**ABSTRACT**

HUGHES, ANDREW JOHN. Impact of Online Self-regulated Professional Development on Technology and Engineering Educators Metacognitive Awareness. (Under the direction of Dr. Cameron Denson and Dr. Aaron Clark).

The study was designed to investigate the impact of professional development on technology and engineering teacher's metacognitive awareness. The study pursued answers to one primary and three secondary research questions involving three groups of technology and engineering teacher's metacognitive awareness based on their participation in professional development. The study had a sample size of 18 ($N$ = 18). There were six participants in three groups. Group one consisted of teachers that actively participated in Transforming Teaching through Implementing Inquiry (T2I2) professional development system. Group two consisted of teachers that did not actively participate in T2I2 professional development system. Group three consisted of teachers that completed National Board for Professional Teaching Standards professional development.

To measure the metacognitive awareness of each group a mixed method design was implemented. The quantitative measure used in this study was Schraw and Dennison's (1994) metacognitive awareness inventory. The Kruskal-Wallis one way analysis of variance by ranks was used analyze the quantitative data. The qualitative measure used was a metacognitive awareness semi-structured open-ended interview. The interviews were analyzed by two coders using a coding rubric. The results and complementarity of both measures were used to identify each group's metacognitive awareness. A comparative analysis was used to describe the essence of each group's metacognitive awareness during common teacher practices.

# Impact of Online Self-regulated Professional Development on Technology and Engineering Educators Metacognitive Awareness

by
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## DEDICATION

This dissertation is dedicated to Brett Leon Davis. Brett taught me many things; kindness, compassion, and the continuous formulation of goals in the face of adversity. I joked about completing my doctorate at 18 years old. When Brett was unable to complete his goals due to a diagnosis of cancer, he continued to remain positive, formulate, and work towards goals. As I am able minded and bodied, to joke about a goal without the intention to complete it would be dishonorable to Brett's life. Brett, you are my inspiration to be a better person and I miss you every day.

## BIOGRAPHY

Andrew John Hughes was born in DuBois, Pennsylvania on April 25, 1984 and raised in Punxsutawney, Pennsylvania. He is one of two children of Owen Keith and Jean Hughes. O. Keith taught technology and engineering education for 35 years before retiring and Jean taught special education for 33 years before retiring. Andrew received an Associate of Engineering Technology degree in Mechanical Engineering from Pennsylvania State University, Bachelor of Science degree in Technology Education from California University of Pennsylvania, Master of Science in Technology from Illinois State University, and Doctor of Education degree in Technology Education with a minor concentration in Adult and Higher Education from North Carolina State University. After completing his master's program Andrew taught technology and engineering education for three and half years in Pennsylvania. During Andrew's time at North Carolina State University, he served as a research assistant for the Transforming Teaching through Implementing Inquiry grant and teaching assistant for an engineering graphics course within the technology education department. Outside of Andrew's academic activities he is an avid motorcyclist and weight lifter. Andrew is married to his loving, caring, and intelligent wife Leslie A. Hughes. Leslie is an associate dean of students at Harvey Mudd College in Claremont, California.

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# CHAPTER ONE: INTRODUCTION

Cognition, the ability to process knowledge and understand through thought, has been a focus of educational research over the past several decades (Anderson, 1995; Piaget, 1971 & 1973; and Vygotski, 1962 & 1978). Metacognition, the capacity to recognize and regulate one's own thinking in real time, was identified by the National Research Council as one of three components fundamental to the teaching and learning process (Bransford, Brown, & Cocking, 1999 as cited by Young, 2010). Examples of metacognitive functions include declarative, procedural, and conditional knowledge as well as planning, monitoring, organizing, debugging and evaluation (Brown, 1978 & 1987; Flavell, 1976 & 1979; Jacobs & Paris, 1987; and Schraw & Dennison, 1994). These metacognitive functions are subcomponents of metacognitive awareness (Schraw & Dennison, 1994).

Ample research has shown that metacognitive awareness is crucial to student learning (Artzt & Armour-Thomas, 1992; Garner & Alexander, 1989; Perfect & Schwartz, 2002; Pressley & Ghatala, 1990; Robson, 2006; and Swanson, 1990). Literature also suggests that teachers play an important role in helping students develop metacognitive awareness by promoting self-regulated learning, engaging students in complex problem solving, and modeling metacognitive behaviors (Baker & Brown, 1980; Paris & Winograd, 1990; Pucheu, 2008; and Schraw, 1998). Thus, there is an emerging focus on teacher's development of metacognition (Prytula, 2012 and Pucheu, 2008). Literature indicates that learning how to learn and regulating learning are imperative for success in the technological age (Davis, 1991; Kafai & Resnick, 1996; Novak & Gowin, 1984; and Suarez-Orozco, 2005). The varying complexity of education entails teachers having the ability to adapt, monitor, and regulate their cognition; also known as self-regulation (Pintrich, 2004; Pucheu, 2008; and Zimmerman, 2002). Self-regulation, a person's regulation of their cognition, has been determined as an important aspect in developing metacognitive awareness (Pintrich, 2004; Pucheu, 2008; Young, 2010; and Zimmerman, 2002).

Implementation of self-regulated learning strategies are often identified as important for teachers and students (Kramarski & Michalsky, 2009; Pintrich, 2004; Pucheu, 2008; and Zimmerman, 2002). "The ability to self-regulate learning is essential for teachers' professional growth during their entire career as well as for their ability to promote these processes among students" (Kramarski & Michalsky, 2009, p. 161). Self-regulation is important for a teacher's ability to plan, monitor, reflect, react, and adapt in the constantly evolving educational environment (Bransford et al., 1999; Corno, 1987; Pintrich, 2004; and Zimmerman, 2002). Furthermore, research has shown that there is a direct link between teacher's metacognitive awareness and the effectiveness of their planning, managing, monitoring, and adjusting (Corno, 1987; Palincsar & Brown, 1984; Paris & Winogard, 1990; Pucheu, 2008; and Swanson, 1990). Teachers with higher levels of metacognitive awareness will have improved learning capability and more effective teacher practices (Ertmer & Newby, 1996; Palinscar & Brown, 1984; Pressley & Ghatala, 1990; Prytula, 2012; Pucheu, 2008; and Swanson, 1990). The literature suggests that when teachers are metacognitively aware, they are able to transfer awareness to their students (Bransford et al., 1999; Darling-Hammond, 1999; and Pucheu, 2008).

