime, and we needed to find answer to the question of how to transport eggs from one place to another. We’ve got to develop a package. And so then we imagined, “Okay, how could we do this?” I gave them constrictions. I told them, “It can’t be bigger than this and this”, and materials were really important. And then we developed it, we came up with the steps, we created a test from 6 feet off a ladder; and then we came back, we redesigned it, picked up our flaws, and then we took it to the roof and dropped it from the roof. So we kind of changed our packaging…

This elementary teacher re-created the egg-drop activity by tying it into finding solutions to a real world problem. Within the context of this real world problem the students experienced the engineering design process and the relevance of engineering in solving real world problems.

\textit{V-2: development of engineering teaching pedagogy.} An important element in the above egg drop activity is that the elementary teacher got her students involved in the process of creating the activity. As illustrated by this example, elementary teachers at the creator stage created opportunities for their students to become active agents in the engineering learning process. This is a big progress the creators made in their

\(^{11}\) An engineering design activity for 3rd-5th graders in the EiE unit of Thinking Inside the Box: Designing a Plant Package (see http://www.mos.org/eie/plants.php for reference).
development of engineering teaching pedagogy. The following are two more examples illustrating this progress.

In the Play Dough activity, a creator gave her students the opportunity to decide on their own methods for testing their play dough. This creator talked about her students’ creative testing methods in the interview such as the “stick to hands or desk test” and “the stamp test” of pressing erasers of various shapes down into the play dough to see if it “kept the shape or closed back”. This creator make her students actively participate in the engineering activity by allowing them some decision power in the teaching and learning process. According to this teacher, allowing the students to come up with their own methods for testing their products would not only motivate the students to learn but would also allow their students to have a clear picture about the goal of their design from the very beginning and what needed to work on for improvement to reach the goal.

Another example came from a third grade teacher, who asked his students to work in groups, do research on what engineers do through websites about engineers, and report back to the class about their findings. This teacher told the researchers that he thought his student learned “a great deal more than they would by listening to my lecture on engineering and engineers”.

Although the roles of active agent the students were allowed to play in the above example differed, the underlying pedagogical purpose was the same: enabling students to construct knowledge through active participation and exploration. This pedagogical purpose characterized and explained the creators’ improved pedagogical practices over teachers in precious stages.
V-3: making interdisciplinary connections. If the word “creating” is used to emphasize what the elementary teachers in the creator stage did in their engineering teaching practice, the word “creative” highlights the quality\textsuperscript{12} of what they did. These elementary teachers’ creativity could be seen in how they combined engineering with the learning and teaching of other disciplines in a way that helped to overcome the contextual constraints of EEE. As some elementary teachers in the study explained, electricity and magnetism are in the 4th grade TAKS (Texas Assessment of Knowledge and Skills) and are the content 4th grade teachers are required to teach to their students. One 4th grade teacher created an engineering unit on “circuit design” and combined this unit with the teaching of electricity and magnetism. Another teacher did something different in her teaching of electricity and magnetism: asking her students to design a box with an alarm to keep people out. Although the two teachers tied engineering into the curriculum in different ways, both of them were doing the same thing: making EEE possible within time constraints and enabling elementary students to experience other non-engineering disciplines through a new lens. One of the two elementary teachers put this in some plain words of her own, “if you would align it [engineering] with what you had to do versus trying to wiggle room for it, that would be helpful”.

Many similar examples emerged from the data. When teaching about buoyancy, an elementary teacher added engineering in and asked her students to produce a boat out of aluminum foil, to use the teacher’s own words, “by sketching it, testing it, and re-designing it”. Another teacher combined engineering with her science lesson about filters,\textsuperscript{12} Quality is used here only in terms of how the engineering teaching practices enhanced the possibility of teaching engineering within time constraints and created new lenses for students to learn other non-engineering disciplines, not in terms of student learning outcomes.
asking her students to design and produce water filters to help people in countries with limited water resources. One of the creators came up with a unit on the engineering design process to design and improve a telescope and integrated it into her lessons on the solar system in order to show her students, to use her own words, “how it is possible to see the solar system without traveling through space”. During the interviews, creators identified in this study talked about their engineering teaching experience and focused on different aspects that elementary engineering teaching needed to build up for their students, including: confidence, motivation to take risks in order to learn rather than necessarily to gain academic points, accepting mistakes, problem-solving, willingness to work as a team, and ability to redesign and improve. Despite these different focuses, one common thing these creators showed us is how being creating and creative may transform engineering teaching.

3.7 Discussion: An Analytical Look at the EEE Adoption and Expertise Development Framework

The EEE adoption and expertise development framework constructed in this study is two dimensional: the EEE adoption dimension and the EEE expertise development dimension. When the elementary teachers in this study were looked at collectively and at a given time, their EEE adoption and EEE expertise development were characterized by synchronic differences showing that they stood at different EEE adoption and EEE expertise development stages despite the fact that they received the same training in engineering teaching and practicing engineering teaching for the same amount of time. In the second round of data analyses, when the elementary teachers were looked at over
time and when comparisons and contrasts were made of the interview data of the same
teacher collected in the two consecutive years of 2009 and 2010, diachronic progression
along the EEE adoption and the EEE expertise development stages was discernible.

In the EEE adoption dimension, four overarching classificatory categories (i.e.,
perception of practicality and sustainability of EE, comfort level with engineering
teaching, perception of EEE benefits to elementary learners, and degree of engineering
integration) emerged from the data of the study and serve the classificatory function of
distinguishing elementary teachers’ EEE adoption into four different stages. These four
stages are different from those stages in Rogers’ (2003) diffusion of innovation model
and the CBAM (Hall & Hord, 1987) in the sense that the four EEE adoption stages are
not general in nature. Instead, these four stages are contextualized in the specific contexts
of teaching engineering to elementary students. Another aspect making the four EEE
adoption stages differ from the Rogers’ (2003) and the CBAM (Hall & Hord, 1987)
stages is the fact that the investigation of EEE adoption in this study did not include the
process of knowing about an innovation and the process of making a decision about
whether or not to implement the innovation, both of which are part of Rogers’ (2003)
diffusion of innovation model and the CBAM (Hall & Hord, 1987). In other words, the
four EEE adoption stages are different in the sense that they focus on the EEE
implementation process to reveal how elementary teachers are different in their EEE
adoption.

Focusing on the EEE implementation process, the four EEE adoption stages reveal
how elementary teachers might be different, both attitudinally and behaviorally, in their
adoption of engineering teaching. So the four EEE adoption stages could be seen as a
combination of the *stages of concern* framework and *the levels of use* framework that is specifically situated in the context of implementing engineering teaching. The four EEE adoption stages could be used as a tool for visualizing elementary teachers’ synchronic differences and diachronic progression in EEE adoption. While the four EEE adoption classificatory categories provide a general sense about what to look at when assessing an elementary teacher’s EEE adoption, the staged descriptive characterizations in each of the four categories furnish more detailed and more structured information for the assessment.

Rogers (2003) concluded that an individual’s perception of the five characteristics of an innovation (i.e., relative advantage, compatibility, complexity, triability, and observability) determines the innovation adoption rate, defined as “the relative speed with which an innovation is adopted by members of a social system (p. 221)”. The EEE adoption category of *perception of practicality and sustainability of EEE* reflects elementary teachers’ perceptions about whether EEE is compatible with their teaching schedule or tasks and whether the effects of EEE could be observable to others. While the category of *comfort level with engineering teaching* shows how elementary teachers feel about the complexity and triability of EEE, the category of *perception of EEE benefits to elementary learners* reveals how elementary teachers think about the relative advantage of EEE. So the first three EEE adoption categories (*perception of practicality and sustainability of EEE, comfort level with engineering teaching, perception of EEE benefits to elementary learners*) reflect, in varying degrees, practice-based perception of the five innovation characteristics associated with EEE.

While the EEE adoption dimension is meant to capture elementary teachers’ differences in their EEE adoption, the EEE expertise development dimension presents a
structured picture of how elementary teachers might be different in their knowledge and skills of teaching engineering. In this picture, the three EEE expertise development categories (contextualization of engineering learning, development of engineering teaching pedagogy, and making interdisciplinary connections) overarch the five EEE expertise development stages and specify areas of engineering teaching expertise where elementary teachers would differ in their engineering teaching practices. These overarching EEE expertise development categories (shown in Table 7) provide us with a framework that could be used to guide research on elementary teachers’ EEE expertise development. In comparison with this specific EEE expertise development framework, Dreyfus’s skill acquisition model would be too generic to render contextualized understanding about elementary engineering teaching.

As mentioned earlier, Berliner (1988a, 1988b) applied the Dreyfus skill acquisition model in studying teaching expertise development and pointed out that there are developmental differences between novice and expert teachers in seven areas of teaching expertise (interpreting classroom phenomena, discerning the importance of events, using routines, predicting classroom phenomena, judging typical and atypical events, and evaluating teaching performance). Berliner’s model deals with general teaching expertise without setting in the teaching and learning context of any particular subject matter. Therefore, the EEE expertise development framework constructed in this study extends Berliner’s model by focusing on the teaching of the specific subject matter of engineering. This study contributed to the literature of teaching expertise development research by identifying specific engineering teaching expertise areas as denoted by the three EEE expertise development categories shown in Table 7. These engineering teaching expertise
3.8 Conclusion

An EEE adoption and EEE expertise development framework was constructed in this study. This framework identified respective classificatory categories in the EEE adoption dimension and the EEE expertise development dimension. With the staged descriptive characterizations, we would be able to classify elementary teachers practicing engineering teaching into specific EEE adoption or EEE expertise development stages falling within each of the classificatory categories. This detailed, operationalized EEE adoption and expertise development framework provides us with useful tools to conceptualize, assess, and track elementary teachers’ EEE adoption and EEE expertise development in their engineering teaching practice. Using the EEE adoption and EEE expertise development framework, professional development providers would be able to map their elementary-teacher learners’ standings at a given time and to assess or track their progress over time in the EEE adoption and EEE expertise development, and may consequently be able to provide elementary teachers with appropriate and most-needed help supporting EEE adoption and EEE expertise development.

Despite the potential usefulness of the EEE adoption and EEE expertise development framework, this study is limited in the sense that the construction of the framework was based on the interview and survey data collected from the participating elementary teachers. In other words, the coding of engineering teaching practices into
different EEE adoption or EEE expertise development stages was based on the elementary teachers’ personal and subjective opinion and judgment of how well they did in their engineering teaching, and this study provided no objective evidence about how well these teachers really did in their engineering teaching. It is, therefore, envisaged that, in future research, classification of elementary teachers’ engineering teaching practices could be tied with objective evidences about the actual effects of the teaching practices. Also, it is hoped that survey instruments or observation protocols could be developed in the future for more effective and efficient classification.
CHAPTER 4. THE IMPACT OF STUDENT TEACHING EXPERIENCES ON PRE-SERVICE TEACHERS’ READINESS FOR TECHNOLOGY INTEGRATION

4.1 Introduction

Positive effects of technology integration on student learning in K-12 education have been reported in previous research (e.g., Dunleavy & Heinecke, 2007; Kulik, 2003; Murphy, 2007; Schroeder et al., 2007; Valdez et al, 2000; Venezky, 2004; Van Lehn et al., 2006; Waxman, Lin & Michko, 2003) and technology integration related knowledge and skills are recognized as an important component of an educator’s knowledge base (ISTE, 2002, 2008). The past decade has witnessed the incessant efforts to increase access to technology resources in schools, from earlier emphasis on classroom desktops and Internet access (Wells & Lewis, 2006) to recent technology infrastructure trends of focusing more on tablets, laptops, electronic readers, interactive whiteboard, document cameras etc (SETDA, 2011). Going along with efforts to increase access to technology resources are efforts made at federal, state, and local levels to prepare teachers for educational technology uses (e.g., the PT3 project in Brush et al., 2003; Mims, Polly, Shepherd, & Inan, 2006; Polly, Mims, Shepherd, & Inan, 2010). NCATE (National Council for Accreditation of Teacher Education) stipulates that technology integration be one of the standards to be met by teacher preparation institutions seeking accreditation (NCATE, 2008), and 46 states have developed technology standards requiring teachers
receiving certification to have the ability to teach effectively with technology (Hightower, 2009).

However, the results of extensive efforts to increase technology access and to prepare teachers for technology integration have not been very promising. The “high-access vs. low-use” paradox (Cuban, Kirkpatric & Peck, 2001) (referring to high access to technology but failure to use it or to use it for low-level learning tasks), is still prevalent among in-service teachers’ technology use practices (Becker, 2001; Culp, Honey & Mandinach, 2005; Ertmer, 2005; Palak & Walls, 2009), and pre-service teachers still feel unprepared for technology integration (Brinkerhoff, Ku, Glazewski, & Brush, 2002; Brown & Warschauer, 2006; Johnson, 2012). Although educational technology courses have been added to teacher education programs in order to prepare pre-service teachers for technology integration (Kleiner, Thomas, & Lewis, 2007; Lawless & Pellegrino, 2007; Polly, Mims, Shepherd, & Inan, 2010), such courses do not necessarily prepare pre-service teachers for effective uses of technology in their future classrooms. One of the reasons for this is that educational technology courses offered in educational programs are typically disconnected from methods courses (Graham, Culatta, Pratt & West, 2004; Mims, Polly, Shepherd, & Inan, 2006) and focus more on technology skills rather than how technology should be used to improve teaching and learning (Angeli & Valanides, 2009; Graham et al, 2004; Hargrave & Hsu, 2000; Jimoyiannis, 2010).

Technology skills alone do not prepare pre-service teachers for technology integration. According to Schrum (1999), three components are important for preparing pre-service teachers for technology integration: (1) skills-based courses, (2) integration of
technology into methods courses, and (3) technology rich field placements. There has been plenty of research conducted to investigate the first two components in terms of how they are related to technology integration (e.g., Collier, Weinburgh, & Rivera, 2004; Graham et al, 2004; Özgün-Koca, Meagher, & Edwards, 2010). However, despite the argument in previous literature for the importance of technology-use enriched student teaching experiences in preparing pre-service teachers for technology integration (Strudler, McKinney, Jones & Quinn, 1999; Strudler & Wetzel, 1999), there is a dearth of empirical research revealing how student teaching experiences help prepare pre-service teachers for technology integration. Also, since teaching is a situated practice involving knowledge of content, pedagogy, and learners (Shulman, 1987) and developing phronesis—situation-specific and context-related knowledge about teaching and learning—is essential for student teachers (Korthagen & Kessels, 1999), it is reasonable to believe that student teaching experiences of “learning about practice in practice” (Darling-Hammond et al, 2005, p.401) would help improve pre-service teachers’ readiness for technology integration. And this would be especially so because student teaching experiences can help bridge theories learned in methods courses with teaching practices (Lloyd & Wilson, 2001). However, little research has been done to provide empirical evidence showing how student teaching experiences are related to pre-service teachers’ readiness for technology integration.

To make the best out of student teaching experiences in preparing pre-service teachers for technology integration, more research needs to be conducted into the less charted area in the literature about how student teaching experiences are related to pre-service teachers’ readiness for technology integration. The purpose of this study was to
contribute to the literature by investigating the impact of student teaching experiences on pre-service teachers’ change or trajectories in readiness for technology integration during student teaching and by revealing pre-service teachers’ lived technology use experience during student teaching. To serve the purpose of this study, a two-phase explanatory sequential mixed methods research design (Creswell, 2009) was adopted.

The following research questions were used to guide the quantitative investigation in this study: (1) Does readiness for technology integration change during student teaching? (2) Are there individual differences in change trajectories? (3) If so, what variables are associated with differences in trajectories? The qualitative investigation in this study sought to answer the following two research questions: (1) How are pre-service teachers’ technology use experiences related to their individual change in readiness for technology integration? (2) What aspects of student teaching experience influence pre-service teachers’ technology uses during student teaching?

Informed by empirical evidence from previous research that teachers’ technology uses are influenced not only by their knowledge and skills pertaining to technology and its uses, but by their self-efficacy beliefs (e.g., Hermans et al, 2008; Lin & Lu, 2010; Mueller et al, 2008; Wang, Ertmer, and Newby, 2004), this study used two instruments in its quantitative investigation to measure pre-service teachers’ readiness for technology integration: the Survey of Pre-service Teachers’ Knowledge of Teaching and Technology (Schmidt et al., 2009) and the Computer Technology Integration Survey (CTIS) (Wang et al., 2004). Data collected using these two instruments were be analyzed using growth curve modeling to determine the impact of pre-service teachers’ student teaching experiences on their individual trajectories of readiness for technology integration.
For the qualitative investigation of this study, a phenomenological research methodology was adopted and face-to-face interviews were conducted with a sample of eleven pre-service teachers from the participants of this study. The purpose of the interviews was to explore the pre-service teachers’ lived experiences of student teaching as related to technology uses. The interview data analyses were first deductive and then inductive. While the results from the deductive qualitative analysis of the interview data were intended to help understand and explain the quantitative results, the inductive qualitative analysis results were intended to help deepen our understandings about the influence of student teaching experiences on pre-service teachers’ readiness for technology integration.

Findings from this study would contribute to the literature by promoting our understanding about pre-service teachers’ experiences with technology use during student teaching. Moreover, by revealing the impact student teaching experiences on pre-service teachers’ individual trajectories of readiness for technology integration, this study would inform teacher educators about what need to be done to make student teaching experiences more promising in promoting pre-service teachers’ readiness for technology integration.

4.2 Literature Review

4.2.1 Readiness for Technology Integration

With positive effects of technology integration on student learning reported in previous research and ever increasing access to technology resources in K-12 classrooms, there is a pressing need for teachers capable of effectively using technology in the
classroom (Grove, Strudler, & Odell, 2004; Lawless & Pellegrino, 2007). Responding to this need are efforts made to prepare teachers for technology integration. According to National Center of Education Statistics (Wells & Lewis, 2006), 83% of public schools offer professional development supporting technology integration for in-service teachers. In teacher education programs, educational technology courses are offered to pre-service teachers and it is reported that nearly every pre-service teacher takes an educational technology course (Mims, Polly, Shepherd, & Inan, 2006; Persichitte, Tharp, & Caffarella, 1997). Great emphasis has been put on increasing teachers’ technology skills and knowledge both in professional development (Mishra & Koehler, 2006; Mueller, Woolda, Willoughby, Ross & Specht, 2008) and in educational technology courses as well (Angeli & Valanides, 2009; Graham et al, 2004; Jimoyiannis, 2010; Mims et al, 2006). Although it is generally agreed in the literature that teachers’ technology competency is a basic condition for educational technology use (Law, Pelgrum, & Plomp, 2008; Lawless & Pellegrino, 2007; Pelgrum & Anderson, 1999), technology skill and knowledge alone would not enable teachers to become ready for technology integration (Graham, Culatta, Pratt, & West, 2004). Readiness for technology integration is also closely related to other technology- and pedagogy-related knowledge domains (Mishra & Koehler, 2006) and self-efficacy beliefs in one’s abilities to work effectively with technology (Albion, 1999).