The belief, that when teachers are metacognitively aware they are able to help students develop their metacognitive awareness, has recently prompted interest in professional development focused on metacognitive awareness (Prytula, 2012 and Pucheu, 2008). Literature implies that some professional development programs unintentionally promote metacognitive awareness in teachers (Ernst, Clark, DeLuca, & Bottomley, 2013; Guskey, 2003; Smylie, Allensworth, Greenberg, Harris, & Luppescu, 2001; Wenglinsky, 2002; WestEd, 2000). Literature further indicates that teacher professional development aimed at improving metacognitive awareness would positively impact teachers' and students' higher-order thinking, problem-solving, self-assessment, self-regulated learning, and self-awareness (Corno, 1987; Guskey, 2003; Leinhardt, 1990; Mundry, 2007; Palincsar, 1986; Paris & Winograd, 1990; Prytula, 2012; Pucheu, 2008; and Wenglinsky, 2000). For teachers currently in the classroom, professional development is often one of the only choices offered for promoting growth in pedagogical practices. Literature has implied that the professional development of teachers will lead to higher student achievement (Bransford et al., 1999; Darling-Hammond, 1999; Guskey, 2003; Pucheu, 2008; and Wenglinsky, 2002). The focus on the development of metacognitively aware teachers has prompted research in the area (Lin, Schwartz, & Hatano, 2005; Prytula, 2012; Pucheu, 2008; Topcu & Ubuz, 2008; and Wilson & Bai, 2010). The research relates to the evaluation of teachers metacognitive awareness and the impact on implementing successful learning strategies (Lin et al., 2005; Pucheu, 2008; and Wilson & Bai, 2010). Research also investigates the impact of professional development programs on teacher's metacognitive awareness (Prytula, 2012 and Topcu & Ubuz, 2008).

Despite the importance of professional development in increasing teachers' effectiveness, schools often use nonspecific, poorly planned, short term, and single day professional development workshops that lack any form of support with implementation (Guskey, 2003; Murphy, 2000; NCES, 2001; Paez, 2003; and Sykes, 1999). These short-term professional development workshops offered by schools almost never have a strategic plan, long-term focus, connection with teacher learning, and especially lack focus on metacognition (Boyle, Lamprianou, & Boyle, 2004; Desimone, Porter, Garet, Yoon, & Birman, 2002; Guskey & Yoon, 2009; Pucheu, 2008; and Smylie et al., 2001). Furthermore, schools are often unable to provide effective forms of professional development, "not because they do not want to, but because they do not know how…" (NCTAF, 1996, p. 5). As a result schools usually offer a one-time professional development session that does not provide an adequate learning opportunity for teachers (Murphy, 2000 and Paez, 2003).

Compounding the problem of professional development lacking a focus on metacognitive awareness is the literature indicating that lower levels of metacognitive awareness is the reason teachers are unable to implement classroom practices expressed during professional development programs (Bransford et al., 1999; Graber, 1998; and Palincsar & Brown, 1984). Teacher's ability to transfer learning may be addressed by designing professional development with a focus on self-regulation and metacognitive awareness (Bransford et al., 1999; Guskey, 2003; Loucks-Horsley, Hewson, Love, & Stiles, 1998; Mundry, 2007; Pucheu, 2008; Wenglinsky, 2000 & 2002). Many schools do not offer professional development specifically focused on improving metacognitive awareness (Guskey, 2003; NCTAF, 1996; and Pucheu, 2008). Furthermore, many schools do not offer professional development that applies suggested characteristics for effectiveness from the literature (Guskey, 2003; NCTAF, 1996; and Pucheu, 2008).

In order for professional development to instill change in teachers, the professional development should have clear and challenging goals, adequate; flexible; structured time, follow-up, support, continuity, critical self-reflection, evaluation, feedback, collaboration, and a long-term goal of improved student achievement (Guskey, 1991 & 2003; Lock, 2006; Mundry, 2007; Smylie et al., 2001; and WestEd, 2000). Effective professional development programs require the teacher to understand students' learning needs (Guskey, 2003 and Sykes, 1999). To ensure effective professional development, numerous characteristics must be considered in addition to metacognitive awareness (Bybee & Loucks-Horsley, 2000; Desimone et al., 2002; Guskey, 1991 & 2003; Learning First Alliance, 2000; Mundry, 2007; Prytula, 2012; Pucheu, 2008; Smylie et al., 2001; Wenglinsky, 2000; WestEd, 2000; and Zohar, 1999). Designers of professional development should consider the macro- and micro-level design characteristics without forgetting the primary goal of teacher professional development. The primary goal of professional development is to improve student achievement by improving teacher practice (Guskey, 2003 and Sykes, 1999). If the need is for students to develop metacognitive abilities, teachers will be expected to teach and model these metacognitive abilities (Pucheu, 2008; Schraw, 2000). This implies that professional development for teachers will need to focus on teacher's metacognitive awareness.

## Significance of the Study

Ensuring that educators receive effective professional development is essential to improving the practice of teaching and ultimately student learning. Effective teaching and learning depends upon students' and teachers' metacognitive awareness (Palincsar, 1986;

Palincsar & Brown, 1984; Paris & Winograd, 1990; and Pucheu, 2008). In addition to the need for more research focused on teachers' metacognitive awareness and professional development that emphasizes metacognitive awareness, there is a need to better understand how and why teachers develop metacognitive awareness (Prytula, 2012). If improving students' metacognitive awareness continues to be an important part of educational reform, then teacher professional development that focuses on metacognitive awareness will be an important emphasis in education (Bransford et al. 1999). Furthermore, as information concerning teacher metacognitive awareness continues to develop, gaps in the existing literature may become more apparent. This study could provide additional and useful information on improving professional development and could help guide teachers' development of metacognitive awareness.

The practical significance of this study is that it will contribute to both teacher and student development of metacognition (Darling-Hammond, 1999; Pucheu, 2008; and Schraw, 2000). In particular, it will help to identify the role of professional development in teachers' development of metacognitive awareness and thus will guide the design and implementation of future professional development programs for teachers. The theoretical significance of this study is that the results contribute to the literature on the connection between professional development and teachers' metacognitive awareness. The results of this study could contribute to the literature concerned with professional development and teachers' metacognitive awareness. This study could also contribute to the literature concerned with the role professional development plays in promoting teachers' and ultimately students' development of metacognitive awareness.

## Background and Context

This study was conducted in the context of a program called Transforming Teaching through Implementing Inquiry (T2I2), a research and development project funded for four years by the National Science Foundation (NSF) (Award #1156629) (Ernst et al., 2013). The project started in the fall 2011 with the development of a highly interactive cyberinfrastructure system for delivering research-based professional development. The professional development was designed for secondary technology and engineering teachers in grades sixth through twelfth (Ernst et al., 2013). There are several goals that the designers of T2I2 attempted to accomplish.

The primary goal for the T2I2 professional development was to increase the participating teachers' ability to manage, monitor, adjust, and contribute in the learning environment (Ernst et al., 2013). Another goal was to increase teachers' understanding of engineering design concepts and the ability to effectively teach these concepts (Ernst et al., 2013). The next goal was to increase the teachers understanding of and ability to address student learning needs (Ernst et al., 2013). The final goal was to increase the teachers' instructional abilities with use of self-assessment (Ernst et al., 2013). All of the goals of T2I2 professional development system had an unintentional direct alignment with teachers' metacognitive abilities. T2I2 also had an alignment with the National Boards for Professional Teaching Standards (NBPTS) professional development.

### National Board for Professional Teaching Standards (NBPST)

In 1987, the NBPST was started with a focus on teacher quality (http://www.nbpts.org/). The NBPST sought to measure teacher quality using the core recommendations presented by A Nation Prepared: Teachers for the 21st Century report. The report suggested the use of standards to determine the quality of teachers and their instruction. In 1989, “What Teachers Should Know and Be Able to Do” was published by the NBPTS. In the document, the NBPTS identified their Five Core Propositions for Teaching. The five core propositions signified the knowledge, skills, dispositions and beliefs that characterized an exemplary teacher.

The Five Core Propositions for Teaching are: (1) Teachers are committed to students and their learning; (2) Teachers know the subjects they teach and how to teach those subjects to students; (3) Teachers are responsible for managing and monitoring student learning; (4) Teachers think systematically about their practice and learn from experience, and (5) Teachers are members of learning communities. After developing the propositions and the standards for the various teaching certification areas, the NBPTS worked on developing a process that would allow all teachers to be fairly and reliably evaluated (http://www.nbpts.org/).

The certification process that NBPTS developed is considered the most rigorous and coveted process in education (http://www.nbpts.org/). The certification process incorporates performance-based tasks and assessments using multiple-measures. Additionally, the teachers’ submitted documentation is peer-reviewed by individuals in the profession. In 1993, the NBPTS started accepting teacher applicants from teachers who were interested in pursuing the certification (Lustick & Sykes, 2006). The unique National Board Certification (NBC) process is considered the benchmark for measuring teachers. The NBC process is still recognized as one of the highest accomplishment for teachers.

The NBPTS requires participants to have a bachelor's degree, completed three years of teaching, and a valid state teaching license. NBPTS certification process entails a teacher developing a portfolio demonstrating their teacher practices and completing six 30 minute content knowledge assessments. The submitted teacher portfolio is assessed by national board evaluators. The portfolio includes two 20 minute videos of the teacher's practice, samples of student work, six 11 page written teacher commentaries, and other artifacts deemed significant by the teacher. The portfolio enables the teacher to document accomplishment that contributed to the learning environment. Written commentaries provides evaluators with a detailed analysis of goals, the purpose of instruction, the teacher's effectiveness, teacher reflections, and rationales of professional judgments.

**Alignment of T2I2 with National Board Certification**

The T2I2 project sought to promote technology and engineering teachers' attainment of NBC by aligning with NBPTS in three key ways. First, T2I2 aligns with NBPTS in the overall goals. The goals for T2I2 are grounded in the mission and vision of NBPTS. Secondly, the 17 learning objects of T2I2 were aligned with the thirteen Career and Technical Education (CTE) standards within NBPTS (Ernst et al., 2013). Table 1 illustrates the alignment between T2I2's 17 learning objects and the 13 CTE standards. Lastly, T2I2 aligns with NBPTS in the use of teacher artifacts. In order to become NBC, teachers must submit two videos commentaries, samples of student work, six written teacher commentaries as well as other teacher artifacts. In order to complete the T2I2 professional development teachers were asked submit shorter versions of six NBPTS teacher artifacts (T2I2: 2 page written commentaries and 5 minute video commentaries versus NBPTS: 11 page written commentaries and 20 minute video commentaries). The six T2I2 teacher artifacts are titled (1) assessment of student learning, (2) demonstration lesson: video capture, (3) demonstration lesson: written commentary, (4) documented accomplishments, (5) fostering teamwork: written commentary, and (6) fostering teamwork: video capture. Furthermore, feedback on the six artifacts is provided to the T2I2 teachers by a national board evaluator using the same artifact rubrics as the NBPTS.