The ultimate purpose of integrating technology into instructional practices is to promote student learning, and this purpose is not achieved by technology per se but by how technology is used (Bernauer, 1995; Mishra & Koehler, 2006). Teachers, as the most direct and most important determinant of how technology can be used, are the key for
effective use of technology. Effective technology integration relies on teachers’ planning and pedagogical knowledge and skills (Bernauer, 1995; Coppola, 2004). Evaluation of teachers’ readiness for technology integration would be inaccurate if their knowledge in the area where technology overlaps with pedagogy is not taken into consideration.

Table 8

*The Seven Knowledge Domains in the TPACK Framework*

<table>
<thead>
<tr>
<th>Knowledge Domain</th>
<th>Descriptions</th>
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<tbody>
<tr>
<td>Technology Knowledge (TK)</td>
<td>Knowledge about standard technologies (such as books, chalk and blackboard) and more advanced technologies (such as the Internet and digital video), and skills for operating particular technologies.</td>
</tr>
<tr>
<td>Content Knowledge (CK)</td>
<td>Knowledge about the actual subject matter that is to be learned or taught.</td>
</tr>
<tr>
<td>Pedagogical Knowledge (PK)</td>
<td>Knowledge about the processes and practices or methods of teaching and learning, involving student learning, classroom management, lesson plan development and implementation, and student evaluation.</td>
</tr>
<tr>
<td>Pedagogical Content Knowledge (PCK)</td>
<td>Knowledge of pedagogy that is applicable to the teaching of specific content.</td>
</tr>
<tr>
<td>Technological Content Knowledge (TCK)</td>
<td>Knowledge of the manner in which technology and content are reciprocally related including how technology affords newer and more varied representation of subject matter and how subject matter is changed by the application of technology.</td>
</tr>
<tr>
<td>Technological Pedagogical Knowledge (TPK)</td>
<td>Knowledge of the existence, components, and capabilities of various technologies as they are used in teaching and learning settings, and conversely, knowing how teaching might change as the result of using particular technologies.</td>
</tr>
<tr>
<td>technological pedagogical content knowledge (TPCK)</td>
<td>Knowledge of the complex interplay of the three components (content, pedagogy, and technology)</td>
</tr>
</tbody>
</table>

Shulman (1986) proposed the Pedagogical Content Knowledge (PCK) framework to advance the notion that teachers’ knowledge exists at the intersection of content and pedagogy and that successful teaching requires blending content and pedagogy into an understanding of how subject matter should be organized, adapted, and represented for instruction. Based on Shulman’s PCK framework, Mishra and Koehler (2006) proposed the Technological Pedagogical Content Knowledge (TPACK) framework as a model of teacher knowledge essential for technology integration. The TPACK framework provides
us with a new lens in understanding teachers’ readiness for technology integration. The TPACK framework defines seven knowledge domains (see Table 8 for brief descriptions) of technology knowledge (TK), content knowledge (CK), pedagogical knowledge (PK), pedagogical content knowledge (PCK), technological content knowledge (TCK), technological pedagogical knowledge (TPK), and technological pedagogical content knowledge (TPCK), and describes the interactions and interplay between and among these seven domains of knowledge.

Mishra and Koehler (2006) developed the TPACK framework based on their years of experience teaching educational courses and proposed it as a measure against the standard approach of focusing mostly on technology knowledge and skills in professional development and teacher education. The TPACK framework illustrates that teachers’ effective uses of technology entails not only technology knowledge and skills but knowledge of technology from the pedagogical and subject matter perspectives. Since TPACK was introduced to the educational research field as a theoretical framework for understanding teacher knowledge required for effective technology integration (Mishra and Koehler, 2006), it serves as a good framework for understanding teachers’ readiness for technology integration.

According to Bandura (1988), “human competency requires not only skills, but also self-beliefs in one’s capacity to use those skills well” (p. 276). While embracing both stand-alone technology knowledge and technology knowledge related to pedagogy and subject as essential for understanding teachers’ readiness for technology integration, we should not neglect the influence of teachers’ self-efficacy beliefs on their readiness for technology integration. In general, self-efficacy beliefs are “beliefs in one’s capabilities
to organize and execute the courses of action required to produce given attainments” (Bandura, 1997, p. 3). In the specific context of technology integration, self-efficacy beliefs are teachers’ beliefs in their capacity to work effectively with technology (Wang et al, 2004). Research from previous literature (e.g., Lin & Lu, 2010; Mueller et al, 2008; Piper, 2003) has shown that teachers’ self-efficacy beliefs for technology integration have strong impact on their technology integration practices. Mueller and his colleagues found in their study (2008) that while high self-efficacy beliefs about computer uses were associated with high level of technology integration, low self-efficacy beliefs about computer uses were associated with low level of technology integration. It was also found that higher perceived self-efficacy increases teachers’ willingness to devote more time and efforts to technology integration and consequently results in better technology integration practices (Lin & Lu, 2010). Empirical evidence from the above studies supports Albion’s (1999) argument that teachers’ self-efficacy beliefs are an important and measurable component of the beliefs that influence technology integration and are an indicator of teachers’ readiness for teaching with technology.

It is revealed in the technology integration research literature that readiness for technology integration is not a single-dimensional construct. Rather, it is multi-dimensional construct that needs to be approached not only from a knowledge-based perspective but from a self-efficacy based perspective. Setting off from both of the two perspectives, the present study applied the Survey of Pre-service Teachers' Knowledge of Teaching and Technology and the Computer Technology Integration Survey (CTIS) (Wang et al, 2004) to measure pre-service teachers’ readiness for technology integration. While the Survey of Pre-service Teachers' Knowledge of Teaching was developed by
Schmidt and her colleagues based on the TPACK framework to measure pre-service teachers’ seven TPACK knowledge domains, the CTIS was developed by Wang and his colleagues to measure pre-service teachers’ self-efficacy beliefs for technology integration.

4.2.2 Student Teaching Experience for Pre-service Teachers

Despite the push for and the trend of earlier clinical experiences, student teaching is usually placed at the end of a teacher education program as a kind of culminating experience for teacher candidates (Darling-Hammmond et al 2005; Greenberg, Pomerance, & Walsh, 2011) where they “are immersed in the learning community and are provided opportunities to develop and demonstrate competence in the professional roles for which they are preparing” (Greenberg, Pomerance, & Walsh, 2011, p. 1). The following passage gives a good account of what pre-service teachers usually do during student teaching and what student teaching means to pre-service teachers (Greenberg, Pomerance, & Walsh, 2011):

During the typical semester-long experience, student teaching candidates must synthesize everything they have learned about planning instruction: collecting or developing instructional materials, teaching lessons, guiding small group activities, and establishing and maintaining order—not to mention meetings with faculty and parents and, in some districts still, taking on lunchroom and playground duties. Passing (or failing) student teaching determines whether an individual will be recommended for certification as a licensed teacher. (p. 1)
Few would dispute the potential value of student teaching—it is regarded by new teachers as the most important part of their teacher preparation experience (Levine, 2006). The importance and potential value of student teaching experiences are not without theoretical and research support. Korthagen and Kessels (1999) contended that student teachers “need knowledge that is situation-specific and related to the context in which they meet a problem or develop a need or concern, knowledge that brings their already existing, subjective perception of personally relevant classroom situations one step further” (p.7). This type of knowledge is called *phronesis* and student teaching provides an opportunity for student teachers to develop *phronesis* by discovering which methods and strategies to use and which course of action to take in specific situations that occur in everyday teaching (Korthagen & Kessels, 1999). The importance for pre-service teachers to develop *phronesis* is rather self-evident given that teaching is “to a great extent, an uncertain and spontaneous craft situated and constructed in response to the particularities of everyday life” (Cochran-Smith & Lytle, 1999, p. 262).

In addition to this knowledge development view toward the benefits of student teaching experiences, research has shown that pre-service teachers developed understanding about students and student needs through the cognitive dissonance experienced when preconceived notion about students and teaching conflicted with student teaching experiences (Eisenhardt, Besnoy, & Steele, 2011). Also, student teaching benefits pre-service teachers by providing them with an opportunity for connecting theory to practice more effectively (Tigchelaar & Korthagen, 2004). However, while there is a bright side to student teaching, there is also a downside. Moore’s (2003) study showed that the pre-service teachers in her study were not able to learn, through
teaching practice, how to apply theory into practice as expected because they were fully occupied with such procedural concerns as time management, teaching expected lessons and content, and classroom management. And according to Clift and Brady (2005), pre-service teachers’ development of new beliefs about teaching may be hindered in face of the complexity of classrooms.

Taken together, the studies referenced above point towards the effects of student teaching experiences on pre-service teachers being difficult to predict. This is understandable given that student teaching experiences are complex systems influenced by myriad factors and interactions. Cuenca (2011) revealed that cooperating teachers’ legitimizing practices of granting pre-service teachers legitimacy to “the tools of the trade”, “the rituals of teaching”, and “tethered learning” are consequential not only in pre-service teachers’ professional identity forming but in the affective and personal dimensions crucial for learning to teach. However, cooperating teachers are but one of the factors that influence student teaching experiences and legitimizing practices are but one aspect of cooperating teachers’ mentoring practices. A more comprehensive view about the complex systems of student teaching experiences could be seen from the four categories identified by Beach and Pearson (1998) regarding the conflicts and tensions perceived by pre-service teachers in their student teaching. These conflicts and tensions are related to (1) issues of curriculum and instruction (e.g., between planned instruction and actual events, between their perceptions and students' perceptions of relevancy, between their own beliefs about curriculum and school-mandated curriculum, and between coverage and constructivism); (2) interpersonal relationships (e.g., relationships with and among students, and with cooperating teachers, teacher colleagues, and
administrators); (3) self-concept and role as teacher (including the need to be liked, the role ambiguity of transitioning from student to teacher, and the inner conflicts of defining self); (4) contextual and institutional issues (e.g., expectations of the University program, the complexities and politics of school systems, and pressures to socialize to the culture of schools and teaching). Imbedded in these conflicts and tensions are various factors and interactions that have their impact on the effects of student teaching experiences. There is a need for further research to understand these factors and interactions and to consequently improve the effects of student teaching experiences in preparing pre-service teachers for their teaching profession.

4.2.3 Student Teaching and Technology Integration

Student teaching has become an essential part of teacher preparation programs because it is an important component for preparing pre-service teachers for future teaching practices (Darling-Hammond et al, 2005; McIntyre, Byrd, & Foxx, 1996; Strudler, McKinney, Jones, & Quinn, 1999). In the context of preparing pre-service teachers for technology integration, student teaching experience and modeling of technology integration by teacher education faculty have been suggested as effective means to prepare pre-service teachers for technology integration (Albion, 1996; Moursund & Bielefeldt, 1999). The terms *mastery experience* (also known as *enactive experience*) and *vicarious experience* (also known as *modeling*) were identified by Bandura (1986, 1988) as two important sources of perceived self-efficacy. While mastery experience is real and direct experience that increases one’s self-efficacy by allowing the individual to experience performance successes, vicarious experience is indirect
experiences that are able to increase one’s self-efficacy beliefs by allowing the individual to observe similar others experiencing performance successes (Bandura, 1988). Since mastery experience and resultant increase of self-efficacy beliefs in technology uses might be achieved through student teaching experiences (Albion, 1999), it is not difficult to understand why student teaching experiences are suggested as an effective means to prepare pre-service teachers for technology integration. From a self-efficacy theory based perspective, one might even argue that student teaching experiences are more powerful than modeling in preparing pre-service teachers for technology because real experiences are more effective than vicarious experiences in increasing self-efficacy beliefs (Albion, 1999).

In addition to the self-efficacy belief based perspective, there is research (e.g., Grove, Strudler, & Odell, 2004, 2007) approaching student teaching experiences and technology integration from a socio-cultural perspective of learning focusing on the mentor-novice relationship between cooperating teachers and student teachers. Lying behind this type of research is the application of the Vygotskian concept of the zone of proximal development (Vygotsky, 1978) in the context of student teaching experiences. That is, pre-service teachers, with support and help from cooperating teachers who are capable and experienced in technology uses, are able to learn more about technology integration than they would independently.

Recognizing cooperating teachers’ potential in helping prepare pre-service teachers for technology integration, some research studies were conducted to explore professional development options to enhance cooperating teachers’ skills and abilities for effective uses of technology in teaching. Brush and his colleagues (2003) reported the
field-based technology integration model adopted by the elementary education program at Arizona State University. With this model, education graduate students with previous K-12 teaching experience and excellent knowledge of effective methods for integrating technology into K-12 curriculum were recruited to provide cooperating teachers with ongoing and onsite training regarding effective uses of technology in various teaching domains. A study conducted by Wetzel, Zambo, Buss, and Padgett (2001) introduced the semester-long workshop for K-8 teachers who agreed to be technology integration models for pre-service teachers during student teaching. The effects of the workshop on those K-8 cooperating teachers were reported in the study. Studies focusing on cooperating teachers also include those offering insights into cooperating teachers’ mentoring practices in preparing student teachers to teach with technology (Grove, Strudler, & Odell, 2004) and how cooperating teachers’ technology performance and learning engagement influenced their mentoring of student teachers for technology integration (Grove, Strudler, & Odell, 2004).

The above referenced studies, though different in their research focuses, share the same idea that cooperating teachers’ mentoring and mentoring practices are important for preparing pre-service teachers for technology integration. Different from the above studies are contextual factor based studies seeking to understand the influence of contextual factors in student teaching experiences on pre-service teachers’ technology uses. Bullock (2004) reported in his research of a case study that mentor teacher and school expectation, district and state requirements, and technology support and availability were enabling and disabling factors influencing pre-service teachers’
decisions about how and when to teach with technology during student teaching and that whether these factors would serve as enablers or disablers was individual dependent.

The list of contextual factors identified by Dexter and Riedel (2003) were a bit different. This list includes the contextual factors of quality and availability of technology at schools, technical support, and quality and availability of technology integration instructional support from mentor teachers. According to this study, these factors determined whether “student teachers at field site use technology and have K-12 students do so” (p.343). Studies focusing on contextual factors in student teaching experience draw our attention beyond university walls to clinical site-determined factors that are different from university-determined ones (e.g., preparation, faculty modeling, and expectation to use technology) (Dexter & Riedel, 2003). The purpose of those contextual factor based studies is to promote our understanding of the influences of clinical site determined factors on pre-service teachers’ technology integration practices and hence allow us to improve the quality of student teaching experiences in preparing pre-service teachers for technology integration.

The above review shows that the value of student teaching experience to pre-service teachers has drawn a lot of attention from technology integration researchers to approach student teaching experience from different perspectives (i.e., self-efficacy theory based perspective, socio-cultural perspective of learning, and contextual factor based perspective). However, despite the insights from the above perspective-based research regarding pre-service teachers’ technology use experiences during student teaching, the basic question “Do student teaching experiences improve pre-service teachers’ readiness for technology integration?” remains unanswered. In the context of
technology integration, the ultimate purpose of student teaching is to prepare pre-service teachers for effective technology uses in future, real classroom settings. To achieve this purpose we need to know, in the first place, the effects of student teaching experiences on pre-service teachers’ readiness for technology integration. Unfortunately, the research literature on technology integration is not informative in this regard. The present study is intended to make up this gap in the literature by investigating quantitatively how student teaching experience is related to pre-service teachers’ readiness for technology integration and by revealing the qualitative stories behind the quantitative relation.

4.3 Methodology

A mixed-methods research design was adopted in this study to investigate the impact of student teaching experience on pre-service teachers’ readiness for technology integration. First, online surveys were used to collect quantitative data, which was then analyzed to answer three questions: (1) Does readiness for technology integration change during student teaching? (2) Are there individual differences in change trajectories? (3) If so, what variables are associated with differences in trajectories? To answer these questions, individual growth modeling (Raudenbush & Bryk, 2002; Singer, 1998; Willett & Sayer, 1994) was applied to examine growth curves in readiness for technology integration during student teaching. Individual growth modeling as a type of multilevel model (also known as mixed, random effects, or hierarchical linear modeling) estimate sample-level overall trajectories and individual-level trajectories. Level-1 and level-2 models were employed with the former estimating the association between the readiness for technology integration and the time variable indicating the passage in time, and the
latter bringing in predictor variables to explain the association if it is statistically significant at level-1.

In the second phase, interview data were collected and analysis of the interview data was intended to answer the following two research questions: (1) How are pre-service teachers’ technology use experiences related to their individual change in readiness for technology integration during student teaching? (2) What aspects of student teaching experience influence pre-service teachers’ technology uses during student teaching? Guided by these two questions, the qualitative part of this study sought to help interpret and understand quantitative findings, and furnish insights about educational technology use experience in student teaching through qualitative descriptive stories.

4.3.1 Sample

The sample consisted of sixty-eight (sixty female and eight male) pre-service teachers from fifteen different programs in the Purdue College of Education. These pre-service teachers did their student teaching in the Fall Semester of 2012 (n=20) and the Spring Semester of 2013 (n=48). Figure 10 shows the distribution of these pre-service teachers in their fifteen respective programs.
<table>
<thead>
<tr>
<th>Programs</th>
<th>Number of Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>AgEd (Agriculture Education)</td>
<td>5</td>
</tr>
<tr>
<td>ArtEd (Art Education)</td>
<td>1</td>
</tr>
<tr>
<td>BioEd (Biology Education)</td>
<td>4</td>
</tr>
<tr>
<td>CheEd (Chemistry Education)</td>
<td>2</td>
</tr>
<tr>
<td>EC Ed (Early Childhood Education)</td>
<td>1</td>
</tr>
<tr>
<td>ESEd (Elementary and Special Education)</td>
<td>4</td>
</tr>
<tr>
<td>EleEd (Elementary Education)</td>
<td>25</td>
</tr>
<tr>
<td>EngEd (English Education)</td>
<td>9</td>
</tr>
<tr>
<td>FCSEd (Family &amp; Consumer Sciences Education)</td>
<td>2</td>
</tr>
<tr>
<td>MathED (Math Education)</td>
<td>9</td>
</tr>
<tr>
<td>MI (Mild and Intense Intervention)</td>
<td>1</td>
</tr>
<tr>
<td>PHEd (Physical and Health Education)</td>
<td>1</td>
</tr>
<tr>
<td>SSEd (Social Studies Education)</td>
<td>1</td>
</tr>
<tr>
<td>Span (Spanish Education)</td>
<td>2</td>
</tr>
<tr>
<td>TechEd (Technology Education)</td>
<td>1</td>
</tr>
</tbody>
</table>

![Figure 10. Education programs of the participants (Study III)](image)

Of the sixty-eight pre-service teachers, five were in graduate programs and the rest sixty-three were in undergraduate programs. There were forty-four pre-service teachers in age group of eighteen to twenty-two, twenty in the age group of twenty-three to twenty-six, two in the age group of twenty-seven to thirty-two, and two in the age group of more than thirty years old.