Table 1

*T2I2 alignment with NBPTS*

| T2I2 learning objects | NBPTS aligned with each learning object | |
|---|---|---|
| Action Research | I. | Knowledge of Students |
| | VI. | Assessment |
| Adapting Instruction | I. | Knowledge of Students |
| | II. | Knowledge of Subject Matter |
| | III. | Learning Environment |
| Data Analysis | VI. | Assessment |
| | X. | Reflective Practice |
| Formative Evaluation Techniques | I. | Knowledge of Students |
| | III. | Learning Environment |
| | V. | Advancing Knowledge of Career and Technical Subject Matter |
| | VI. | Assessment |
| Initial Student Evaluation | I. | Knowledge of Students |
| | VI. | Assessment |
| | VII. | Workplace Readiness |
| Designing Standards Based STEM | II. | Knowledge of Subject Matter |
| | V. | Advancing Knowledge of Career and Technical Subject Matter |
| | VII. | Workplace Readiness |
| Lab and Class Management | III. | Learning Environment |
| | V. | Advancing Knowledge of Career and Technical Subject Matter |
| | X. | Reflective Practice |

Table 1 Continued

| | | |
|---|---|---|
| STEM Curricula | I. | Knowledge of Students |
| | V. | Advancing Knowledge of Career and Technical Subject Matter |
| | VII. | Workplace Readiness |
| | VIII. | Managing and Balancing Multiple Life Roles |
| Best Practices | I. | Knowledge of Students |
| | III. | Learning Environment |
| | IV. | Diversity |
| Classroom Quality | III. | Learning Environment |
| | IV. | Diversity |
| | VII. | Workplace Readiness |
| | IX. | Social Development |
| Enhancing Classroom Creativity | I. | Knowledge of Students |
| | III. | Learning Environment |
| | IV. | Diversity |
| | X. | Reflective Practice |
| Implementing Learning Activities | I. | Knowledge of Students |
| | II. | Knowledge of Subject Matter |
| | V. | Advancing Knowledge of Career and Technical Subject Matter |
| | VII. | Workplace Readiness |
| Multiculturalism in the Classroom | I. | Knowledge of Students |
| | IV. | Diversity |
| | VIII. | Managing and Balancing Multiple Life Roles |
| | IX. | Social Development |
| Working with Special Populations | I. | Knowledge of Student |
| | III. | Learning Environment |
| | IV. | Diversity |
| | VII. | Workplace Readiness |
| | IX. | Social Development |
| Professional Organizations | XI. | Collaborative Partnerships |
| | XII. | Contributions to the Education Profession |
| School and Community | XI. | Collaborative Partnerships |
| | XIII. | Family and Community Partnerships |
| Student Organizations | X. | Reflective Practice |
| | XI. | Collaborative Partnerships |
| | XIII. | Family and Community Partnerships |

## T2I2, NBPTS, and Metacognition

The T2I2 professional development system was designed using many of the suggested characteristic for effective professional development from the literature including: challenging goals, flexible time, continuity, coherence, critical reflection, teacher evaluation, teacher feedback, enhancing teacher content and pedagogical knowledge, and direct focus on student improvement (Ernst et al., 2013; Guskey, 1991 & 2003; Mundry, 2007; Smylie et al., 2001 and WestEd, 2000). Even though T2I2 professional development was designed with a consideration of many effective characteristics from the literature, a connection to metacognition was not an explicit consideration. Although, due to T2I2's connection with the NBPTS and its use of certain effectiveness characteristics, the T2I2 professional development had a notable connection to metacognitive practices. The teachers that actively participated in the T2I2 professional development system were having metacognitive experiences (Flavell, 1979). This study investigated if these unintentional metacognitive experiences were enough to promote the development of metacognitive awareness. This study aimed to explore the level and essence of teacher's metacognitive awareness based on their participation in either T2I2 or NBPTS professional development.

T2I2 professional development's alignment with the NBPTS, as indicated by the use of shorter teacher artifacts, the same artifact rubrics, and NBPTS evaluator as well as the 17 learning objects and 13 CTE standards (see Table 1). T2I2 participants are asked to submit four 2 page written commentaries, two 5 minute video commentaries, and complete 5 question quizzes at the end of each of the 17 learning objects. T2I2 and NBPTS use the same artifact scoring rubrics that measure a teacher's effectiveness by evaluating some of metacognitive awareness subcomponents (see Appendix E). Metacognitive awareness is also part of the T2I2 professional development through the self-regulated learning, critical reflection on practice, and inclusion of the requirement for the teachers to generate shorter versions of six NBPTS teacher artifacts (CREDE, 2002 and Ernst et al., 2013).

## Purpose of the Study

The purpose of this study was to explore technology and engineering teachers' level of metacognitive awareness at the time of the study, according to their participation in one of two professional development programs, T2I2 and NBPTS. As a convergent complementarity mixed-methods study, the research design had quantitative, qualitative, and convergent components to understand the complex phenomenon of metacognitive awareness (Creswell, 2007 & 2014 and Creswell & Plano, 2007). In the quantitative component, participants' self-reported their level on Schraw and Dennison's (1994) metacognitive awareness inventory (MAI) (see Appendix A). The completed MAIs were collected and analyzed in order to measure participants' current levels of metacognitive awareness. The data was used to compare groups of participants on their metacognitive awareness. Additionally, the groups were compared based on the two components and eight subcomponents of metacognitive awareness (Schraw and Dennison, 1994). In the qualitative component, the researcher conducted semi-structured open-ended interviews to investigate the phenomenon of participant's metacognition (see Appendix B). The convergence and divergence of the quantitative and qualitative findings were synthesized in order to increase the understanding of the participant's level of metacognitive awareness as well as provide a detailed phenomenological description of each group's metacognition during common teacher practices.

## Problem Statement

Teachers need metacognitive awareness (metacognition), a skill that is central to teaching and learning, in order to teach this skill to students and foster student learning (Kramarski & Michalsky, 2009; Pucheu, 2008; Schraw, 1998; and Young, 2010). Yet teacher professional development (opportunities to learn skills that will improve their teaching practice) is often unsuccessful at fostering effective teacher practices due to teachers' lack of metacognitive awareness (Bransford et al., 1999; Pucheu, 2008; and Schraw, 1998). Professional development without a focus on metacognitive awareness will not enable teachers with the required metacognitive awareness to transfer professional development training into effective teacher practices (Bransford et al., 1999; Pucheu, 2008; and Schraw, 1998). The T2I2 professional development program described above is a promising professional development opportunity for 6-12th grade technology and engineering teachers, but could use a more explicit focus on developing teacher's metacognitive awareness.