The pre-service teachers doing student teaching in Fall 2012 were independent from those doing student teaching in Spring 2013 group, meaning pre-service teachers in the fall group were not members of the spring group and vice versa. The pre-services in both groups graduated after their student teaching. The first reason for selecting these participants was that the College of Education at Purdue University is both state and nationally accredited and has a diverse student teacher population of twenty-two different teaching majors. More importantly, this college adopts the model of a single educational technology course separated from other methods courses. Since such a model is still
predominant in teacher education programs (Belland, 2009; Hargrave and Hsu, 2000), the participants of this study are representative of how technology courses are offered in teacher preparation programs. The study participants were recruited through the Office of Field Experiences (OFE) and all emails to these participants were sent via the OFE.

4.3.2 Research Design

A two-phase explanatory sequential mixed methods research design (Creswell, 2009) was adopted in this study. Phase-1 was a quantitative study using online survey data to investigate the impact of student teaching experiences on pre-service teachers’ trajectories of readiness for technology integration. In phase-2, a phenomenological research method was adopted and face-to-face interviews were conducted to look into pre-service teachers’ lived student teaching experience to help explain and to better understand the quantitative results from Phase-1. To better serve this purpose, the initial ten interview questions developed at the beginning of this study were modified and finalized into sixteen questions based on the quantitative results from Phase-1. In this study, the quantitative study in Phase-1 and the qualitative study in Phase-2 were given the same weight with both of them working together from different perspectives to serve the ultimate purpose of this study.

In phase-1, the pre-service teachers’ technology readiness for technology integration was measured using the sixteen items from the CTIS (Wang et al, 2004) representing self-efficacy beliefs for technology integration, and the sixteen items from the three subscales (i.e., TK, TPK, and TPACK) in the Survey of Pre-service Teachers’ Knowledge of Teaching and Technology (Schmidt et al., 2009) indicating technology and
pedagogy related technology integration knowledge (detailed information about these
two survey instruments are presented in the Instruments section). Also included in the
questionnaire were questions asking the pre-service teachers to fill out demographic
information (see Appendix B) about their name, gender, age range, major, educational
level (graduate or undergraduate), school of student teaching, number of credits of
professional education courses (such as Block, methods, and pedagogical content
courses), and number of credits of courses requiring educational technology courses, and
prior teaching experience. The questionnaire was administered to the participants both in
the Fall 2012 group and the Spring 2012 group three times: a) before their student
teaching, b) in the middle of their student teaching, and c) at the end of their student
teaching.

In the first of the three surveys for the Spring 2013 group, one item was added to
the questionnaire asking the participants to check the box and leave their contact
information if they wanted to participate in a follow-up face-to-face interview about
forty-five minutes to an hour. The pre-service teachers were also informed about the
incentive of 20 dollars in cash for participating in the interview. Those who volunteered
to participate in the follow-up interview were contacted through email to set up times for
the interviews at the end of the student teaching. All the interviews were audio-recorded
and transcribed.

4.3.3 Instruments

The pre-service teachers’ readiness for technology integration was measured three
times during the student teaching using a questionnaire combining two Likert-style
survey instruments developed and used in previous technology integration research studies: the Survey of Pre-service Teachers’ Knowledge of Teaching and Technology (Schmidt et al., 2009) and the Computer Technology Integration Survey (CTIS) (Wang et al., 2004). Both of the two survey instruments use a 5-point likert-like scale: $DS =$ Strong Disagree; $D =$ Disagree; $N =$ Neither Agree/Disagree; $A =$ Agree; and $SA =$ Strongly Agree.

The CTIS, containing twenty-one items, was originally developed and used by Wang and his colleagues (Wang et al., 2004) to measure pre-service teachers’ self-efficacy beliefs about technology integration. Exploratory Factor analysis conducted by the researchers of this study using pre-survey data produced a two-factor solution explaining 55.36% of the systematic covariance among the items. The first factor (eigenvalue = 9.85), representing “computer technology capabilities and strategies”, accounted for 46.92% of the covariance and consisted of sixteen items with loadings ranging from .51 to .84. The second factor (eigenvalue = 1.77), representing external influences of computer technology use (e.g., restrains, oppositions, etc.), accounted for 8.4% of the covariance and consisted of five items with loadings ranging from .56 to .77. The researchers in the original study decided to use only the sixteen items in the first factor because they were interested in the pre-service teachers’ abilities to use technology in strategic ways. Another factor analysis was conducted in the original study with the post-survey data producing a one-factor (with eigenvalue of 9.85 and explaining 59.86% of the systematic covariance) solution. This factor analysis results confirmed the sixteen-item instrument as valid in measuring a single construct. Cronbach’s alpha of .94 (for
pre-survey) and .96 (for post-survey) on the sixteen items indicated that the final sixteen-item instrument was highly reliable.

Since the technology integration is more about pre-service teachers’ abilities to use technology in strategic ways than about external influences of computer technology use, the present study followed what the researchers in the initial study (Wang et al, 2004) did and used the sixteen-item instrument without the five items within the second factor.

The *Survey of Pre-service Teachers’ Knowledge of Teaching and Technology* originally designed by Schmidt and her colleagues (2009) consists of seven subscales measuring pre-service teachers’ knowledge in the seven knowledge domains within the TPACK framework: technology knowledge (TK), content knowledge (CK), pedagogical knowledge (PK), pedagogical content knowledge (PCK), technological content knowledge (TCK), technological pedagogical knowledge (TPK), and technological pedagogical content knowledge (TPCK). There are in total forty-seven items in the seven subscales of the instrument. This study used the three subscales of TK (seven items), TPK (five items), and TPCK (eight items) because these three subscales are technology related and are therefore relevant to the focus of this study. The subscale of TCK is also technology related but was not used in this study. The reason for this was that the *Survey of Pre-service Teachers’ Knowledge of Teaching and Technology* was specifically designed for pre-service teachers majoring in elementary or early childhood education and was thus focused on the content areas of literacy, mathematics, science, and social studies. The four items in the TCK subscale are specifically related to these four content areas, consequently rendering this subscale inapplicable for this study. It is for the same reason that the first four items related to these four content areas in the TPCK subscale
were used in this study. Therefore, a total of sixteen items from the TK (seven items), TPK (five items), and TPCK (four items) subscales were used in this study.

Schmidt and her colleagues (2009) conducted exploratory factor analysis on items within each of the seven subscales in the instrument. According to the results, all the three subscales of TK, TPK, and TPACK produced one factor accounting for 49.36%, 65.32%, 64.63% variance of items in respective subscales. The Cronbach’s alpha for each set of items in the three subscales was .82, .86, and .92 respectively.

In addition to the Survey of Pre-service Teachers’ Knowledge of Teaching and Technology (Schmidt et al., 2009) and the CTIS (Wang et al, 2004), an interview protocol was developed for the follow-up individual face-to-face interviews and then revised based on the quantitative data analysis results. The interview questions in the protocol were intended to help interpret and understand quantitative findings, and to learn about the pre-service teachers’ technology use experiences during their student teaching.

4.3.4 Measures

Technology integration readiness (TIR) scores. Technology integration readiness was indicated by the technology integration readiness score I (referred to as TIR Score_1 hereafter) and technology integration readiness score II (referred to as TIR Score_2 hereafter) obtained respectively from the sixteen items of the CTIS (Wang et al, 2004) and the sixteen items from the Survey of Pre-service Teachers’ Knowledge of Teaching and Technology (Schmidt et al., 2009). Each item response in the two sixteen-item sets was scored with a value of 1 assigned to Strongly Disagree, all the way to 5 for Strongly Agree. The total score for each set of the items was calculated. In other words, each
study participant had a total score on self-efficacy beliefs about technology integration (TIR Score_1) and a total score on technology and pedagogy related technology integration knowledge (TIR Score_2). These two scores were the dependent variables which combined to indicate the pre-service teachers’ readiness for technology integration.

Day. Day was the variable indicated the passage of time. In other words, the values of this variable represented how many days the study participants had been student teaching when responding to the online surveys of the study. The study participants had one to three data points for this variable depending on how many times they responded to the survey. Since the first online survey was conducted before the student teaching, the value for the first data point of the variable day was zero for all study participants. The online survey data showed the dates when the participants responded to the surveys. With these dates, the values for the second and/or third data points of the variable day were calculated using SAS.

Professional-courses. The profession-courses was used in this study as a predictor variable representing the number of credits of professional-courses the study participants had taken in the Purdue educational programs with no indication of their performance in such courses. These courses included block, methods, and content courses. The study participants indicated the number of credits of such courses in the online surveys.

EdTech-courses. The variable EdTech-courses represented the number of credits of courses requiring using educational technology the study participants had taken in the Purdue educational programs. This variable had no indication of the study participants’ performance in such course. The study participants were instructed in the online surveys to include all courses they had taken in the educational programs that required using
educational technologies. So these courses included not only the specific educational
technology course offered but other methods courses already counted in the variable of
professional-courses. EdTech-courses was used as a predictor variable in the study.

Prior-teaching. Study participants indicated in the surveys whether they had
previous teaching experience or not. Prior-teaching was a dummy variable (0 = having
no previous teaching experience, 1 = having previous teaching experience) used to
indicate having prior teaching experience or lacking prior teaching experience among the
participants. This dummy variable provided no specific information about the prior
teaching experience of the study participants.

Grade-level. Study participants either taught at either the elementary level or the
secondary level during the student teaching. Grade-level was created as a dummy
variable using “0” to indicate the elementary level and “1” to indicate the secondary level.

4.3.5 Data Analysis

Quantitative data analysis. To examine intra-individual change in readiness for
technology integration over time during student teaching, growth curves were estimated
within a mixed modeling (also known as multi-level modeling) framework (Raudenbush
were fitted and day was the variable represented the passage in time in the growth curve
models. At level-1, study participant’s educational technology readiness scores—TIR
Score_1 and TIR Score_2—were separately modeled as a function of day, and both linear
and quadratic models were estimated. Following Singer and Willett (2003), the level-1
quadratic models were as:
\[
\text{TIR Score}_{1ij} \text{ (or TIR Score}_{2ij} = \pi_{0i} + \pi_{1i}(\text{day}_{ij}) + \pi_{2i}\text{day}^2 + \epsilon_{ij}
\]

The outcome (the dependent variable) was the study participants’ TIR Score_1 or TIR Score_2 for individual \(i\) at day \(j\). The intercept, \(\pi_{0i}\), was the predicted TIR Score_1 or TIR Score_2 at day zero before the student teaching the started. The linear coefficient \(\pi_{1i}\), estimated the rate of change (slope) which was the predicted daily amount of change in Score_1 or Score_2 for participant \(i\). The quadratic coefficient, \(\pi_{2i}\), estimated amount of curvature for person \(i\), and \(\epsilon_{ij}\) represented the errors on each participant \(i\) at day \(j\).

The linear and quadratic growth models yielded parameter estimates that defined both the sample-level overall trajectory (fixed effects) and within-person trajectories (random effects) as indicated by individual deviations from the overall trajectory. The SAS Proc Mixed procedure produced the variances of the random effects. Significant variances at level-1 growth curve models would indicate that the participants differ in level and in rate of change and that it would make perfect sense to proceed to level-2 models. To explain individual differences, the four predictor variables, \textit{professional-courses, EdTech-courses, prior-teaching, and grade-level}, were introduced into the level-2 models. For all models, an unstructured covariance matrix was specified because the survey data of this study were of unequally spaced intervals and an unstructured covariance matrix is more appropriate for this type of data than other possible covariance structures.

Qualitative data analysis. The qualitative data of this study consisted of eleven individual, face-to-face interviews. The analysis of the interview data was both deductive and inductive. Deductively, the analysis was guided by the quantitative findings for the
The purpose of helping interpret the findings and seeking answers to questions unanswered by the quantitative data analysis. This deductive analysis process left room for identifying emerging themes providing new insights into the participants’ experience in educational technology uses during student teaching. In the inductive qualitative analysis (Patton, 2002) process, while reading the interview data, data bits related to aspects of educational technology use experiences that were not addressed or considered in the quantitative data analysis were noted. These data bits were accompanied by analytical memos of ideas about what they meant.

After finishing reading the interviews, all the data bits were put together. They were read, along with their accompanying analytical memos, and then carefully grouped into patterns according to their look-alike or feel-alike qualities (Lincoln & Guba, 1985). Comparisons were then made across the patterns to form coding categories. Short descriptions were put on the patterns and each category was given a name and a rule of inclusion. To ensure the validity of data analysis, the data bits were mixed together and a second party was asked to regroup the data bits into the patterns and the patterns into the categories. The first and second groupings and categorizations were compared, and differences were discussed with the original interviews as a reference whenever necessary. Based on the comparison and discussion, the patterns and the coding categories were modified. These new patterns and coding categories were tested by reading the interview data again. The testing process looked for further evidence that either challenged or supported these coding categories, and these coding categories were revised to reflect new emerging patterns. The comparisons and revisions went on until no new patterns emerged, and the categories were saturated (Strauss & Corbin, 1998). The
final list of patterns and coding categories together with the deductive analysis results were used to present the “qualitative” stories behind the quantitative findings regarding the impact of student teaching experiences on readiness for technology integration.

4.4 Quantitative Results and Discussion

4.4.1 Quantitative Results

The participants in this study had one to three measurements of TIR Score_1 and TIR Score_2 depending on how many times they responded to the online surveys. The frequency distribution of the number of measurements is shown in Table 9. More than 60% of the study participants had all three measurements.

Table 9

<table>
<thead>
<tr>
<th>Number of TIR scores measurements</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9</td>
<td>13.2%</td>
</tr>
<tr>
<td>2</td>
<td>18</td>
<td>26.5%</td>
</tr>
<tr>
<td>3</td>
<td>41</td>
<td>60.3%</td>
</tr>
</tbody>
</table>

When analyzing the survey data, the sample-level overall trajectories for TIR Score_1 and TIR Score_2 were examined, and the existence of individual differences around the overall trajectory was weighed. Then, the variable professional-courses, EdTech_courses, prior-teaching, and grade-level were examined as predictors of individual differences in intra-individual change in TIR scores.

*Linear and quadratic growth curve models for TIR Score_1.* As suggested by Singer and Willett (2003), the unconditional means model is the first model one should
always fit. Following this suggestion, the unconditional means model for TIR Score_1 was first fitted as shown in the first column of Table 10. The unconditional means model is the intercept only model with the absence of predictors at every level, and it estimates a fixed effect only for intercept and random effects only for the variance of the intercept and the residual. The fixed effect for intercept indicated that the average level of self-efficacy beliefs about technology integration (TIR Score_1) before the student teaching was 61.86 out of 80 possible points. The variance for the intercept was 43.81 and that of the residual was 77.88 indicating respectively between- and within-person variability in self-efficacy beliefs about technology integration.

The unconditional means model describes and partitions the outcome variation (Singer & Willett, 2003). This allows estimation of intra-class correlation which is the proportion of the total outcome variation lying between people. In this case, it was .36 (\(\frac{43.81}{43.81+77.88}\)), which means that 36% of the total variability in self-efficacy beliefs about technology integration was due to between-person differences (i.e., individual differences). The remaining 64% of the total variability was within-person variation indicating the amount individual study participants varied from themselves over time during the student teaching. The unconditional model serves as baseline model to be compared with to judge later, more complex models.
The second and third column of Table 10 show linear and quadratic growth curve models of TIR Score_1. Because the quadratic effect was not significant, focus was placed on the estimate shown in the second column. The fixed effect for the intercept shows that the average score of self-efficacy beliefs about technology integration before the student teaching was 55.48. The fixed effect for the slope was significant and positive (\(= 0.11\)), indicating that at the sample-level TIR Score_1 increased at a rate of 0.11 units per day. This overall trajectory graphically is depicted in Figure 11.
Random effects can be found in the lower part of Table 10. The variance of the intercept was the estimated variance of individual deviations from the overall intercept and was statistically significant. This means that the study participants showed significant differences in level of self-efficacy beliefs about technology integration. The variance of the slope, an estimate of the degree to which individuals differ in rate of change, was also significant. This means that study participants were significantly different in the rate of change on self-efficacy beliefs about technology integration. The covariance between intercept and slope was significant and negative (-0.453), indicating that, while individuals with lower initial level of self-legacy beliefs about technology integration had a faster change rate, individuals with higher initial level of self-legacy beliefs about technology integration had slower change rate.

Comparing the linear growth curve model for the TIR Score_1 with the unconditional means model, the $Pseudo-R^2$ statistic (Singer & Willett, 2003) was calculated. The $Pseudo-R^2$ statistic is an estimate of the proportional reduction in residual
variance as predictors are added, and according to McArdle and Woodcock (1997), an estimate of effect size similar to $R^2$. In this case, the Pseudo-$R^2$ is .68 (from $\frac{77.88 - 25.25}{77.88}$), indicating that the predictor variable, day, explained 68% of within-person variance in self-efficacy beliefs about technology integration. The fit statistics (-2 log likelihood and Akaike’s Information Criterion) shown in Table 10 decreased in size from the unconditional means model to the linear growth curve model, indicating better fit of the linear growth curve model.

Linear and quadratic growth curve models for TIR Score_2. An unconditional means model was also fitted for TIR Score_2. The results for this model are shown in the first column of Table 11. The fixed effect for the intercept indicates that the average score for technology and pedagogy related technology integration knowledge (TIR Score_2) before the student teaching was 58.38 out of 80 possible points. The variance for the intercept was 60.39 and that for the residual was 74.95. The former represented between-person variability in technology and pedagogy related technology integration knowledge (indicated by TIR Score_2) and the latter represented within-person variability in such knowledge.

The intra-class correlation was .48 (from $\frac{60.39}{60.39 + 64.95}$), indicating that 48% of total variability in TIR Score_2 was between-person variation due to individual differences, and 52% of total variability in TIR Score_2 was within-person variation due to individual changes in the score over time during the student teaching. This was almost half between-person and half within-person, which is quite different from the TIR Score_1 case where
more of the total variability in the score for self-efficacy beliefs of technology integration is within-person variance.