## Research Questions

This study was guided by the main research question, "What effects did Transforming Teaching through Implementing Inquiry online professional development system have on technology and engineering teachers' metacognitive awareness?" The three sub-questions were as follows:

a. How do technology and engineering teachers that actively participated in Transforming Teaching through Implementing Inquiry online professional development system compare to NBC technology and engineering teachers in terms of metacognitive awareness?

b. How do technology and engineering teachers that did not actively participate in Transforming Teaching through Implementing Inquiry online professional development system compare to NBC technology and engineering teachers in terms of metacognitive awareness?

c. What is the essence of technology and engineering teacher's metacognitive awareness while performing established teacher practices?

These questions enabled the researcher to investigate the connection between professional development and metacognitive awareness of teachers.

## Methodology

This section provides a description of the convergent complementarity mixed methods research design that was utilized by this study. As a convergent study, both quantitative and qualitative data were collected at the same time, analyzed separately, and then the results of both methods were analyzed together (Creswell, 2007 & 2014). The study design is also considered a complementarity design (Creswell & Plano, 2007). In a complementarity design, quantitative and qualitative data complement each other as they measure a single complex phenomenon in different ways (Creswell & Plano, 2007). The study was conducted over a sixteen-week period in the fall 2014 semester. There were a total of 18 participants that completed both the quantitative and qualitative phases, 3 additional participants only completed the quantitative phase. The participants were selected based on their participation in either T2I2 or NBPTS professional development. The participants were placed into three groups: (1) participants that actively participated in T2I2, (2) participants that did not actively participate in T2I2, and (3) participants that are NBC in CTE. Group three participants were include in this study for two reasons. The first reason was the connection between T2I2 and NBPTS professional development as well as their connection with metacognition. The second reason was NBPTS reputation as a quality benchmark for teachers. Research as indicated that the NBPTS process recognizes teacher excellence by certifying accomplished, exemplary teachers (Bond, Smith, Baker, & Hattie, 2000).

The use of mixed method designs are important for investigating metacognition due to the challenges in measuring metacognition (Akturk & Sahin, 2011 and Schraw, 2009). Schraw (2009) points out that no single method will allow for a complete understanding of metacognitive awareness and its multiple components. The purpose of a complementarity mixed method design is to use the gathered data to strengthen the analysis providing a more complete understanding of a single complex phenomenon, in this case metacognitive awareness (Greene, Caracelli, & Graham, 1989). Bryman (2006) details gaining a complete understanding of a researched entity by using mixed method designs. Metacognitive and research design literature was used to determine and refine the design of this study. The use of mixed methods designs when investigating multifaceted complex entities, like metacognition, is suggested in the metacognitive and research design literature (Akturk & Sahin, 2011; Creswell, 2014; Schraw, 2009; and Veenman, Van Hout-Wolters, & Afflerbach, 2006). Literature also indicates mixed method designs offer an improved depth and breadth in the analysis, resulting in a more comprehensive understanding of the researched concept

(Bryman, 2006; Creswell, 2007; and Denzin & Lincoln, 1994).

Prytula (2012) and Pucheu (2008) were previous studies that helped further define and guide the design of this study. Prytula (2012) used interviews and other forms of qualitative data to describe the essence of participation in a professional learning community and how it affected teacher's metacognitive awareness. Pucheu (2008) used Schraw and Dennison's metacognitive awareness inventory, a scoring rubric inventory, observations, and interviews to analyze participant's ability to implement scoring rubrics. Due to the focus on metacognitive awareness impacted by participation in professional development in this study, it was helpful to analyze the use of interviews and the metacognitive awareness inventory in Prytula's (2012) and Pucheu's (2008) studies. For this study, the quantitative data was collected using Schraw and Dennison's (1994) MAI (see Appendix A). The MAI is a 52 item self-reported instrument. The qualitative data was collected using a nine question metacognitive awareness interview (see Appendix B).

## Data Analysis

As with a convergent study, the analysis of the quantitative and qualitative data was performed separately and then later combined for an additional analysis. The Kruskal-Wallis one-way analysis of variance by ranks was used to analyze the quantitative data from the MAI. The Kruskal-Wallis test was selected based on the ability to compare two or more independent groups, small sample size in the study, non-normally distributed data, and the ranking of data to decrease impact of outliers (Sheskin, 2004). The quantitative analysis was done using Statistical Package for the Social Sciences (SPSS). The Kruskal-Wallis test was used to compare the three group's metacognitive awareness across both components and eight subcomponents of metacognitive awareness (see Table 3). The analysis of the qualitative data was performed by two independent and trained coders. The participants' responses were ranked by the coders using a coding rubric (see Appendix B). The coder's ranks were then compared using Cohen's kappa to determine the level of agreement (Sheskin, 2004). Cohen's kappa was selected based on ability of the statistic to offer a chance correlated agreement between two independent raters (Sheskin, 2004). After both the quantitative and qualitative data were analyzed, the results were further analyzed using comparative analysis to develop a more complete understanding of each group's metacognitive awareness. The analyses of the quantitative, qualitative, and combined data was used to describe the essence of each group's metacognition during common teacher practices (Creswell, 2007). Additionally, the analyses were used to provide answers to the research questions.

## Limitations

The study has several limitations. It will not study or evaluate any of the following: the overall effectiveness of the T2I2 professional development system; the transfer of metacognitive awareness from the teacher to the students; or the teachers' metacognitive awareness prior to their participation in T2I2 professional development. Thus, it will not measure the teachers' before and after levels of metacognitive awareness or their changes in metacognitive awareness over time. In addition, it will not investigate factors that may hinder effective professional development (Darling-Hammond & McLaughlin, 1995 and Smylie et al., 2001). The study controls for several variables but is not able to control for other extraneous variables that may impact teachers' levels of metacognitive awareness.