Table 11

*Growth Curve Models for TIR Score_2*

<table>
<thead>
<tr>
<th>Parameter and fit statistics</th>
<th>Unconditional</th>
<th></th>
<th>Linear</th>
<th></th>
<th>Quadratic</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimate</td>
<td>SE</td>
<td>Estimate</td>
<td>SE</td>
<td>Estimate</td>
<td>SE</td>
</tr>
<tr>
<td>(Fixed effects)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>58.38</td>
<td>1.14***</td>
<td>52.95</td>
<td>1.40***</td>
<td>53.25</td>
<td>1.46***</td>
</tr>
<tr>
<td>Slope</td>
<td>0.095</td>
<td>0.01***</td>
<td>0.33</td>
<td>0.27</td>
<td>0.02</td>
<td>0.01</td>
</tr>
<tr>
<td>Curvature</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Random effects)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>60.39</td>
<td>15.25***</td>
<td>95.69</td>
<td>22.82***</td>
<td>103.83</td>
<td>23.99***</td>
</tr>
<tr>
<td>Slope</td>
<td>0.003</td>
<td>0.00*</td>
<td>0.88</td>
<td>0.29***</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Curvature</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Covariance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept, Slope</td>
<td>-0.28</td>
<td>0.16</td>
<td>-4.98</td>
<td>3.08</td>
<td>0.16</td>
<td>0.16</td>
</tr>
<tr>
<td>Intercept, Curvature</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slope, Curvature</td>
<td>-0.02</td>
<td>0.00*</td>
<td>-0.02</td>
<td>0.01**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Residual</td>
<td>64.945</td>
<td>9.04***</td>
<td>28.87</td>
<td>5.83***</td>
<td>25.44</td>
<td>4.81***</td>
</tr>
<tr>
<td>-2LL</td>
<td>1257.4</td>
<td></td>
<td>1198.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AIC</td>
<td>1263.4</td>
<td></td>
<td>1210.9</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: -2LL = -2 Log likelihood; AIC = Akaike’s Information Criterion; * p < .05; ** p < .01; *** p < .001

Both linear and quadratic models were estimated for TIR Score_2. Again, the quadratic model was not significant. As shown in the second column of Table 11, the fixed effect for the intercept of the linear model indicated that the average score of technology and pedagogy related technology integration knowledge (TIR Score_2) before student teaching was 52.95. The score for this knowledge at the sample-level, as indicated by the significant and positive linear slope (0.095), increased at a rate of 0.095 units per day. Figure 12 gives a graphic representation of this overall trajectory.
The random effects in the lower part of the second column of Table 11 show that the variance for intercept and slope were significant. This means the participants of this study were significantly different in their level of technology and pedagogy related technology integration knowledge and in its rate of change over time. The insignificant covariance between slope and intercept indicated that the initial level of technology and pedagogy related technology integration knowledge had no influence on one’s change rate.

The Pseudo-$R^2$ statistic yielded by comparing the linear growth model with the unconditional means model was .56. This means that the addition of the slope term was associated with a decrease of 56% in the within-person variance from the baseline model. In other words, 56% of the within-person variance in technology and pedagogy related technology integration knowledge was explained by change over time. The fit statistics (-2 log likelihood and Akaike’s Information Criterion) for the unconditional means model
and for the linear growth model were shown in Table 11. The decreased size of each statistics indicated the better fit of the linear growth curve model.

**Level-2 model: Professional-courses and EdTech-courses as predictors.** After finding significant variability in technology integration readiness trajectories, the focus was then put on level-2 models seeking answer to the question: What can explain such variability? To answer this question, I first estimated two level-2 models for TIR Score_1: one with *professional-courses* as predictor; the other with *EdTech-courses* as predictor.

Table 12 shows a level 2 model for TIR Score_1 including *professional-courses* as a predictor and a slope-by-*professional-courses* interaction term. The fixed estimate of *profession-course* was insignificant indicating that those individuals taking more professional courses did not show significantly higher levels of self-efficacy beliefs about technology integration than those taking fewer professional courses. The interaction term was also insignificant. This means that the rate of change in self-efficacy beliefs about technology integration did not vary with the numbers of credits of professional courses taken.
Table 12

*Growth Model of Professional-courses and TIR Score_1*

<table>
<thead>
<tr>
<th>Parameter, interaction, and fit statistic</th>
<th>Estimate</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed effects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>53.86</td>
<td>2.60***</td>
</tr>
<tr>
<td>Slope</td>
<td>0.14</td>
<td>0.024***</td>
</tr>
<tr>
<td>Professional-courses</td>
<td>0.04</td>
<td>0.05</td>
</tr>
<tr>
<td>Slope × professional-courses</td>
<td>-0.000</td>
<td>0.00</td>
</tr>
<tr>
<td>Random effects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variance (intercept)</td>
<td>102.97</td>
<td>23.66***</td>
</tr>
<tr>
<td>Variance (slope)</td>
<td>0.005</td>
<td>0.00**</td>
</tr>
<tr>
<td>Covariance (intercept, slope)</td>
<td>-0.45</td>
<td>0.18*</td>
</tr>
<tr>
<td>Residual</td>
<td>24.97</td>
<td>5.08***</td>
</tr>
<tr>
<td>-2LL</td>
<td>1192.0</td>
<td></td>
</tr>
<tr>
<td>AIC</td>
<td>1208.0</td>
<td></td>
</tr>
</tbody>
</table>

Note: -2LL = -2 Log likelihood; AIC = Akaike’s Information Criterion; * p < .05; ** p < .01; *** p < .001

The results for the level-2 growth model including *EdTech-courses* and the slope-by-*EdTech-courses* term are shown in Table 13. Again, the fixed estimate of *EdTech-courses* and the interaction term were insignificant. This means that the number of credits of educational technology or educational technology related courses did not influence either the level of self-efficacy beliefs about technology integration or the shape of change trajectories.
Table 13

**Growth Model of EdTech-courses and TIR Score_1**

<table>
<thead>
<tr>
<th>Parameter, interaction, and fit statistic</th>
<th>Estimate</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fixed effects</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>54.95</td>
<td>2.24***</td>
</tr>
<tr>
<td>Slope</td>
<td>0.12</td>
<td>0.02***</td>
</tr>
<tr>
<td>EdTech-courses</td>
<td>0.13</td>
<td>0.41</td>
</tr>
<tr>
<td>Slope × EdTech-courses</td>
<td>-0.003</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Random effects</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variance (intercept)</td>
<td>104.39</td>
<td>23.99***</td>
</tr>
<tr>
<td>Variance (slope)</td>
<td>0.005</td>
<td>0.00**</td>
</tr>
<tr>
<td>Covariance (intercept, slope)</td>
<td>-0.45</td>
<td>0.18*</td>
</tr>
<tr>
<td>Residual</td>
<td>25.16</td>
<td>5.14***</td>
</tr>
<tr>
<td>-2LL</td>
<td>1193.8</td>
<td></td>
</tr>
<tr>
<td>AIC</td>
<td>1209.8</td>
<td></td>
</tr>
</tbody>
</table>

Note: -2LL = -2 Log likelihood; AIC = Akaike’s Information Criterion; * p < .05; ** p < .01; *** p < .001

Professional-courses and EdTech-courses were also introduced into the level-2 growth models for TIR Score_2. These two models also respectively estimated the slope-by-professional-courses and slope-by-EdTech-courses interaction terms. As shown by the results in Table 14 and Table 15, the fixed effects for professional-courses and EdTech-courses were insignificant and the two interaction terms were not significant.

This means that both professional-courses and EdTech-courses told the same story: they did not influence level of technology and pedagogy related technology integration knowledge and its shape of change trajectories.
### Table 14

**Growth Model of Professional-courses and TIR Score_2**

<table>
<thead>
<tr>
<th>Parameter, interaction, and fit statistic</th>
<th>Estimate</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fixed effects</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>53.49</td>
<td>2.55***</td>
</tr>
<tr>
<td>Slope</td>
<td>0.12</td>
<td>0.02***</td>
</tr>
<tr>
<td>Professional-courses</td>
<td>-0.01</td>
<td>0.05</td>
</tr>
<tr>
<td>Slope × professional-courses</td>
<td>-0.00049</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Random effects</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variance (intercept)</td>
<td>95.7</td>
<td>22.82***</td>
</tr>
<tr>
<td>Variance (slope)</td>
<td>0.003</td>
<td>0.00*</td>
</tr>
<tr>
<td>Covariance (intercept, slope)</td>
<td>-0.29</td>
<td>0.16</td>
</tr>
<tr>
<td>Residual</td>
<td>28.70</td>
<td>5.77***</td>
</tr>
<tr>
<td>-2LL</td>
<td>1196.3</td>
<td></td>
</tr>
<tr>
<td>AIC</td>
<td>1212.3</td>
<td></td>
</tr>
</tbody>
</table>

Note: -2LL = -2 Log likelihood; AIC = Akaike’s Information Criterion; * p < .05; ** p < .01; *** p < .001

### Table 15

**Growth Model of EdTech-courses and TIR Score_2**

<table>
<thead>
<tr>
<th>Parameter, interaction, and fit statistic</th>
<th>Estimate</th>
<th>SE</th>
</tr>
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<tbody>
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<td><strong>Fixed effects</strong></td>
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<tr>
<td>Intercept</td>
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<td>2.19***</td>
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<td>Slope</td>
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<td>0.02***</td>
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<tr>
<td>EdTech-courses</td>
<td>-0.08</td>
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<tr>
<td>Slope × EdTech-courses</td>
<td>-0.002</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Random effects</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variance (intercept)</td>
<td>95.99</td>
<td>22.87***</td>
</tr>
<tr>
<td>Variance (slope)</td>
<td>0.003</td>
<td>0.002*</td>
</tr>
<tr>
<td>Covariance (intercept, slope)</td>
<td>-0.29</td>
<td>0.16</td>
</tr>
<tr>
<td>Residual</td>
<td>28.70</td>
<td>5.78***</td>
</tr>
<tr>
<td>-2LL</td>
<td>1198.3</td>
<td></td>
</tr>
<tr>
<td>AIC</td>
<td>1214.3</td>
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</tr>
</tbody>
</table>

Note: -2LL = -2 Log likelihood; AIC = Akaike’s Information Criterion; * p < .05; ** p < .01; *** p < .001

**Level-2 model: Prior-teaching as predictor.** Table 16 shows a model that includes *prior-teaching* and the slope-by-*prior-teaching* interaction term. *Prior-teaching* was coded as “0” if a study participant had no previous teaching experience before the student teaching or as “1” if the participant had. The fixed effect estimate for *prior-
teaching is insignificant meaning that having prior teaching experience did not make a difference in the study participants’ level of self-efficacy beliefs about technology integration.

Table 16

**Growth Model of Prior-teaching and TIR Score_1**

<table>
<thead>
<tr>
<th>Parameter, interaction, and fit statistic</th>
<th>Estimate</th>
<th>SE</th>
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</thead>
<tbody>
<tr>
<td>Fixed effects</td>
<td></td>
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</tr>
<tr>
<td>Intercept</td>
<td>54.03</td>
<td>2.09***</td>
</tr>
<tr>
<td>Slope</td>
<td>0.08</td>
<td>0.02***</td>
</tr>
<tr>
<td>Prior-teaching (1= yes, 0 = no)</td>
<td>3.17</td>
<td>2.84</td>
</tr>
<tr>
<td>Slope × prior-teaching</td>
<td>0.06</td>
<td>0.03*</td>
</tr>
<tr>
<td>Random effects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variance (intercept)</td>
<td>100.13</td>
<td>23.08***</td>
</tr>
<tr>
<td>Variance (slope)</td>
<td>0.004</td>
<td>0.002*</td>
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<tr>
<td>Covariance (intercept, slope)</td>
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<td>0.18**</td>
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<tr>
<td>Residual</td>
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<td>5.21***</td>
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<tr>
<td>-2LL</td>
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</tr>
<tr>
<td>AIC</td>
<td>1191.9</td>
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</tbody>
</table>

Note: -2LL = -2 Log likelihood; AIC = Akaike’s Information Criterion; * p < .05; ** p < .01; *** p < .001

The slope-by-prior-teaching interaction is significant, indicating that prior-teaching experience predicted individual differences in intra-individual change. In other words, prior-teaching was a significant predictor of individual TIR Score_1 trajectories. To better demonstrate this, the respective trajectories for those with prior teaching experience and those without were calculated. The trajectories were shown in Figure 13. It is easy see from the graph that those with prior teaching experience had faster change rate in TIR Score_1 than those without prior teaching experience.
A growth model including prior-teaching and the slope-by-prior-teaching term was tested with TIR Score_2 as the dependent variable. The results of this model in Table 17 show that the fixed effect for prior-teaching is insignificant. This means that having prior teaching experience or not before the student teaching did not influence an individual’s level of technology and pedagogy related technology integration knowledge (TIR Score_2).

*Figure 13. TIR Score_1 trajectories for individuals with and without prior teaching experience, showing different rates of change*
Table 17

*Growth Model of Prior-teaching and TIR Score_2*

<table>
<thead>
<tr>
<th>Parameter, interaction, and fit statistic</th>
<th>Estimate</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fixed effects</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>51.27</td>
<td>2.02***</td>
</tr>
<tr>
<td>Slope</td>
<td>0.06</td>
<td>0.02***</td>
</tr>
<tr>
<td>Prior-teaching (1= yes, 0 = no)</td>
<td>3.55</td>
<td>2.76</td>
</tr>
<tr>
<td>Slope × prior-teaching</td>
<td>0.05</td>
<td>0.02*</td>
</tr>
<tr>
<td><strong>Random effects</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variance (intercept)</td>
<td>90.62</td>
<td>21.79***</td>
</tr>
<tr>
<td>Variance (slope)</td>
<td>0.002</td>
<td>0.002</td>
</tr>
<tr>
<td>Covariance (intercept, slope)</td>
<td>-0.31</td>
<td>0.16*</td>
</tr>
<tr>
<td>Residual</td>
<td>28.97</td>
<td>5.84***</td>
</tr>
<tr>
<td>-2LL</td>
<td>1181.7</td>
<td></td>
</tr>
<tr>
<td>AIC</td>
<td>1197.7</td>
<td></td>
</tr>
</tbody>
</table>

Note: -2LL = -2 Log likelihood; AIC = Akaike's Information Criterion; * p < .05; ** p < .01; *** p < .001

Like the results for TIR Score_1, the slope-by-*prior-teaching* interaction term was significant, indicating prior teaching experience influenced the shape of the change trajectories of TIR Score_2. Again, this relationship was depicted graphically in Figure 14. The two lines in Figure 14 represent the overall change trajectories of TIR Score_2 for those with prior teaching experience and for those without. The trajectory for those with prior teaching experience had a positive and steeper slope, indicating that the TIR Score_2 for those with prior teaching experience increased at a significantly faster rate than those without prior teaching experience.
Figure 14. TIR Score_2 trajectories for individuals with and without prior teaching experience, showing different rates of change

*Level-2 model: Grade-level as predictor.* Compared with the afore-discussed level-2 predictors (i.e., *professional-courses, EdTech-courses,* and *prior-teaching*), the variable *grade-level* is more of a contextual factor giving information about what age groups of students the study participants were working with during their student teaching. *Grade-level* was coded as “0” for those teaching at the elementary level (grades 1-6) and as “1” for those teaching at the secondary level. *Grade-level* was considered as a between-person (level-2) predictor, with the hope that the results could help quantify some contextual influence on the levels and trajectories of TIR Score_1 and TIR Score_2.
The results of the model for TIR Score_1 that included grade-level and slope-by-grade-level are shown in Table 18. The insignificant fixed effect indicated that grade-level had no influence on one’s level of self-efficacy beliefs of technology integration. The \( p \)-value for the interaction term is 0.09. Although it’s true that a finding is merely “significant” or “insignificant” and that \( p \)-value of .05 is our accepted standard, the choice was made in this study to be less stringent about \( p \)-value and the .09 of the interaction term was interpreted as “marginally significant”. This was done because this study is quite exploratory in identifying predictor variables that influences the change rate or trajectories of pre-service teachers’ technology integration readiness during student teaching.
Figure 15. TIR Score_1 trajectories for individuals at the elementary level and the secondary level, showing different rates of change.

The negative and marginally significant estimate of the interaction term indicated that study participants teaching at the elementary level demonstrated faster change rate over time in self-efficacy beliefs of technology integration (TIR Score_1) and this difference in change rate between grade levels should not be ignored. The graph in Figure 15 was intended to help visualize this difference.
A growth model for TIR Score_2 with grade-level and the slope-by-grade-level interaction term was also estimated. This model rendered similar results (shown in Table 19). The fixed estimate was insignificant and the p-value (= 0.09) for the interaction term was marginally significant. This means that grade-level had no influence on the level of technology and pedagogy related technology integration knowledge (TIR Score_2). Those study participants teaching at the elementary level had a faster progress rate in technology and pedagogy related technology integration knowledge than those teaching in the secondary level and this difference in the change trajectories should not be dismissed as negligible. Figure 16 shows this difference graphically.

**Table 19**

*Growth Model of Grade-level and TIR Score_2*

<table>
<thead>
<tr>
<th>Parameter, interaction, and fit statistic</th>
<th>Estimate</th>
<th>SE</th>
</tr>
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<tbody>
<tr>
<td><strong>Fixed effects</strong></td>
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<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>53.61</td>
<td>1.84****</td>
</tr>
<tr>
<td>Slope</td>
<td>0.11</td>
<td>0.02****</td>
</tr>
<tr>
<td>Grade-level (1= secondary level, 0 = elementary level)</td>
<td>-1.38</td>
<td>2.85</td>
</tr>
<tr>
<td>Slope × grade-level</td>
<td>-0.04</td>
<td>0.02*</td>
</tr>
<tr>
<td><strong>Random effects</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variance (intercept)</td>
<td>96.49</td>
<td>22.99***</td>
</tr>
<tr>
<td>Variance (slope)</td>
<td>0.003</td>
<td>0.002**</td>
</tr>
<tr>
<td>Covariance (intercept, slope)</td>
<td>-0.32</td>
<td>0.17</td>
</tr>
<tr>
<td>Residual</td>
<td>28.50</td>
<td>5.69****</td>
</tr>
<tr>
<td><strong>-2LL</strong></td>
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<td></td>
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<tr>
<td>AIC</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: -2LL = -2 Log likelihood; AIC = Akaike’s Information Criterion; * 0.05 < p < 0.1; **p < .05; *** p < .01; **** p < .001
4.4.2 Discussion

The quantitative results of this study revealed that both the overall sample trajectory of TIR Score_1 and that of TIR Score_2 were characterized by linear increase. Around the overall positive linear trends was the significant variability as demonstrated by the growth curve models. In other words, participants in this study demonstrated individual differences over time in the rates at which they progressed in self-efficacy beliefs of technology integration (TIR Score_1) and in technology and pedagogy related technology integration knowledge (TIR Score_2). In the exploration of explanations for the individual variability in change rate over time, this study yielded quantitative results allowing us to approach technology integration readiness and its change during student teaching from new lens. These quantitative results also provided some guidance about where to go in the subsequent qualitative inquiry in this study.
An individual-based perspective toward technology integration readiness. The overall sample trajectories (as shown in Figure 11 and Figure 12) for the TIR Score_1 and TIR Score_2 show that overall, these two scores underwent significant increase over time during the student teaching. This finding is not surprising given the well-documented benefits of student teaching to pre-service teachers (e.g., Eisenhardt et al., 2011; Greenberg et al., 2011; Korthagen & Kessels, 1999; Tigchelaar & Korthagen, 2004). What is really important is the finding of significant variability in the individual trajectories around the overall trajectories. In the two linear growth curve models (see Table 10 and Table 11), the significant intercept variance meant that individuals differed in the levels of their self-efficacy beliefs of technology integration and their technology and pedagogy related technology integration knowledge, and the significant slope variance meant that their rates of change were different.