## Definitions

*Metacognition*. Metacognition: thinking about thinking or the monitoring and regulation of thinking (Flavell, 1979); "metacognition refers, among other things, to the active monitoring and consequent regulation and orchestration of these processes in relation to the cognitive objects or data on which they bear, usually in service of some concrete goal or objective" (Flavell, 1976, p. 232).

*Cognition*. Cognition: conscious mental activities: the activities of thinking, understanding, learning, and remembering (Merriam-Webster's online dictionary, n.d.)

*Metacognitive Awareness Inventory* (MAI)-- Metacognitive Awareness Inventory (MAI): a self-reported 52 question instrument for measuring levels of metacognitive awareness, consisting of two factors with five levels of awareness across eight components of metacognition (Schraw & Dennison, 1994)

*Metacognitive Awareness.* Perception of one's own knowledge of cognition and regulation of cognition (Brown, 1978; Flavell, 1979; Schraw & Dennison, 1994)

*Regulation of Cognition.* One of the two major components in metacognitive awareness, includes five subcomponents that enable the control portion of metacognition (Schraw & Dennison, 1994)

*Knowledge of Cognition.* One of the two components in metacognitive awareness, includes three subcomponents that enable the reflective practice portion of metacognition (Schraw & Dennison, 1994)

*Planning.* Planning, goal setting, and allocating resources (Schraw & Dennison, 1994)

*Monitoring.* On-line assessment of one's learning or strategy use (Schraw & Dennison, 1994)

*Organizing.* Implementing strategies and heuristics that help one manage information (Pucheu, 2008)

*Information Management.* Organizing, elaborating, summarizing, and selectively focusing on important information (Pucheu, 2008 & Schraw & Dennison, 1994)

*Evaluating.* Post-hoc analysis of performance and strategy effectiveness (Schraw & Dennison, 1994)

*Debugging.* Strategies used to correct performance errors or assumptions about the task or strategy use (Schraw & Dennison, 1994)

*Declarative Knowledge.* Knowledge about learning and one's cognitive skills and abilities (Schraw & Dennison, 1994)

*Procedural Knowledge.* Knowledge about how to use strategies (Schraw & Dennison, 1994)

*Conditional Knowledge.* Knowledge about when and why to use strategies (Schraw & Dennison, 1994)

*Technology and Engineering Teachers*. Technology and Engineering Teachers:

teachers that have a state certification in technology education and are currently employed to teach content using technology, engineering, and design curriculum

*Professional Development.* Professional Development: refers to the improvement or growth of skills and knowledge, usually with direct towards improving student achievement (Guskey, 2003; Loucks-Horsley et al., 1998)

*T2I2.* Transforming Teaching through Implementing Inquiry (T2I2): a research and development grant funded by the National Science Foundation with a goal of producing a highly interactive cyberinfrastructure for delivering research-based professional development to teachers (NSF Award #1156629)

*National Board Certification.* National Board Certification: teacher recognition from the NBPTS, National Board for Professional Teaching Standards (NBPTS): an organization started in 1987 with the goal of evaluating and advancing the quality of teaching and learning through the development of professional teaching standards. Considered in the teaching profession as one of the highest accomplishments for teachers (http://www.nbpts.org/).

## Chapter Summary

This chapter discusses the need for research related to teachers' metacognitive awareness. The primary goal of the study was to understand the role that T2I2 professional development has in impacting technology and engineering teachers' metacognitive awareness. The secondary goal of the study was to measure the differences in technology and engineering teachers' metacognitive awareness based on their participation in either T2I2 or

NBPTS professional development. The final goal was to describe each group's metacognition while performing common teacher practices. Literature indicated the importance of professional development focused on metacognition (Bransford et al., 1999; Prytula, 2012; and Pucheu, 2008). Although, few studies have been completed regarding metacognition as a characteristic of professional development (Prytula, 2012 and Pucheu, 2008). This study was conducted in the fall semester of 2014. The MAI and metacognitive awareness interview were used to investigate participants' metacognitive awareness. Due to the complexity of metacognition, literature suggests the use of mixed method designs when investigating metacognition (Akturk & Sahin, 2011; Creswell, 2014; Veenman et al., 2006). The participants were selected and grouped based on their participation in professional development. The use of the MAI was due to its identification as the only available, psychometric reliable measure ($\alpha = .90$, Schraw and Dennison, 1994) of metacognitive awareness (Baker & Cerro, 2000 and Pucheu, 2008). The metacognitive awareness interview was used to provide a more complete perspective of the participants' metacognitive awareness (Bryman, 2006; Creswell, 2007; and Denzin & Lincoln, 1994). This chapter has provided introductory evidence of the reason and method for investigating professional development's role in impacting teacher's metacognitive awareness. Later chapters will detail this study of metacognitive awareness.

# CHAPTER TWO: LITERATURE REVIEW

The purpose of this study was to investigate how participation in professional development impacted technology and engineering teacher's metacognitive awareness. The role and importance of metacognitive awareness as a characteristic of professional development was presented in the review of literature. Metacognitive awareness has two primary components, knowledge of cognition and regulation of cognition. The importance of teacher's metacognitive awareness and consequent student awareness was detailed by reviewing relevant literature, previous research, and findings from the research. Previous research was reviewed to identify elements of measuring metacognition. The literature expressed the difficulty in measuring metacognition due to its complexity. The use of multiple methods was suggested by the literature for the purpose of developing a more comprehensive understanding of metacognition. The literature also indicated that multiple methods could be used to counteract possible weaknesses in any one measure. Next, the literature on professional development was reviewed. The review consisted of literature from the general educational domain as well as the relevant literature within the domains of STEM education and online professional development. Professional development's primary goal of improving student achievement was discussed. Literature was reviewed to detail characteristics of effective professional development. The characteristics were divided into macro- and micro- level based on when they should be considered in the design of professional development. Literature on the importance and process of evaluating professional development was reviewed. Finally, the limitations and challenges of delivering effective professional development was detailed.

## Metacognitive Awareness and Metacognition

Metacognitive awareness, the deliberate ability to explain one's knowledge and regulation of cognition, is woven into the history of human experience. Several centuries ago, Plato discussed thinking about thinking and being aware of one's thinking (Spearman, 1923 as cited by Georghiades, 2004). Similarly, Sandi Ureña (2008) mentioned that Aristotle discussed the mind having powers that could not be seen or heard (as cited by Akturk & Sahin, 2011). Aristotle's ideology on the mind's powers further established the foundation for metacognition. Piaget's (1950, 1971, & 1973) work on cognitive development psychology revealed that the stages of cognitive development were distinguishable, observable, and with the proper method measurable. Expanding on the work of Jean Piaget, John Flavell (1976) was the first scholar to conceptualize metacognition. Flavell (1976) used the term metamemory to describe a person's knowledge of their own memory. Flavell (1976) also defined metacognition as "one's knowledge concerning one's own cognitive processes and products or anything related to them, e.g., the learning-relevant properties of information or data. For example, I am engaging in metacognition if I notice that I am having more trouble learning A than B; if it strikes me that I should double check C before accepting it as fact" (p. 232).

### Definitions of Metacognition

Flavell's (1976) definition of metacognition is frequently used in metacognitive literature. A more concise definition of metacognition is thinking about thinking and is also credited to Flavell. There are several definitions for metacognition including: "individuals' having information about their cognitive structure and being able to organize this structure"

(Brown, 1987; Dunlosky & Hertzog, 2000; Flavell, 1979; Georghiades, 2004; Jacobs & Paris, 1987; Livingston, 1997; Schraw, 1994; and Wellman, 1985 as cited by Akturk & Sahin, 2011 p. 3732). The numerous and varying definitions of metacognition indicates the lack of consensus (Young, 2010). The areas of metacognitive research as well as the identified components of metacognition are often used as an operational definition for metacognition (Young, 2010). The two main areas of metacognitive research are regulation of cognition and knowledge of cognition (Brown, 1978 & 1987 and Flavell, 1976 & 1979). Additionally, there are a variety of terms from the literature, related to metacognition, that use metacognition to describe them.

Today, the term metacognition has become a catch-all and is used to express several related concepts including: thinking process, information management, beliefs about thinking, executive abilities, judgments of learning, self-management, self-regulation, metamentation, self-reflection, meta-learning, and metacomponents (Bogdan, 2000; Leader, 2008; O'Neil & Spielberger, 1979; and Veenman et al., 2006). The variety of definitions and terms for metacognition may be part of the reason that metacognition is considered ambiguous (Akturk & Sahin, 2011). Additionally, metacognition has several identified components and subcomponents including: awareness, metacognitive knowledge, metacognitive experiences, person knowledge, task knowledge, strategy knowledge, monitoring, regulation, and orchestration of cognitive processes (Flavell, 1976 & 1979). Brown (1978 & 1987) indicated that metacognition includes the components and subcomponents of knowledge of cognition, regulation of cognition, awareness, planning, checking, and monitoring. Jacobs and Paris (1987) added several additional components to metacognition including self-appraisal, self-management, procedural knowledge, conditional knowledge, and declarative knowledge.

Here it is beneficial to distinguish between metacognition and cognition: According to Schraw (2001), metacognition is the comprehension of how to complete a task and cognition is essential for completing the task. According to Senemoğlu (2005), metacognition is the awareness of one's own knowledge and regulation of learning; cognition is required for awareness and understanding of a problem. Furthermore, metacognition is necessary for an individual to observe, develop, and evaluate their knowledge and adapt it for different circumstances, whereas cognition is required to formulate information (Gourgey, 1998). Ultimately, a person requires metacognition in order to have cognitive effectiveness.

The commonly presented constructs in the literature on metacognition's definitions, components, and subcomponents is a person's awareness of their knowledge and regulation of cognition (Baker & Brown, 1980; Jacobs & Paris, 1987; Pucheu, 2008; Schraw & Dennison, 1994; and Young, 2010). Flavell (1979) incidentally discussed a person's metacognitive awareness of their knowledge, understanding, affective state, and difficulty with tasks. Swanson (1990) defined metacognition as a person's awareness of monitoring and regulating their own learning. Wilson (1998) explained metacognition as a person's knowledge, awareness, organization, and evaluation of their thinking processes and strategies. Scarr & Zanden (1984) defined it as a person's awareness, comprehension, and regulation of their mental state, skills, memory, and behavior. Similarly, Royer, Cisero, and Carlo (1993) defined metacognition as a person's awareness of their cognitive processes. Metacognitive awareness is the term used to describe an individual's ability to detail their knowledge and regulation of cognition (Schraw & Dennison, 1994). Table 2 identifies the components and subcomponents of metacognitive awareness presented in the literature.

Table 2

*Components and Subcomponents of Metacognitive Awareness*

| | Literature on Metacognition | | | |
|---|---|---|---|---|
| Components and Subcomponents of Metacognitive Awareness | Schraw and Dennison (1994) | Flavell (1976, 1979) | Jacobs and Paris (1987) | Brown (1978, 1987) |
| Awareness of Cognition | ✓ | ✓ | | ✓ |
| Knowledge of Cognition | ✓ | ✓ | ✓ | ✓ |
| Regulation of Cognition (Self-management) | ✓ | ✓ | ✓ | ✓ |
| Procedural Knowledge | ✓ | | ✓ | |
| Conditional Knowledge (Strategy Knowledge) | ✓ | ✓ | ✓ | |
| Declarative Knowledge (Person Knowledge) | ✓ | ✓ | ✓ | |
| Planning | ✓ | | ✓ | ✓ |
| Monitoring | ✓ | ✓ | ✓ | ✓ |
| Organizing (Information Management) | ✓ | | | |
| Debugging (Checking Outcomes) | ✓ | | | ✓ |