Previous research on student teaching and technology integration has not considered and focused on individual differences and changes over time, let alone quantified such differences and changes. This study revealed and documented that there was considerable variation among pre-service teachers in their readiness for technology integration and in its change rate over time. This finding calls for an individual-based perspective in our research, admitting and explaining individual differences for the purpose of revealing effective ways of directing pre-service teachers into desirable technology integration trajectories.

Effects of professional-courses and EdTech-courses. Technology skill courses and methods courses involving teaching technology integration have been suggested in the literature as two important components for preparing pre-service teachers for technology
integration (Schrum, 1999). Also known in the literature is the idea that technology integration requires knowledge in the area where content, pedagogy, and technology meet as shown in the TPACK framework (Mishra & Koehler, 2006). Since the variable professional-courses indicated mostly block and content courses excluding the technological aspect of the TPACK framework, the results that professional-courses was not able to determine or predict the study participants’ change trajectories in both TIR Score_1 and TIR Score_2 provided some evidence support the idea underlying the TPACK framework (Mishra & Koehler, 2006) that effective uses of technology requires knowledge combining technology, pedagogy, and content in instruction.

Since the variable EdTech-courses referred to the educational technology course and methods courses requiring technology uses that the study participants had taken, it was reasonable to expect EdTech-courses to be able to predict individual differences in levels of TIR Score_1 and TIR Score_2, as well as individual differences in intra-individual change for these scores. However, the results from this study failed to confirm the predictions. The insignificant fixed estimates of EdTech-courses, and the insignificant interaction terms (see Table 13 and Table 15) indicated that EdTech-courses did not influence level of technology integration readiness and the shape of the change trajectories. Why was it the case? This question became one of the questions that guided the subsequent deductive analysis of the interview data.

Although the fixed effect estimates of EdTech-courses were insignificant for both TIR Score_1 and TIR Score_2, it might be worth pointing out that this variable tends to influence TIR Score_1 and TIR Score_2 in opposite directions. As suggested by the positive fixed effect estimate of EdTech-courses in the TIR Score_1 model and the
negative fixed effect estimate of *EdTech-course* in the TIR score-2 model, the increase in the number of credits of methods and educational technology courses taken would increase TIR Score_1 but decrease TIR Score_2. Although the increase and decrease were not large enough to establish *EdTech_course* as significant a predictor, such results definitely went against our expectation that the number of credits of methods and educational technology courses taken should be positively associated with pre-service teachers’ technology integration self-efficacy beliefs and their technology and pedagogy related technology integration knowledge. While this unexpected result of the results calls for future research and further investigation, it urged me to seek possible explanations through the interview data analysis.

*Relevance and effects of prior-teaching as a predictor.* The findings from this study indicated that participants having prior teaching experience were not different from each other in their TIR Score_1 and TIR Score_2. However, participants with prior teaching experience demonstrated a significantly faster rate of progress in these two scores than those without. While the growth curve models revealed that the participants of this study demonstrated significant variability in the shapes of their individual trajectories of readiness for technology integration (as indicated by TIR Score_1 and TIR Score_2), the growth model with *prior-teaching* as a predictor pinpointed *prior-teaching* as a significant variable for predicting the shape of individual trajectories of readiness for technology integration.

What can be learned from the results of the growth models including *prior-teaching* is that the trajectories of the pre-service teachers’ readiness for technology integration varied from individual to individual depending on having or having no prior
teaching experience. Although the quantification of how the amount and the quality of prior teaching experience are related to the rate of change in readiness for technology integration is beyond the scope of this study, the results of the growth model with prior-teaching suggested that allowing pre-service teachers to acquire some teaching experience would expedite their progress in readiness for technology integration during student teaching. This is definitely a desirable result that would serve the ultimate purpose of student teaching: to help pre-service teachers develop competence in the professional roles they are preparing for (Greenberg, Pomerance, & Walsh, 2011).

The perspective of viewing teaching as a situated practice (e.g., Korthagen & Kessels, 1999; Shulman, 1987) has well established in the literature. This perspective may explain, at a macro-level, why prior teaching experience was able to make a difference in the participants’ shapes of trajectories for readiness technology integration. But it is still unclear, at a micro level, about the mechanism of how prior teaching experience was able to serve as an accelerator for the increase of technology integration readiness. Is this mechanism related to “enactive experience” (Bandura, 1986, 1988) or phronesis (Korthagen & Kessels, 1999) about technology uses developed in prior teaching experience? Or, there are other stories involved in the mechanism? This became another part that the subsequent interview data analysis results would hopefully shed light on.

Relevance and effects of grade-level as a predictor. Students, as the target audience of pre-service teachers’ instruction, are an important part in the student teaching context. However, one would easily notice, through a review of previous literature on student teaching and technology integration, that students were excluded from the
landscape of contextual factors. Little is known about students’ influence on pre-service teachers’ development in readiness for technology integration. In this study, an attempt to remedy this gap was made by introducing the variable grade-level into the growth models. As shown by the results, grade-level had no influence on the study participants’ self-efficacy beliefs about technology integration and their technology and pedagogy related technology integration knowledge. This result was of no surprise because it was not expected that teaching at either the elementary level or the secondary level would make one become more confident in or more knowledgeable about technology integration.

However, the results indicated that the influence of grade-level on the participants’ rate of change in readiness for technology integration was marginally significant. Though the term “marginally significant” is always a target of criticism of methodological researchers, this marginal significance was not dismissed as negligible given the exploratory nature of this study. Instead, grade-level was regarded as an important variable for predicting individual trajectories of readiness for technology integration, and this variable was kept within view when analyzing the interview data, trying to answer the question “In what way(s) do grade levels (the elementary level or the secondary level in the case of this study) influence the rate of progress in readiness for technology integration?”.

Deductive analysis guide for interview data. As discussed above, the quantitative data analysis results gave rise to a list of questions that hopefully could be answered by the interview data. Questions included in this list are: 1) Why was EdTech-courses not able to predict the progress rate in readiness for technology integration? 2) Why did the influence of EdTech-courses on TIR Score_1 and that on TIR Score_2 go opposite
directions? 3) Why did having or not having prior teaching experience make a difference in the study participants’ rate of progress in readiness for technology integration? 4) Why did grade-level render influence on the study participant’s rate of progress in readiness for technology integration? These questions provided a sense of direction of what to look for in the inductive analysis of the interview data.

4.5 Qualitative Results and Discussion

Of the sixteen-eight online survey participants, fifteen volunteered to participate in the follow-up interview. However, only eleven finally showed up and finished the interview. All of the eleven interview participants were White. The interview participants’ demographic information regarding their major, gender, and the grade level they taught were shown in Table 20. The deductive analysis results and inductive analysis results of the interview data are presented separately in this section, and pseudonyms of the interview participants are used in presenting the results.

Table 20

Demographics of the Interview Participants (Study III)

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<th>Major</th>
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<tbody>
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<tr>
<td>Art Education</td>
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</tr>
<tr>
<td>Biology Education</td>
<td>1</td>
</tr>
<tr>
<td>Chemistry</td>
<td>1</td>
</tr>
<tr>
<td>Elementary Education</td>
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<tr>
<td>English Education</td>
<td>2</td>
</tr>
<tr>
<td>Social Studies Education</td>
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<tr>
<td>Spanish Education</td>
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<tr>
<td>Gender</td>
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<td>Elementary</td>
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</tr>
<tr>
<td>Secondary</td>
<td>9</td>
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</tbody>
</table>
4.5.1 Deductive Interview Data Analysis Results

The deductive analysis of the interview data sought to answer the four questions emerging from the quantitative data analysis. The deductive analysis results presented in this section were arranged based on the four questions.

*Question 1: Why was EdTech-courses not able to predict the progress rate in readiness for technology integration?*

The overall sample trajectories for TIR Score_1 and TIR Score_2 indicated that the pre-service teachers in this study were significantly different in their progress rate in readiness for technology integration (i.e., both in self-efficacy beliefs about technology integration and in technology and pedagogy related technology integration knowledge). It was expected that the variable *EdTech-courses* would be able to predict the progress rate in readiness for technology integration. However, the quantitative data analysis results indicated that this variable was not able to predict the progress rate in readiness for technology integration. The following three issues identified through the deductive interview data analysis provided us with some clues for understanding why this was the case.

The first issue is related to the differences between technology uses learned in teacher education program and those actually happening in real classrooms. As shown by interview data, technology use in real classrooms was much more complicated and less straightforward than how it was presented in the methods or educational technology courses. Laura, the pre-service teacher in chemistry education, said in her interview: “My methods classes taught us some technology use, like the simulation, how to use, how to
find just general help online… We were asked to use it in our lesson plans, and that’s it”.

As reflected in Laura’s comment, in the methods and educational technology courses, the pre-service teachers learned how to use some educational technologies and used these technologies in some projects or lesson plans. But, their focus was on the presence of educational technologies, and as long as a particular technology was used, they did not have to think much about content and pedagogy related issues in using the technology. This situation was found voiced by Mary, the pre-service teacher of English Education, who said in her interview that, though the methods course she took required using some technology, “My methods courses were more about connecting with students and staff members and involving students like on a day to day intellectual way, not so much technology. I feel like they—the professors—see that as kind of a separate entity”.

However, things became different when the pre-service teachers used technologies in their student teaching: they had to match the technology with particular content they taught, consider students’ learning needs, and pay attention to students’ response to the technology uses. Alice, the pre-service teacher in biology education, had to decide what technology to use to better teach DNA replication to her students while considering if this technology could help keep her students on task. When Lisa, the pre-service teacher in Spanish Education, actually started teaching a class of twenty-eight students in a classroom with two tiny speakers, she realized the need to use a recording program asking her students to record something in Spanish that she could go back and listen to it on her own time. To use Lisa’s words, the purpose of doing this was “to see what they are doing right, what they are doing wrong, and it’s just a lot more effective than trying within a class period to listen to all these different kids talk”. In addition to
examples like these, the interview participants talked in the interviews that they had to take the needs of their ESL (English as a Second Language) students or their IEPs (Individualized Education Programs) students into consideration and had to accommodate their students’ short attention span when using technologies in teaching. The interview participants realized that their students grew up around technology and were technology savvy. Consequently, while some of these interview participants became uncertain about what technologies to use to engage their students, some discussed with their students and allowed them to choose, in Lisa’s words, “whether they want to do it [technology] my [the teacher’s] way or whether they want to do it their own way”.

It can be learned through the interview data that technology uses the pre-service teachers learned in the methods and educational technology courses were of more decontextualized fashion. However, technology uses in real classrooms were contextualized, having to dealing with content- and learner-related issues. This decontextualizedness vs. contextualizedness might help explain why EdTech-courses was not able to explain the pre-service teachers’ differences in progress rate in readiness for technology integration.

The second issue helping explain why EdTech-courses failed to predict the shapes of individual trajectories of readiness for technology integration was related to the pre-service teachers’ unpreparedness for educational technology trends in schools. Five out of the eleven interview participants had Smart Boards in their classrooms. Two other interview participants mentioned in the interview that the schools where they student taught were planning to purchase Smart Boards for each classroom in the schools. According to these pre-service teachers, having Smart Board in the classrooms was an
educational technology trend in schools. However, they admitted that they were not prepared for this trend. As they said in the interview, they did learn how use Smart Board in the methods and educational technology courses they took, but it was not enough for them to know how to use it in teaching on a daily basis. Terry, another pre-service teacher in Spanish Education, talked about her Smart Board learning experience in the educational technology course:

It was like you had to go for one day and you went and you sat with like fifteen other people in a little tiny conference room with a Smart Board and they said here’s the Smart Board here’s how it works here’s how you can use it. That was my only experience with a Smart Board. I had never actually been in a classroom where it was utilized. So, it’s completely different to say here it is and here’s how to use it. That’s different than being in a classroom and learning from it. I had never been in a classroom where a Smart Board was being used for instructional purposes not just teaching you how to use a Smart Board...

Before actually integrating Smart Board into teaching specific content, these pre-service teachers had to learn more about how to use it by either asking their cooperating teachers to teach them or by figuring out themselves. This was like what Alice said in the interview that “I had to get all the little embarrassing tidbits doing with Smart Board out of the way so I did not do that in front of a class”.

Another educational technology trend in the schools mentioned in the interview was “one to one” laptop or iPad for students. Two of the interview participants who taught in high schools told me that all students except freshmen in these two schools had laptops and classes with all freshmen can always check out laptops from the computer
labs. In other high schools where some of the interview participants student-taught, the administration was really enthusiastic about getting all students an iPad. One of the high schools was looking into a pilot “one to one” iPad program and had started training some of the teachers to teach with iPad. In face of this “one to one” laptop or iPad trend in schools, the interview participants felt that they were not prepared. These participants voiced the urgent need for such trend to be reflected in methods and educational technology courses. Quite representative of this voice was what Joy, another pre-service teacher in English education, said in the interview:

Every student will have a tablet or a laptop in front of them at all times. We’ll have to have classes to prepare for that. We’ll have to have a new way to make lesson plans, because our lesson plans are based around the fact that my students have a piece of paper and a pencil in front of them... Probably right now, probably soon, maybe next year or the year after that, there should definitely be in the lesson plan lessons in college classes when we, educators, are learning how to plan a lesson around the fact that all our students all have a laptop or tablet in front of them.

In addition to the above mentioned educational technology trends, the schools where the interview participants student-taught were using learning management systems like PowerSchool and My Big Campus and other technologies like Eno Board, Scantron and GradeCram. These pre-service teachers were not familiar these technologies and the following quotes from two of these pre-service teachers might tell us something about how they feel about this situation: “It would had been nice to get a precursor into these technologies before starting the student teaching” (by Alice, the pre-service teacher in
biology education); and “Just being exposed to some of the technologies that all of the schools in the area might have variations of would have been a good thing to make me better prepared for the future” (by Jane, a pre-service teacher in elementary education).

As shown by the interview data, the afore-mentioned educational technology trends were not reflected in the methods and educational courses taken by these pre-service teachers. Also, these courses did not cover some educational technologies these pre-service teachers had to use during student teaching, which was quite understandable given the great variety of educational technologies and their ever-changing landscape. But, we may get some clues from these trends and technologies about why EdTech-courses was not able to predict the study participants’ progress rate in readiness for technology integration.

The third issue that could help answer Question 1 was related to the sequence of the educational technology course in the education programs and the disconnection between methods and educational technology courses. It’s worth repeating that the education programs the study participants enrolled in adopted the single educational technology course model (Belland, 2009; Hargrave and Hsu, 2000) and the variable EdTech-courses refers to the number of credits of courses, including the educational technology course and the methods courses, that require using educational technologies. A problem related to the sequence of the educational technology course in the education program was identified in the interview data. The following quote from the interview data provides an effective and straightforward way to understand this problem:

I think most education students take that class [referring to the educational technology course] when they first decide to be a teacher maybe their freshman year at Purdue. You
don’t actually get into the classroom to have the opportunities to really use what you’re learning until the end of your senior year and for some students it’s even after that. They don’t student teach until their fifth year. So, for me, a lot of the things that I learned I didn’t have an opportunity to practice between my freshman year and three and a half years later when I needed to use it in the classroom. So, I think I had to relearn a lot of the things that I maybe had down pat when I took that class. (Terry, the pre-service teacher in Spanish Education)

One of the interview participants referred to this problem as “a time thing”. However, this “time thing” was not just a time issue related to the long time interval—at least three and a half years according to the quote, between the educational technology course and student teaching. It was an issue of lacking practice of what had been learned in the educational technology course. Since the pre-service teachers definitely took some methods courses during this long time interval, one might ask the question: Couldn’t these pre-service teachers get some practice in the methods courses? Here is the problem the pre-service teachers talked about in the interview regarding the disconnection between the educational technology course and other methods courses.

As Lisa said in the interview, “the talk of educational technology just kind of stopped in EDCI 270 [the course code for the educational technology course]”. Some pre-service teachers made comments in the interview on how connections could be made between the educational course and other methods courses, such as “In my other methods classes if they would have assigned us some sort of test to use what we learned in EDCI 270. I think that would have helped (by Lisa, the pre-service teacher in Spanish education)”; and “In the methods classes if we would have kind of reviewed all of those
technologies and kind of continued talking about how we could use them…” (Joy, the
pre-service teacher in English Education), just to quote two of the interview participants.
From such comments we can at least learn that, for these pre-service teachers, learning
how to use educational technology should not just be a “one-semester thing”; and the
requirement in methods courses of asking pre-service teachers to incorporate a particular
technology into a lesson plans would not be very useful in helping the learning of using
educational technology unless the talks about how educational technology uses are
continued.

The sequence problem related to the educational technology course and the
problem of disconnection between methods and educational technology courses helped
shed some light on why EdTech-courses failed to predict the pre-service teachers’
progress rate in readiness for technology integration. More importantly, these two
problems imply the need to re-think the sequence of the educational course in education
programs and the need to make effective connections between methods and educational
technology courses.

*Question 2: Why did the influence of EdTech-courses on TIR Score_1 and TIR Score_2
go opposite direction?*

In the quantitative data analysis results, the positive fixed effect estimates for
EdTech-courses in the growth model for TIR Score_1 and the negative fixed effect for
TIR Score_2 showed that EdTech-courses tend to influence TIR Score_1 and TIR
Score_2 in opposite directions: the increase in EdTech-courses would increase TIR
Score_1 but would decrease TIR Score_2. Although EdTech-courses was not a
significant predictor for TIR Score_1 and TIR Score_2, the inductive analysis of the interview data still sought to contribute to our understanding about how the variable of EdTech-courses was related to the pre-service teachers self-efficacy beliefs about technology integration and their technology and pedagogy related technology integration knowledge.

The answer to Question 2, as revealed by the interview data, is quite simple: technology knowledge translates but knowledge about combining technologies with specific learning contexts (e.g., specific learners, content, and teaching strategies) does not. Quite illustrative of the meaning of this answer is the following quotation from Joy, the pre-service teacher in English education:

Technology translates, like if you know how to make a PowerPoint of your lesson, it’s gonna be a PowerPoint of your lesson when you get into the real classroom. I think the real difference is when you are practicing in your methods courses, you’re giving a lesson to your peers and they are listening perfectly. They really are engaged no matter what they are going to be engaged because they are your peers. They’re into education. They want to learn. When you go into a high school classroom full of ninth graders and it’s seven o’clock in the morning. They’re not even looking at you. They’re half asleep or they’re trying to text or they’re trying to do something else. So I think that is the real difference…

This quote conveys the idea of translatability of technology knowledge. That is, technology knowledge about a specific educational technology (e.g., knowing how to make PowerPoint slides or make a movie on Windows Movie Maker), once gained, would always be readily available to be used. For some pre-service teachers in the
interview, such technology knowledge could be easily picked up even if it was a bit forgotten because of the long interval between the educational course and the student teaching. However, knowledge of teaching effectively with educational technology in real classrooms was not readily able to be translated from knowledge of technology uses the pre-service teachers were familiarized with in methods and educational technology courses. This untranslatability was related to the decontextualizedness and contextualizedness respectively characterizing technology uses in methods and educational technology and technology uses in real classroom settings, which were pointed out earlier.

Since TIR Score_1 mainly measures pre-service teachers’ beliefs about their own technology knowledge and ability of using technology, the translatability of technology knowledge would help explain the positive effect of EdTech-courses on TIR Score_1. But for TIR Score_2, which focuses on pre-service teachers’ knowledge and ability of combining technology and pedagogy into teaching, it was completely different. Because the knowledge of technology uses gained in methods and educational technology courses were not readily translatable into knowledge of using technology to teach effectively in real classroom, it would be unsurprising to see the negative effect of EdTech-courses on TIR Score_2.

Question 3: Why did having or having no prior teaching experience make a difference in the study participants’ rate of progress in readiness for technology integration?

The quantitative data analysis results indicated that prior-teaching had a significant positive effect on individual TIR Score_1 and TIR Score_2 trajectories,
meaning that those pre-service teachers with prior teaching experience made significantly faster progress in readiness for technology integration than those without prior teaching experience. The analysis of the interview data provided some clues explaining why this was the case.

As Terry said in the interview, prior-teaching experience gave “the opportunity to actually be involved in the creation of lesson plans and to implement my ideas about using technology into actual lessons and to integrate the things I learned at Purdue into the curriculum”. Generally speaking, those pre-service teachers with prior-teaching experience got real world practice of planning and teaching with educational technology. In addition, as mentioned earlier in this section, some educational technology trends and educational technologies in the schools were not covered by the methods and educational technology courses taken by the study participants. According to the interview data, those pre-service teachers having prior teaching experience got a chance to familiarize themselves with these educational trends and educational technologies, thus being able to make faster progress in readiness for technology integration. Also mentioned earlier is the decontextualizedness of technology uses in methods and educational technology courses versus the contextualizedness required for effective technology uses in real classrooms. For those pre-service teachers with prior teaching experience, they were able to develop some ideas, through their prior teaching experience, about real classroom contexts (as related to students, content, and pedagogy) and how such contexts might influence technology uses. Therefore, it was reasonable to see these pre-service teachers made faster progress in readiness for technology integration during student teaching.
Role-change emerged from the interview as a factor helping explain why prior-teaching was significant in predicting individual trajectories of readiness for technology integration. The following is what Sue, a pre-service teacher in elementary education, said in the interview about role-change:

I think that the kind of context is different… It’s when the role changes from student to teacher. I think is the way you look at it changes. Because when you are sitting in a class in an EDCI 270 class you’re the student. They’re teaching you… But then when you are actually using it for your own teaching purposes, the way you deal with the technology is much different. The way you approach the technology is different… so when you’re the instructor, the way you use the technology, the way you think about the technology is different. Your intent with it changes. And so I think that’s the biggest difference and the biggest…

Role-change is unavoidable for every pre-service teacher leaving education programs to start teaching in real classrooms, and transitioning from student to teacher involves conflicts, tensions, and ambiguities (Beach & Pearson, 1998). Such conflicts, tensions, and ambiguities, in the specific context of talking about educational technology uses, may be more related to changes in the way of approaching, using, and thinking about technology and in the “intent with technology” as mentioned in the above quote. Prior teaching experience would allow someone to experience such changes, which would consequently facilitate one’s role-change in using educational technologies and accelerate one’s progress in readiness for technology in technology integration during student teaching.
Question 4: Why did grade-level render influence on the study participants’ rate of progress in readiness for technology integration?

The quantitative data analysis results indicated that, though grade-level did not make a difference in the study participants’ level in TIR Score_1 and TIR Score_2, it was marginally significant in predicting the study participants’ progress rate in these two scores. Although the results were only marginally significant, the interview data was still examined in an attempt to reveal the qualitative story behind the relationship between grade-level and the progress rate in readiness for technology integration. Of the eleven pre-service teachers participating in the interview, eight taught in high school and two taught in elementary school. There was one pre-service teacher in Art Education who was licensed in K-12 and student-taught both K-6 kids and 6th and 7th graders. Admittedly, the unbalanced numbers of pre-service teachers who taught in elementary school and those who taught middle or high school limited the power of the interview data in presenting a comprehensive picture regarding the clues for answering Question 4. Based on the interview data, two factors were identified that could help explain the influence of grade-level on the pre-service teachers’ progress rate in readiness for technology integration.

The first factor was related to the difference in student characteristics between elementary and secondary students. According to Jane and Sue, the two pre-service teachers teaching in elementary schools, they could easily get their elementary students excited and engaged by using some educational technologies. The elementary students were excited about doing math on Smart Board, and as Jane recalled, they kept asking “Can we come up and write the answer, or can we come draw it?” They were excited to use Kindle and “were so engaged in reading on Kindle instead of a hard copy of book”.
Flash and animation media were effective in getting and keeping their attention. In contrast, those pre-service teachers teaching in middle or high schools had a hard time getting their students excited and engaged by using technologies. According to some of these teachers, their students were just not interested or did not care no matter what technology was used. As commented by the pre-service teachers, their secondary students were very tech savvy. For some of the pre-service teachers, this explained the lack of interest among their students in whatever technologies they used in class. What make things worse was that a lot of secondary students had smart phones, iPod, or iPad, and were “constantly wired in with their technology”, as mentioned by Terry in her interview. Secondary students were always trying to text or do something else with their own technology instead of paying attention to the technology used by their pre-service teachers.

Kay, the pre-service teacher in art education who student-taught both elementary and secondary students at the same said something in the interview that gave a rather good summary of the afore-mentioned difference between elementary and secondary students:

With the little kids, the more flash you have, like the more interest you have, the easier it is to keep their attention, to get their attention. With the older kids, they don’t care either way. It would have to be something completely over-the-top to get their attention. But most of the time, they just don’t care. They don’t really want to talk with you about anything.

Such differences between elementary students and secondary students consequently made a difference between those student-teaching in elementary schools
and those in secondary schools: the elementary pre-service teachers felt more comfortable, confident, and competent in using technology in teaching than the secondary pre-service teachers. This difference might help explain why those secondary pre-service teachers in this study demonstrated a slower progress rate in readiness for technology integration than those elementary pre-service teachers.

The second factor that could help explain this difference in progress rate between the secondary and elementary pre-service teachers was related to the difference in degrees of specialization between subjects taught in elementary schools and those taught in secondary schools. Jane and Sue, the two pre-service teachers in elementary education, were more of a generalist teaching all subjects in self-contained classrooms. The subjects they taught were of low specification level, which made it relatively easy to find educational technologies serving specific instructional purposes. For these pre-service teachers, sometimes a single educational technology would serve a bunch of instructional purposes of teaching different subjects: using Smart Board, they could bring up different shapes in teaching math and different coins for learning about money; they could do different writing and brainstorming activities; they could play a video clip to lead the students through a virtual tour in a history lesson; they could get Elmo hooked up for teaching reading, etc.

In comparison, the subjects taught by those secondary pre-service teachers in this study were more specialized making it more difficult to match appropriate educational technologies with specific instructional purposes: Alice, a pre-service in biology education, had to look for technology helping her better teach DNA replication and do the base-pair-matching activity in DNA molecule; Laura, the chemistry teacher, had to
look for online simulations that could help her teach or demonstrate some chemistry concepts (e.g., gas laws, fission, fusion). Joy, one of the two interview participants in English Education, taught 9-12 graders World Literature, Speech, Theatre, and Advanced Theatre. This pre-service teacher commented in the interview, “All of my classes are very specialized”. This situation might be very rare at the elementary level. According to this teacher, teaching classes specialized as such required more time and effort for preparing the classes and technology uses.

As shown above, the difference in the degrees specification between subjects taught at the elementary level and those taught the secondary level technology resulted in a difference in technology uses between the elementary and the secondary pre-service teachers. It might be reasonable to expect that this resulting difference in technology use would make the elementary and secondary pre-service teacher feel differently about their knowledge about educational technologies and about their abilities to teach with educational technologies, hence the quantitative result that those study participants student-teaching at elementary schools made faster progress in both TIR Score_1 and TIR Score_2 than those student-teaching at secondary schools.

4.5.2 Discussion Based on Deductive Interview Data Analysis Results

The deductive interview data analysis results presented above provided clues for answering the four questions arising from the quantitative data analysis results. Table 21 summarizes the clues from the deductive interview data analysis for each of the four questions.
Table 21

Summary of the Deductive Interview Data Analysis Results

<table>
<thead>
<tr>
<th>Question</th>
<th>Clues from deductive interview data analysis</th>
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| **Question 1**: Why was EdTech-courses not able to predict the progress rate in readiness for technology integration? | 1) While educational technology uses learned in methods and educational technology courses were straightforward and decontextualized, educational technology uses happening in real classrooms were complicated and contextualized;  
2) The pre-service teachers were unpreparedness for educational technology trends in the schools.  
3) The educational technology course was taken too early in the education programs and the methods and educational technology courses were disconnected. |
| **Question 2**: Why did the influence of EdTech-courses on TIR Score_1 and TIR Score_2 go opposite direction? | 1) Technology knowledge from methods and educational technology courses was translatable to real classrooms.  
2) Knowledge of combining technology knowledge with pedagogy to teach specific content in real classrooms could not readily translated from what had been learned in the methods and educational technology courses. |
| **Question 3**: Why did having or having no prior teaching experience make a difference in the participants’ rate of progress in readiness for technology integration? | 1) The pre-service teachers with prior teaching experience got real world practice of planning and teaching with educational technologies.  
2) The pre-service teachers with prior teacher experience got a chance to familiarize themselves with new educational technology trends in schools.  
3) Prior teaching experience would help facilitate the role-change process. |
| **Question 4**: Why did grade-level render influence on the participants’ rate of progress in readiness for technology integration? | 1) The pre-service teachers in the elementary levels and those in the secondary levels may feel differently about their confidence and competency in teaching with technology because of the differences in student characteristics between elementary and secondary students (i.e., elementary students were easily excited about and engaged by using some educational technologies, but secondary were not).  
2) The elementary and secondary pre-service teacher feel differently about their knowledge about educational technology and their abilities of using educational technologies to teach because of the difference in degrees of specialization between subjects taught in elementary schools and those taught in secondary schools. |
The single educational technology course model is still dominant in education programs (Belland, 2009; Hargrave and Hsu, 2000) and this may cause the sequence of this single educational course in educational technology programs to be an issue. In the study participants’ case, they took the educational technology course in their freshmen year. A good aspect of taking this course early on was to at least help the pre-service teachers develop some “what”, “how”, “why” ideas about educational technology uses which might come in handy in later methods courses calling for integrating educational technology into lesson planning. But because of the long time interval and lack of practice due to disconnections between methods and educational technology courses, what was learned in the educational course might have been forgotten long before student teaching, as reported by the pre-service teachers in the interview. To solve this problem, the education programs of the study participants may consider adding a senior advanced educational technology course in the teacher preparation curriculum. This senior advanced educational technology course is not just intended to refresh the memory of what is learned in the previous educational technology course, but rather to better prepare pre-service teacher for real classroom technology uses by such means as modeling technology integration, effective technology integration case study, and inviting real-classroom teachers as guest speakers.

Another problem indentified through the deductive interview data analysis was the disconnection between the educational technology course and the methods courses. Typically, educational technology courses offered in education programs are independent from methods courses (Graham, Culatta, Pratt & West, 2004; Mims, Polly, Shepherd, & Inan, 2006). So the disconnection between the methods and educational technology
courses reported by the pre-service teachers in the interview was not uncommon.

Strengthening the connections between methods and educational technology courses would give pre-service teachers more practice in applying what is learned in educational technology courses in lesson planning and implementing technology uses in peer teaching. Co-teaching between educational technology and methods course faculty (Green, Kennedy, Chassereau, & Evans, 2012) can be a good way to strengthen connections between methods and educational technology courses. If co-teaching is not possible, information sharing between educational technology and methods course faculty would extend modeling and practicing of educational technology uses well beyond educational technology courses into methods courses.

As pointed out earlier, the interview data showed that the elementary students and secondary students responded differently to technology uses by their pre-service teachers. Elementary students and secondary students are in difference developmental stages: School Age (6-12 years old) and Adolescence (12-18 years old) (Erikson, 1993). We can expect that differences exist between elementary students and secondary students in the three fundamental domains of development: physical (biological), cognitive, and psychosocial (emotional-social) development. As the effects of growth and development on an individual’s willingness and ability to make use instruction has been increasingly acknowledged by educators (Bastable & Dart, 2006), it makes perfect sense calling for research efforts in the field of educational technology to investigate how developmental differences influence the effects of educational technology usage on elementary and secondary students. Findings from such research can be utilized by teacher educators to foster pre-service teachers’ understanding about how to design and develop
developmentally appropriate technology-integrated instruction. In addition, according to the student teaching requirements, student teachers at the elementary program were required to do one unit of integrating educational technologies during student teaching. Did this requirement contributed to the elementary pre-service teachers’ faster progress rate in readiness for technology integration than the secondary pre-service teachers? Future research is needed to answer this question and findings from such research may direct us to new ways of helping pre-service teachers make progress in readiness for technology integration during student teaching.

The deductive interview data analysis results provided us with some ideas about how prior teaching experience might influence pre-service teachers’ progress in readiness for technology integration during student teaching. This result should lead us to realize the importance of early field experience in helping better prepare pre-service teachers for technology integration in student teaching and beyond student teaching. In educational programs, student teaching is traditionally placed at the end as culminating experience. Despite this tradition, many programs “are now entwining carefully designed clinical experiences early and throughout the program” (Darling-Hammond et al, 2005, p.401) given the benefits of field experiences, such as helping apply and reinforcing what has been learned in coursework (Koerner & Rust, 2002), allowing the development of *phronesis* (Korthagen & Kessels, 1999), and helping bridge theory with practice (Tigchelaar & Korthagen, 2004). In the context of preparing pre-service teachers for technology integration, the benefits of early field experience before student teaching are multiple. Early field experience will allow pre-service teachers to develop knowledge of educational technologies used in schools and become familiar with some new educational
technology trends in schools. More importantly, pre-service teachers will get an opportunity to practice using educational technologies in real classrooms, thus developing some *phronesis* or situation- and context-specific knowledge of using educational technologies in classroom teaching. All of these benefits combined will accelerate pre-service teachers’ progress in readiness for technology integration during student teaching and consequently make them better prepared for teaching with educational technologies.

4.5.3 Inductive Interview Data Analysis Results

In addition to the deductive interview data analysis, the interview data were analyzed inductively, allowing themes regarding the study participants’ educational technology uses to emerge. Those themes that were not addressed in the deductive interview data analysis results section were presented in this section. Three themes were identified through the inductive interview data analysis. The three themes and the patterns falling under these themes are presented as follows.

*Theme 1: School educational technology resources and readiness for technology integration*

*School educational technology availability influences pre-service teachers’ readiness for technology integration.* The term school educational technology availability is used here to refer to how well the schools where the study participants student-taught were equipped in terms of educational technologies. Educational technologies available at the schools varied greatly: there were schools having Smart Board in each classroom, “one to one” iPad for teachers, and “one to one” laptop for students, in addition to all the
classroom “basics” of a computer, a projector, and an overhead; there were schools like the one in the Chicago Public School System which was really underfunded with only a few classrooms that had a projector and only one computer lab in the building for 1,700 kids; and there were schools standing between these two extremes of educational technology availability.

John, a pre-service teacher in social studies education who student taught in an inner city school in Chicago Public School system, did not have a projector in his classroom and had limited chance to use the only computer lab in the building which was unfortunately always full. He said something about his technology use experience in the interview:

In classrooms I grew up in, if teachers wanted to supplement some type of new content they could put a movie on or they could show a demonstration or show different projects or show different websites of things to explore new material. I never had an opportunity to do that… I really like to use a lot of technology. But they’re really with a shortage of that at the school I taught at. When I made the attempt to get out of that comfort zone of what teachers typically do and do something new, I felt discouraged because I couldn’t really do it.

So, school educational technology availability decided the amount of educational technology the study participants were exposed to and the amount of practice of teaching with educational technology these participants could get during the student teaching. Consequently, school educational technology availability affected the study participants’ readiness for technology integration by influencing: 1) their knowledge of educational technologies used in schools; 2) their knowledge of understanding educational
technology uses from students’ perspective; and 3) their knowledge of matching educational technology uses with specific content. As pointed out in the previous section of deductive interview data analysis results, acquisition of knowledge about effective uses of educational technology in real classrooms relied heavily on practicing educational technology integrated instruction on real students. Unfortunately, this would not happen unless physical access to educational technologies was available in the schools.

School educational technology support influences pre-service teachers’ readiness for technology integration. Based on the interview data, school educational technology support in this study refers to educational technology trainings and technical support available at the schools where the study participants student-taught. Most of these schools provided certain types of educational technology training to their teachers, and the student teachers were allowed to attend these trainings. Table 22 categorizes three types of training available at the schools, and each category was accompanied with examples from the interview data.
### Educational Technology Training Available at the Schools

<table>
<thead>
<tr>
<th>Educational Technology Training</th>
<th>Examples</th>
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<tbody>
<tr>
<td>Routine-oriented training</td>
<td>“The training gave us basic information like what we had access to and what was available to us in the rooms and that was it…” (Sue, the pre-service teacher in elementary education)</td>
</tr>
<tr>
<td>Technology knowledge oriented training</td>
<td>“They offered seminars about how to use Smart Board and My Big Campus, because the school is switching from STI to My Big Campus and is going to combine everything”. (Alice, the pre-service teacher in biology education)</td>
</tr>
<tr>
<td>Content, pedagogy, and technology integrated training</td>
<td>“So, I went to a Smart Board training workshops after school one day and they had all of the world language teachers come in and go play on someone’s Smart Board and someone from the IT department said ‘here are a lot of things you might not realize you could be doing with Smart Board, here’s how we can cater them to your classroom specifically with world languages.’ So, that was really helpful”. (Terry, the pre-service teacher in Spanish education)</td>
</tr>
</tbody>
</table>

The usefulness of training in enhancing the study participants’ readiness for technology increased from the “routine-oriented training” to the “content, pedagogy, and technology integrated training”. In addition to the content of the trainings, administrative support or push for educational technology trainings were a factor urging the pre-service teachers to use educational technologies and consequently influence their readiness for technology integration. While some interview participants felt the push for educational technology uses by the school administration from the frequent seminars or workshops for educational technology training, some got such information from some specific measures taken by the administration. One example of such measures was what mentioned by Jane in the interview: “…the principal organized a technology team by
some of the teachers and is encouraging them to go to different meetings, I mean, professional development and learn about Smart Boards and different types of technology and come in and teach the other teachers about it more. So I think that is really great…”

Technical support was identified as a factor in this study that may discourage the study participants to use educational technology, hence influencing their readiness for technology integration. According to the interview participants, one of the downfalls of technology was that it would break from time to time. There were situations such as those described by Lisa: “Our computers have crashed at school. Our network has crashed at school. Our printers have crashed. Pretty much everything that can crash has crashed in my time there. I have definitely seen the effects of being dependent on it [technology]”.

However, what really held some of the study participants back from teaching with technology was not situations like this but rather lack of technical support when running into such situations. Mary said in the interview: “The school I student taught…oh my god, they have the world at their fingertips. They have a technical department where have like a group of computer analysts and IT specialists… They’re real fixers, fixing things really quick…” But not every was as lucky as Mary. Alice told me what she did to prepare for the poor technical support in her school: “I always have a backup plan when I’m using technology…” This backup plan, for many other interview participants, may only mean not to use technology in their teaching as much as they would really like to, because based on the interview data, they felt very frustrated by the poor technical support in the schools where they student taught.
Theme 2: Cooperating teachers and readiness for technology integration

Cooperating teachers' educational technology knowledge and educational technology uses influence pre-service teachers’ readiness for technology integration. Of the eleven interview participants, nine had only one cooperating teacher and two had two cooperating teachers. These cooperating teachers’ educational technology knowledge and educational technology uses decided whether their student teachers had an opportunity to learn from them about educational technologies and theirs uses, thus rendering some effects on the student teachers’ readiness for technology integration.

Based on the interview data, three of the thirteen cooperating teachers were elderly teachers in their fifties or sixties. These cooperating teachers didn’t know much about educational technologies and the following were the comments made by the student teachers on their respective cooperating teacher: “She is very timid and afraid of technology”; “She does not use any of the technology and is very paper based”; and “She uses minimal technology”. There were two other cooperating teachers in their thirties to forties, though having some knowledge about educational technology, seldom taught with technology. The pre-service teachers of these five cooperating teachers unanimously said in the interview that they did not learn from their cooperating teachers about educational technologies and their uses.

The absence of knowledge of educational technology and/or the absence of teaching with educational technology found in the above five cooperating teachers limited their student teachers’ opportunity to learn during student teaching. In contrast, the remaining eight cooperating teachers possess certain amount of knowledge about educational technologies and used educational technologies in their teaching. These eight
cooperating teachers, by answering questions or modeling technology uses, provided
their student teachers extra opportunities to learn, although what the pre-service teachers
learned from these cooperating teachers varied: ranging from general technology
knowledge (e.g., how to use specific features of Smart Board, how to share through
Google Drive and check student drop-offs, and how to use grade cam) to ways of using to
specific technology to teach specific content (e.g., how to hook up iPad to Smart Board
through WiFi port to do competitive writing exercises and how to use the transparency
feature of Elmo to improve teaching reading).

Cooperating teachers’ mentoring styles influence pre-service teachers’ readiness
for technology integration. The eleven interview participants observed their cooperating
teacher for one week to two weeks before teaching independently. Three styles of how
the cooperating teachers mentored the pre-service teachers in using educational
technologies emerged from the interview data. The interview data used to identify these
three mentoring styles, of course, did include the data of those five cooperating teachers
having little educational technology knowledge and/or using no educational technologies
in teaching. The cooperating teachers’ mentoring styles influenced the pre-service
teachers’ readiness for technology integration by deciding how much and in what ways
the pre-service teachers could learn about educational technology uses from their
cooperating teachers. Table 23 summarizes the three mentoring styles with their main
characteristics specified and with quotes from the pre-service teachers for describing each
of the styles.
Table 23

Cooperating Teachers’ Mentoring Styles

<table>
<thead>
<tr>
<th>Mentoring Style</th>
<th>Descriptive Quotation</th>
<th>Main Characteristics</th>
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<tr>
<td>Hands-off style</td>
<td>“…in my particular situation, my cooperative teacher had an office separate from her classroom. So, whenever I was in the classroom starting on week 3, most of the time she was in her office. And, I was in the classroom by myself. In many ways that was positive, but in terms of my technology use, I think I could have grown more and improved at a quicker pace if she had been in there for more time to be able to say here’s how you can make this better, here’s how you can make that better, here’s how this could flow more smoothly. In that way, I think that would have been the biggest thing to help me improve my technology in student teaching, if I had that extra crutch and feedback. In some ways it was nice but in others I would have really enjoyed having that extra feedback from her”. (Terry, the pre-service teacher in Spanish education)</td>
<td>Cooperating teachers left their student teachers totally alone to do their teaching. Mentoring about educational technology uses took place in answering the student teachers’ occasional questions.</td>
</tr>
<tr>
<td>Dictation style</td>
<td>“my cooperating teacher has YouTube videos that are related to the topic. She also has objectives and power point notes. So the students know up front and then she clicks and it is like the first thing. And then she clicks the next slide and then it is the next thing… She definitely told me to do the power point notes and do the objectives on the board. She’s like make sure I have a power point slide every day for them to see up on the board when they walk into the classroom. They see what their objectives are and for the notes of the vocab definitions and things like that. She definitely wanted me to do that… So we are doing these three things”. (Joy, the pre-service teacher in English education)</td>
<td>Cooperating teachers put their student teachers under close supervision and asked their student teachers to teach with educational technologies the way they themselves had been doing.</td>
</tr>
<tr>
<td>Partnership style</td>
<td>“I feel like my cooperating teacher and I worked as a great team. So we did everything together, we learned together with that. Thanks… Yeah I mean we use Smart Board, like for math every single day. With reading and writing activities we do that, she tests everything on the iPad and she taught me how to do that, so I did not need to write down data anymore, it’s on the iPad… she links her iPad to the Smart Board and taught me how to do it and the kindles… I don’t know if that’s her idea or not, but she was the one who wanted to get one for every single student so she was really open to technology so she loves doing that stuff so I learned a lot from her”. (Jane, the pre-service teacher in elementary education)</td>
<td>Cooperating teachers helped their student teachers learn educational technologies as a team member or partner, allowing rooms for the student teachers to practice and explore educational technology uses.</td>
</tr>
</tbody>
</table>
Terry, the pre-service teacher quoted for the *hands-off mentoring style* hoped that her cooperating could be with her for more time and teach her more about using educational technologies so that she could grow more and improve at a quicker pace. But, such ideal results might not be possible if cooperating teachers took up the *dictation mentoring style* described above. The *dictation mentoring style* might carry bad effects on pre-service teacher well beyond student teaching especially if the practices of educational technology uses forced upon pre-service teachers by cooperating teachers are inappropriate and/or ineffective. In comparison, the *partnership mentoring style* represented the most desirable mentoring practice that could allow pre-service teachers to learn more about teaching with educational technologies during student teaching.

*Theme 3: Personal beliefs about educational technologies and readiness for technology integration*

School educational technology resources and cooperating teachers’ educational technology knowledge, their educational technology practices, and mentoring styles were all contextual factors in the schools that would influence the pre-service teachers’ readiness for technology integration. At personal level, the pre-service teachers’ beliefs about educational technology stood behind their practices of technology use, rendering influence on their readiness for technology integration. These personal beliefs about educational technologies include *misconceptions about technology integration* and *personal conceptualization of the usefulness of educational technologies.*

*Misconceptions* about using educational technologies. An open-ended item was added to the third online survey for the pre-service teachers the 2013 Spring group,
asking them to write down educational technologies they used in their student teaching.

These educational technologies were categorized and are presented in Table 24.

Table 24

*Educational Technologies Used by the 3rd Online Survey Participants in the 2013 Spring Group*

<table>
<thead>
<tr>
<th>Categories</th>
<th>Educational Technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Devices and equipment</td>
<td>computers; Smart Board; Eno Board; Promethean Board; iPad; projector; laptop (including individual laptops for students); Elmo; Kindle; Kindle Fire; overhead; Temperature Probe; pH meters, calorimeters, spectrophotometer; Document Camera</td>
</tr>
<tr>
<td>Software and tablet applications</td>
<td>Microsoft PowerPoint, Word, Outlook, and Excel; Socrative; Kidspiration; Study Island; Renaissance Place; class participation system</td>
</tr>
<tr>
<td>Web 2.0 tools and online resources</td>
<td>Prezi; YouTube; GenBank; Khan Academy; JeopardyLabs; Nearpod; Reaching Eggs; Discovery Educationa; online simulators</td>
</tr>
</tbody>
</table>

The interview participants were asked in the interview to talk about what educational technologies they used and how they integrated educational technologies into their teaching. Although the educational technologies the interview participants talked about in the interview did not cover all listed in Table 24, the interview data did provide some idea about how educational technologies were used by the study participants during their study teaching. While the interview data revealed that some interview participants used educational technologies in engaging and interactive ways for achieving specific instructional objectives, some interview participants still had misconceptions about technology integration.

One of the misconceptions was taking *using technology* as technology integration. While technology integration refers to planned and purposeful technology uses to engage
students with content and achieve certain learning objectives, using technology focuses on technology presence and is characterized by random uses of technology. For example, the speaker in the following interview excerpt simply using technology instead of integrating technology:

One of the major components in my classroom has always been the Smart Board. It’s great for videos and stuff. If I ever just don’t plan enough lesson and I throw on a random YouTube video and they can watch that on the Smart Board. It’s like a full screen TV to them. So they enjoy it and I like having that backup plan... I can pull about like random whale videos they may never have thought of or like songs about dinosaurs. Stuff like that is silly, but it adds a whole bunch to what they can actually view as opposed to me just standing up there talking. (Alice, the pre-service teacher in biology education)

Another misconception among the interview participants was using technologies only as media for carrying information that could help save time. Mary, the pre-service teachers in English education, said in the interview that the two main technologies she used were PowerPoint and YouTube videos. She said in the interview, “I have the notes up on the PowerPoint for them to copy so I don’t have to spend that time writing on the board. And I feel like the students see that as just like that’s their everyday life”. For Jack, a pre-service teacher in agriculture education, Smart Board and overhead were not difference because they were but media helping to carry information: “I don’t like the Smart Board because I have to have my back to them and that’s just an opportunity for them to misbehave or throw things or who knows what they are doing while my back is to them. So, I pull out the overhead projector a lot. So I can look at them”.

There were also pre-service teachers talking in the interview about showing movies as a reward to students or leading students to the computer lab to type essays as part of their technology integration practices. Such technology use practices were also not technology integration. Rather, they reflected the pre-service teachers’ misconceptions about technology integration that prevented them from making the best use of student teaching as an opportunity to explore how educational technologies could be integrated into teaching and learning.

Personal conceptualization of the usefulness of educational technologies. Most of the interview participants expressed their beliefs in the usefulness of educational technologies. They conceptualized the usefulness of educational technologies in different ways (e.g., educational technologies’ engaging power, helping learning through seeing, making content comprehensible, and improving student interactions) and were enthusiastic about using educational technologies during the student teaching, though not necessarily in effective ways. Two interview participants, however, did not every much believe in the usefulness of educational technologies and did not use technologies much in their teaching despite the high educational technology availability in the schools where they student-taught. One of the two interviewers was Jack, the pre-service teacher in agriculture education. Jack said in the interview:

I mean, the everyday life of the average American citizen has more and more technology, so you think, “oh, you need to integrate that into the classroom”. I would say not so much. There’s no need for it. There’s not. But I would say that my thinking has evolved a little bit to remove technology a little bit from the classroom. Because, I mean, the more our society relies on technology anyway, the
more problems that we’re going to have with consistency and whether it works or not. I mean, that’s just the fact of technology, you just don’t know what’s going to go wrong and if you’re going to be able to fix. And a lot of times you can’t. So, I would think, the classroom would be a lot smoother if technology was removed from the classroom. Because, I mean, like I said, it’s situational based on the teacher, the content, and the classroom, and the school. But I would say that there doesn’t need to be as much as the movement towards where it’s going. But, with saying that, I also haven’t seen it to be what’s like the advantage of it. But I just… it’s not that I don’t like technology. I do… but I just don’t think that it is needed or has to be had in the classroom.

According to this pre-service teacher, there was no need for technology and he did not see the advantage of it in the classroom. Based on what Jack said, his disbelief about educational technology was related to the potential of technology to go wrong as well as his idea about differences in subject matter content. As he also said in the interview, technology was helpful for teaching subject like English but was not for agricultural educational because “it’s a lot more hands-on stuff”. Another disbeliever was Kay, the pre-service in Art Education mentioned earlier. This disbeliever did not go to such an extreme as to think there was no need for technology in the classroom. But, she did believe, as Jack did, that the usefulness of educational technologies was dependent on the content taught. When talking about using Smart Board, she said:

“I think math is great for it [Smart Board]. You can write on the board, you can help the students do the problems; you can work with the programs that you’re using. I think it’s much more intuitive. With art, it’s not… what you see on the
screen is not ever what you actually get out of a product, if you’re doing it by hand. I actually think that, for me, as an art educator, there are other effective ways. Because students actually need to see, like, putting pencil to paper. They actually need to see you painting something. I think it’s good for videos, it’s good for certain demos, but as a whole, I think it kind of gets lost in the art department. Because you can’t really use it too much. You can’t actually, like, use it what it’s meant for. So as you know, student teaching, it didn’t really do me any good. Because every school now has at least a projector in every classroom. And a projector would’ve been all I needed.

What could be learned from these two pre-service teachers is that personal conceptualizations about the usefulness of educational technologies would determine how pre-service teachers would use educational technologies and how much they would use them in their teaching, which would consequently render influence on pre-service teachers’ readiness for technology integration. Such a claim might also be supported by a counter example, John, the pre-service teacher in social studies education who student-taught in the Chicago Public School System. This pre-service student taught in a high school with extremely limited educational technology resources, but he was definitely a believer of the usefulness of educational technologies. This is what he said in the interview:

I would take the road less traveled regardless, even if my peers didn’t do it. It’s something I grew up on. It’s made my education here so much better by being able to use technology and stuff. I would definitely use it regardless of what my
peers did in any institution. Even if that technology was limited, I would still implement it as much as possible.

4.5.4 Discussion Based on Inductive Interview Data Analysis Results

Previous research (e.g., Bullock (2004; Dexter and Riedel, 2003) on student teaching and technology uses has identified contextual factors, such as technology support and availability at schools, and integration instructional support from mentor teachers) that had influence on pre-service teachers technology uses. As an attempt to quantify the relationship between student teaching contextual factors and readiness for technology integration, this study had originally planned to add two items in the third online survey asking the participants to 1) rate how well the schools where they student taught were equipped in terms of educational technologies as either “poor” or “good”; and 2) respond “yes” or “no” to the question “Was your cooperating teacher supportive and helpful in preparing you for technology integration?”. However, this study design idea was eventually dismissed because, given the diversity of educational technologies and the complexity of perceptions about inter-personal relationships, the answers to the questions in the above mentioned items would never be perfectly dichotomous and defined in simple black and white terms.

Fortunately, the inductive interview data analysis results furnished us with some insights on how some contextual factors at the schools influence the pre-service teachers’ readiness for technology integration. According to the results, contextual factors influencing the pre-service teachers’ readiness for technology integration included school educational technology availability, educational technology trainings, technical support,
cooperating teachers’ educational technology knowledge and usage, and their mentoring styles. These contextual factors indentified in this study either confirmed and supplemented the findings from previous research (e.g., Bullock, 2004; Dexter & Riedel, 2003; Grove, Strudler, & Odell, 2004, 2007). More importantly, these contextual factors allow us to approach from pre-service teachers’ perspective to understand how school technology resources and cooperating teachers might influence pre-service teachers’ learning and practice of educational technology usage and consequently have a impact on their readiness for technology integration.

Education programs actually have no control over the contextual factor related to the availability of technology and technical support in schools. It’s also not always possible and affordable, as reported in some previous research studies (Brush et al, 2003; Wetzel et al, 2001), for educational programs to provide cooperating teachers with training or workshops on technology integration. But, educational programs can always provide workshops or seminars to help their pre-service teachers to develop strategies facilitating the establishment of true mentorship characterized by ongoing relationship of learning, dialogue, and support, rather than by just answering occasional questions or providing ad hoc help.

In addition to the factors at the school context level, the inductive interview data analysis identified factors on a personal level that had influence on the pre-service teachers’ educational technology uses and that might consequently have impact on their readiness for technology integration. These personal level factors include misconceptions about using educational technologies and personal conceptualization of the usefulness of educational technologies. The pre-service teachers’ misconceptions about using
educational technologies were embedded in their uses of educational technologies that were random or lacked purpose and in their uses of educational technology conforming to what has been documented in the literature as “low level uses” (Cuban, Kirkpatric, & Peck, 2001; Culp, Honey, & Mandinach, 2005; Ertmer, 2005; Palak & Walls, 2009). Hamilton (2007) defined integration by defining “what integration is not”:

Integration is NOT the use of managed instructional software, where a computer delivers content and tracks students’ progress. Integration is NOT having students go to a computer lab to learn technical skills while the classroom teacher stays behind to plan or grade papers. Integration is NOT using the Internet to access games sponsored by toy manufacturers or popular television shows. Integration is NOT using specialty software for drill and practice day after day. Integration does NOT replace a teacher with a computer. (p.21)

Unfortunately, what is not technology integration is exactly what some of pre-service teachers and even in-service teachers are doing in the classrooms. To prepare pre-service teachers for effective uses of educational technologies, educational programs should make efforts to help their pre-service teachers to develop correct understandings about technology integration.

Although the interview data showed that the pre-service teachers conceptualized the usefulness of educational technologies differently, the pre-service teachers could be categorized into two groups: believers and disbelievers of the usefulness of educational technologies. Those disbelievers, based on the interview data, used educational technology in their teaching minimally. Noticeably, the disbelievers related their disbelief of the usefulness of educational technologies to the specific disciplines they taught.
While this, in certain respects, confirmed the basic idea behind the TPACK framework (Mishra & Koehler, 2006)—that technology integration takes place only in the context of specific subject matter content—it also highlighted the possibility that a teachers’ technological pedagogical content knowledge would be limited, if not totally impossible, given his/her disbelief in the usefulness of educational technologies in helping learning.

The literature is replete with research investigating how educational technology practices were related teachers’ beliefs, such as self-efficacy beliefs of technology integration (e.g., Lin & Lu, 2010; Mueller et al, 2008; Wang, Ertmer, and Newby, 2004) and teacher-centered or student centered pedagogical beliefs (Hermans, Tondeur, van Braak, &Valcke, 2008). There is little research looking into how teachers’ beliefs about the usefulness of educational technology are related to their technology practices. But why bother? With strong pushes for using educational technologies in schools and in education programs, we are assuming that teachers’ belief in the usefulness of educational technology is automatic. However, the inductive interview data analysis results indicated that this assumption was doubtful and we may have to think about how to encourage our pre-service teachers to integrate educational technologies. One thing we can do is to utilize evidence from research on real classroom technology integration practices showing the positive effects of educational technologies on student learning results and learning experience in various disciplines. Integrating such evidence and real classroom examples from research into methods and educational technology courses would help pre-service teachers see good reasons for integrating technology into their teaching. These reasons might then turn into something internal that better encourages
and motivates pre-service teachers to integrate educational technology than external pushes for technology integration from education programs or schools.

4.6 Conclusion

This study contributed to the literature by helping improve our understanding of the effects of student teaching on pre-service teachers’ readiness for technology integration. Quantitatively, this study revealed that the pre-service teachers underwent significant progress in readiness for technology integration (as indicated by TIR Score_1 and TIR Score_2) during student teaching and that the two dummy variables of grade-level and prior-teaching were identified as significant in predicting the differences in individual trajectories for TIR Score_1 and TIR Score_2. Qualitatively, while providing clues helping interpret and explain quantitative results, this study identified factors influencing pre-service teachers’ educational technology practices during student teaching and consequently influencing their readiness for technology integration. Based on deductive and inductive interview data analysis results, the following recommendations were made to help make student teaching experience more rewarding in improving pre-service teachers’ readiness for technology integration.

**Recommendation 1**: Adding a senior advanced educational technology course to teacher preparation curriculum;

**Recommendation 1**: Strengthening the connections between methods and educational technology courses;

**Recommendation 3**: Fostering understandings of how developmental differences influence the effects of educational technology usage on elementary and secondary students;

**Recommendation 4**: Offering early clinical experience before student teaching;
Recommendation 5: Helping pre-service teachers develop strategies to establish desirable mentorship with cooperating teachers conducive to the learning of technology integration;

Recommendation 6: Deepening pre-service teachers’ understandings about technology integration;

Recommendation 7: Motivating pre-service teachers to integrate technology into teaching using evidence and through real classroom examples.

There were three sampling limitations to this study: (1) the sample sizes for the online surveys (n=68) and the interviews (n=11) were small; (2) the numbers of pre-service teachers in different majors were unbalanced, and so were the numbers of male and female students in the online surveys and the interview; (3) the sample for the interview was not representative of the majors included in the online surveys (e.g., no pre-service teachers in math education in the interview). In addition to these sampling limitations, the carryover effects resulting from the fact that the participants of this study were measured three times using the same questionnaire. Although the administrations of the three surveys were at least 6 weeks apart, there might still be carryover effects causing a threat to the internal validity of the study.

Despite the sampling limitations and the potential internal validity issues, this study has given rise some questions worth future research attention. These questions include, but are limited to, the following: What need to be done to make methods and educational technology courses significant in predicting pre-service teachers’ progress in readiness for technology integration? What might be the influence of developmental differences between elementary and secondary students on the effects technology integration and how we can prepare pre-service teachers to deal with such influence?
What can we do to correct pre-service teachers’ misconceptions about technology integration? How are pre-service teachers’ personal beliefs about the usefulness of educational technology related to their motivation to teach with educational technology?

It is hoped that questions like the above rising along with the findings of this study would serve as new directions for future technology integration research. It is also hoped that, working in these new directions, future technology integration will yield findings furnishing us with new insight about what changes or improvements are necessary in teacher education. Ultimately, this will enable pre-service to make good progress in readiness for technology integration during and beyond student teaching.
CHAPTER 5. UNDERSTANDING THE LEARNING TO TEACH PROCESS:
CONCLUSION

The elementary teachers in Study I and Study II were learning to teach engineering to elementary students, and the pre-service teachers in Study III were learning to teach with educational technologies. These teachers’ learning to teach took place in real world K-12 classrooms. Looking into their real classroom teaching practices, the three studies revealed the learning to teach processes these teachers were engaged in and the dynamics involved in the learning to teach processes. Findings from the three studies have implications for professional development and teacher preparation and for future research on learning to teach.

5.1 Findings of the Learning to Teach Process

5.1.1 The Learning to Teach Outcomes

Recall the definition of learning given by Alexander, Schallert, and Reynolds (2009) saying that “Learning is a multidimensional process that results in a relatively enduring change in a person or persons, and consequently how that person or persons will perceive the world and reciprocally respond to its affordances physically, psychologically, and socially” (p. 186). The “relatively enduring change” resulted from the learning to teach process was different for the in-service teachers or pre-service teachers in the three studies.
The “enduring change” for the elementary teachers in Study I was the development of PCK for teaching engineering to elementary students; for the elementary teachers in Study II, it was the adoption of engineering teaching and the development of engineering teaching expertise; and for pre-service teachers in Study III, it was the progress made in the readiness for technology integration. These “enduring changes” or learning outcomes are important for the teachers in the three studies and are good to be known by teacher educators or professional development providers because these enduring changes definitely would make these teachers more capable in their future teaching.

5.1.2 The Dynamics of the Learning to Teach Processes

In addition to the above learning outcomes, the three studies yielded findings regarding the dynamics of the learning to teach processes the elementary teachers or the pre-service teachers were engaged in. These findings are important, if not critical, for teacher educators and professional development providers because an understanding of the dynamics means the possibility to intervene the dynamics and to cause it to change for the purpose of making better learning outcomes taking place in teachers.

The dynamics of the learning to teach process revealed in Study I was that the elementary teachers were engaged in a trial-failure-success process deeply rooted in real classroom teaching practices where they interacted with engineering content, pedagogy, elementary students, and classroom and school contexts to transform knowing-about into engineering PCK. The dynamics of the learning to teach process revealed in Study II shows that adopting engineering teaching in elementary classrooms and developing
expertise in teaching engineering to elementary students are each a multidimensional and staged process where elementary teachers’ standings in the EEE adoption stages and EEE expertise development stages evolve over time through engineering teaching practice.

The dynamics of the process of learning to teach with educational technology revealed in Study III manifests itself not only in pre-service teachers’ progress in readiness for technology integration during student teaching but also in the mechanisms of various contextual- and personal-level factors (e.g., school educational technology availability, school technical support, cooperating teachers’ mentoring styles, grade level, prior teaching experience, personal beliefs about the usefulness of educational technologies, etc.) working to render influence on pre-service teachers’ readiness for technology integration.

5.1.3 The Teaching Challenges in the Learning to Teach Processes

Although the learning results and the dynamics of the learning to teach process, as summarized above, were different, the teachers in the three studies all encountered teaching challenges during the learning to teach processes. These teaching challenges were different in terms of what they were about: in Study I and Study II, the teaching challenges were related to teaching engineering to elementary students; for the pre-service teachers in Study III, the teaching challenges were related to integrating educational technologies into teaching and learning. Despite this difference, the teaching challenges had some characteristics that were parallel across three studies.
The first such characteristic is that the teaching challenges in all three studies were content-bound, student-specific, and context-related. In other words, the teaching challenges were rooted in an area where content, students, and specific school and classroom context factors interacted. The second such characteristics is that the teaching challenges in each of the three studies served as an essential component in the learning to teach process making learning to teach happen. Specifically, this means that it was by means of getting to know these teaching challenges, thinking about how to overcome them, and trying to overcome them through teaching practices that the teachers in the three studies learned how to teach. From a researcher’s perspective, the teaching challenges in three studies served as an important key to understand the learning to teach process. This was another characteristic of the teaching challenges that paralleled across all three studies.

5.2 Implications for Professional Development, Teacher Preparation, and Future Research

The significance of the three studies lies not so much in revealing those rather static learning outcomes mentioned earlier as in unraveling the dynamics of the learning to teach processes that brought about the learning outcomes. The dynamics of the learning to teach processes revealed in the three studies have important implications for professional development, teacher preparation, and future research, and the implications were at both micro level and macro level.

At the micro level, the dynamics of learning to teach engineering revealed in Study I urge engineering professional development providers to think about how to
extend professional development into real elementary classrooms to facilitate elementary teachers’ development of engineering PCK. For educational researchers, the dynamics revealed in Study I can serve as a starting point guiding future research that seeks to identify effective ways to channel or change the learning to teach engineering process to achieve desirable learning results. In Study II, the dynamics of the learning to teach process was embedded in the EEE adoption and expertise development framework. This framework would provide engineering professional development providers with a micro-level guideline for tracking, assessing, and supporting elementary teachers’ in EEE adoption and EEE expertise development, and would provide educational researchers with a sense of direction regarding where to look into in their future innovation adoption and expertise development research in the area of elementary engineering education.

The dynamics of the learning to teach process in Study III allow us to see how those contextual- and personal-level factors influence pre-service teachers’ readiness for technology integration. These factors are clues for teacher educators regarding where to work on to make student teaching experience more fruitful in preparing pre-service teachers for teaching effectively with educational technologies in real classrooms. Moreover, the dynamics of the learning to teach with educational technology process revealed in study III has spotted many under-researched areas (e.g., the relation between prior teaching experience and the development of readiness in technology integration during student teaching, and the influence of student grade levels on student teachers’ technology use experience) that merit future research attention from educational researchers.
Learning is a multidimensional process, and so is learning to teach. By revealing the above mentioned dynamics lying behind the learning to teach engineering processes or the learning to teach with educational technology process, the three studies in this dissertation enable us to have access, at the micro-level, to specific dimensions of the multidimensional learning to teach process. At the macro-level, the three studies combined show us that: (1) the learning to teach process is a dynamic process subject to the influence of various contextual- and personal-level factors; (2) real classroom teaching practices are the most active and dynamic part in the learning to teach process; (3) the learning to teach process is a highly personal experience for each individual teacher; and (4) the learning to teach process brings changes in teachers in terms of their knowledge, skills, and understanding of teaching. These macro-level notions about the learning to teach process carry suggestions for future research examining the learning to teach process: (1) always examining and understanding the learning to teach process in specific contexts; (2) embracing real classroom teaching practice as an ideal setting for investigating the learning to teach process; (3) adopting an individual-based perspective toward the learning to teach process; and (4) examining the learning to teach process while keeping an eye on possible learning to teach results.

The three studies in this dissertation have yielded findings that contribute to our understanding of the learning to teach process both at the micro-level and the macro-level. It is hoped that findings from the three studies will be able to equipped teacher educators or professional development providers with new insights about how to improve teachers’ learning to teach experience and to help teachers learn better. It is also hoped that the
findings from the three studies would inspire and help more future research that seeks to deepen our understanding about the learning to teaching process.
BIBLIOGRAPHY
BIBLIOGRAPHY

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Appendix A: Interview Protocol

1. Please give me a little bit basic information about your student teaching (e.g. the grade level(s) you taught, general information about the school, your major…)

2. Will you rate yourself as technology savvy?

3. Please give some examples of integrating educational technologies into instruction during your student teaching, it can be technology integration by yourself, by your cooperating teachers, or other teachers or student teachers in the school where you did student teaching.

4. What do you think of the effects your technology uses during student teaching on student learning?

5. What are some of the educational technologies you saw in the school where you student taught?

6. Is this school well-equipped or poorly-equipped in term of educational technologies?

7. What is your impression of general atmosphere in the school in terms of embracing or encouraging educational technology uses? Or in other words, did you feel encouraged in your student teaching to use educational technologies in your teaching?

8. What did you think about your cooperating teacher’s using of technology in his/her instruction? What did you learn from your mentor teacher about educational technology uses during your student teaching?

9. In what ways you think educational technology or method courses are useful in preparing you for using educational technologies in student teaching?

10. How do you think technology uses in your student teaching (by yourself or by others as you observed in your student teaching) are different from what you have learned in your educational technology and method courses?

11. Is there any situation during your student teaching that made you feel the need to integrate technology into your instruction? If there is, please specify. (For example, you noticed some
specific learning difficulties in your students and you thought some educational technologies
might be helpful in overcoming these learning difficulties.

12. What are the difficulties or barriers you perceived during your student teaching that prevented
you or other teachers from using technologies in teaching?

13. Did you think you get a better chance to practice educational technology uses during your
student teaching? Why or why not?

14. What’s your idea of how educational technology in teaching should be used? Do you think
your idea of how educational technology should be used in teaching has changed as a result
of your student teaching? Please explain.

15. Did you think your student teaching experiences made you feel better prepared for technology
integration? Why or why not?

16. What aspect or aspects of student teaching experiences do you think need to be improved or
changed to allow you to have a better opportunity to learn how to integrate technology
effectively into teaching and learning?
Appendix B: Survey Instrument for Measuring Pre-service Teachers’ Readiness for Technology Integration

Thank you for taking time to complete this survey. Please answer each question to the best of your knowledge. Your thoughtfulness and candid responses will be greatly appreciated. Your individual name will be coded and will not at any time be associated with your responses. Your responses will be kept completely confidential and will not influence your course grade. Before taking the survey please check the box below.

☐ I have read the consent form for this survey and agree to participate in the survey voluntarily.

Part I: Demographic Information:

1. Name: ________________________________

2. Gender

☐ Female  ☐ Male

3. Age range:

☐ 18–22  ☐ 23–26  ☐ 27–32  ☐ 32+

4. Major and area of specialization: -

____________________________________________________

5. Program level

☐ Undergraduate  ☐ Graduate

6. The name of the school where you are doing your student teaching: _________________________

7. The number of credits of Content courses you have already taken (such as courses for non-teaching majors in the same discipline) ________________________________.

8. The number of credits of Professional Education courses you have already taken (such as Block, methods, and pedagogical content courses) ________________________________.

9. The number of credits of courses using educational technology you have already taken (can already be counted in content and professional education credits) ________________________________.
10. Do you have previous teaching/student teaching experiences?

☐ Yes  ☐ No

**Part II:**

**Direction:** The purpose of this survey is to determine how you feel about integrating technology into classroom teaching. Technology is a broad concept that can mean a lot of different things. For the purpose of this survey, technology is referring to digital technology/technologies—that is, the digital tools we use such as computers, laptops, iPods, handhelds, interactive, whiteboards, software programs, etc. For each statement below, indicate the strength of your agreement or disagreement by circling one of the five scales (i.e., Strongly Disagree = SD; Disagree = D; Neither Agree/Disagree = N; Agree = A; Strongly Agree = SA).

<table>
<thead>
<tr>
<th>Statement</th>
<th>SD</th>
<th>D</th>
<th>N</th>
<th>A</th>
<th>SA</th>
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<tbody>
<tr>
<td>1. I feel confident that I understand computer capabilities well enough to maximize them in my classroom.</td>
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<td>2. I feel confident that I have the skills necessary to use the computer for instruction.</td>
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<td>3. I feel confident that I can successfully teach relevant subject content with appropriate use of technology.</td>
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<td>4. I feel confident in my ability to evaluate software for teaching and learning.</td>
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<td>5. I feel confident that I can use correct computer terminology when directing students' computer use.</td>
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<td>6. I feel confident I can help student when they have difficulty with the computer.</td>
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<td>7. I feel confident I can effectively monitor students' computer use for project development in my classroom.</td>
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<td>8. I feel confident that I can motivate my students to participate in technology-based projects.</td>
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<td>9. I feel confident I can mentor students in appropriate uses of technology.</td>
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<td>10. I feel confident I can consistently use educational technology in effective ways.</td>
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</table>
11. I feel confident I can provide individual feedback to students during technology use. □SD □D □N □A □SA

12. I feel confident I can regularly incorporate technology into my lessons, when appropriate to student learning. □SD □D □N □A □SA

13. I feel confident about selecting appropriate technology for instruction based on curriculum standards. □SD □D □N □A □SA

14. I feel confident about assigning and grading technology-based projects. □SD □D □N □A □SA

15. I feel confident I can be responsive to students' needs during computer use. □SD □D □N □A □SA

16. I feel confident about using technology resources (such as spreadsheets, electronic portfolios, etc.) to collect and analyze data from student tests and products to improve instructional practices. □SD □D □N □A □SA

17. I know how to solve my own technical problems. □SD □D □N □A □SA

18. I can learn technology easily. □SD □D □N □A □SA

19. I keep up with important new technologies. □SD □D □N □A □SA

20. I frequently play around with the technology. □SD □D □N □A □SA

21. I know about a lot of different technologies. □SD □D □N □A □SA

22. I have the technical skills I need to use technology. □SD □D □N □A □SA

23. I have had sufficient opportunities to work with different technologies. □SD □D □N □A □SA

24. I can choose technologies that enhance the teaching approaches for a lesson. □SD □D □N □A □SA

25. I can choose technologies that enhance students’ learning for a lesson. □SD □D □N □A □SA

26. My teacher education program has caused me to think more deeply about how technology could influence the teaching approaches I use in my classroom. □SD □D □N □A □SA
27. I am thinking critically about how to use technology in my classroom. □ SD □ D □ N □ A □ SA

28. I can adapt the use of the technologies that I am learning about to different teaching activities. □ SD □ D □ N □ A □ SA

29. I can select technologies to use in my classroom that enhance what I teach, how I teach, and what students learn. □ SD □ D □ N □ A □ SA

30. I can use strategies that combine content, technologies, and teaching approaches that I learned about in my coursework in my classroom. □ SD □ D □ N □ A □ SA

31. I can provide leadership in helping others to coordinate the use of content, technologies, and teaching approaches at my school and/or district. □ SD □ D □ N □ A □ SA

32. I can choose technologies that enhance the content for a lesson. □ SD □ D □ N □ A □ SA

**Part III: Please list all technologies you have used in your instruction during your student teaching.**

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13 This part was included only in the third online survey.
VITA
I am a PhD candidate in Learning Design and Technology at Purdue University and will receive my PhD degree in December 2013. My research focuses on technology integration, K-12 teachers' knowledge and skills for effective technology-integrated instruction, and models and frameworks guiding and assessing K-12 teachers' technology integration practices. While pursuing my PhD, I am working as a graduate research assistant in the Institute for P-12 Engineering Research and Learning (INSPIRE) at Purdue. I have a Graduate Certificate in Applied Statistics from Purdue University, Master of Arts in Foreign Linguistics and Applied Linguistics from Sichuan University, and Bachelor of Arts in Technology English from West China University of Medical Sciences.