Table 2 Continued

| | | |
|---|---|---|
| Evaluating (Self-appraisal) | ✓ | ✓ |

## Metacognitive Awareness

According to the literature, metacognitive awareness is the combination of two main components: knowledge of cognition and regulation of cognition (Baker & Brown 1980, Flavell, 1979; Jacobs & Paris, 1987; and Schraw & Dennison, 1994). Jacobs and Paris (1987) determined that the component knowledge of cognition requires a metacognitive self-awareness of three areas: declarative, procedural, and conditional knowledge. The second component, regulation of cognition, is a person's control and monitoring of their cognitive processes especially surrounding learning and processing information (Brown, 1987). There have been numerous regulatory skills identified (Brown, 1987; Hunter-Blanks, Ghatala, Pressley & Levin, 1988; Marine & Escribe, 1994; Pintrich & DeGroot, 1990; Schraw and Dennison, 1994; Schraw, Dunkle, Bendixen & Roedel, 1995; and Steinberg, Bohning, & Chowning, 1991). For this study the five regulatory subcomponents of particular interest are: planning, organizing, monitoring, debugging, and evaluating (Schraw, 1998 and Schraw & Dennison, 1994). Table 3 shows the subcomponents of metacognitive awareness and description of each subcomponent.

### Knowledge of Cognition

"Any kind of self-appraisal of cognition can be classified as either declarative, procedural, or conditional knowledge." (Jacobs & Paris, 1987, p. 259). The term declarative knowledge refers to the knowledge a person has about their cognitive skills and abilities (Jacobs & Paris, 1987 and Schraw & Dennison, 1994). A person with declarative knowledge knows what impacts their learning, the learning of others, and what they do and do not know (Jacobs & Paris, 1987 and Schraw & Dennison, 1994). The term procedural knowledge refers to a person's knowledge about how to use strategies and techniques to accomplish cognitive tasks (Jacobs & Paris, 1987 and Schraw & Dennison, 1994). The term conditional knowledge refers to the knowledge a person has regarding when and why to use strategies for accomplishing cognitive tasks (Jacobs & Paris, 1987 and Schraw & Dennison, 1994). A person with conditional knowledge knows when and why to present an idea. A person with conditional knowledge knows the appropriate time to use strategies and has cognitive reasoning for why to use specific strategies.

**Regulation of Cognition.**

Regulation of cognition was described early in metacognitive literature by Flavell (1976 & 1979) and Brown (1978). During a learning opportunity, like a professional development program, people regulate their thinking through planning, monitoring, organizing, debugging, and evaluating (Brown, 1978; Flavell, 1979; and Schraw & Dennison, 1994). Brown (1987) defined regulation of cognition as "the activities used to regulate and oversee learning" (p. 68). Brown (1987) separated the activities involved in regulating cognition into three actions: (1) planning behaviors, (2) monitoring behaviors, and (3) checking outcomes. Jacobs and Paris (1987) also indicated the importance of planning, monitoring, and evaluation. Schraw and Dennison (1994) determined from their review of literature that the five regulatory subcomponents discussed extensively in the literature are planning, information management (organizing), monitoring, debugging, and evaluating.

The term planning is used to describe a person's ability to select appropriate planning strategies, set goals, and allocate resources (Pucheu, 2008; Schraw, 1998; and Schraw & Dennison, 1994). A person with an awareness of their planning would be able to describe in detail their planning, goal setting, and allocation of resources related to accomplishing a cognitive task. The organizing and information management subcomponents are connected (Pucheu, 2008 and Schraw & Dennison, 1994). Organizing is the cognitive use of strategies and techniques to manage information (Pucheu, 2008). Information management is the active process of organizing, elaborating, summarizing, and selectively focusing on important information for the purpose of mental restructuring due to cognitive dissonance (Pucheu, 2008 and Schraw & Dennison, 1994). During monitoring a person assesses their cognition and strategy effectiveness (Brown, 1987 and Schraw & Dennison, 1994). When teachers are monitoring, they add the assessment of students' learning and cognitive functioning to their monitoring. During the process of debugging a person uses strategies to identify and correct errors and assumptions about tasks and implemented strategies (Schraw and Dennison, 1994). The subcomponent of evaluating is the post-hoc analysis of performance and strategy effectiveness (Schraw & Dennison, 1994).

Table 3

*Description of Metacognitive Awareness Subcomponents*

| Subcomponents of Metacognitive Awareness | Description of Subcomponent |
|---|---|
| Procedural Knowledge | knowledge about how to use strategies and techniques to accomplish cognitive tasks (Jacobs & Paris, 1987 and Schraw & Dennison, 1994) |
| Conditional Knowledge | knowledge about when and why to use strategies for accomplishing cognitive tasks (Jacobs & Paris, 1987 and Schraw & Dennison, 1994) |
| Declarative Knowledge | knowledge a person has about their cognitive skills and abilities (Jacobs & Paris, 1987 and Schraw & Dennison, 1994) |
| Planning | ability to select appropriate planning strategies, set goals, and allocate resources (Pucheu, 2008; Schraw, 1998; and Schraw & Dennison, 1994) |
| Monitoring | cognitive assessment of self, others, and strategy effectiveness (Brown, 1987; Pucheu, 2008; and Schraw & Dennison, 1994) |
| Organizing | use of strategies and techniques to manage information (Pucheu, 2008) |
| Information Management | process of organizing, elaborating, summarizing, and selectively focusing on important information (Pucheu, 2008 and Schraw & Dennison, 1994) |

Table 3 Continued

| | |
|---|---|
| Debugging | use of strategies to identify and correct errors and assumptions about tasks and implemented strategies (Schraw and Dennison, 1994) |
| Evaluating | post-hoc analysis of performance and strategy effectiveness (Schraw & Dennison, 1994) |

## Importance of Metacognitive Awareness

The power of the mind to think about and regulate one's own cognition is the key not only to learning, but also to teaching others. "Metacognition fills a unique niche in the self-regulatory phylum, by providing domain-general knowledge and regulatory skills that enable individuals to control cognition in multiple domains" (Schraw, 1998, p. 118). Georghiades (2004) further detailed the importance of metacognition in his review of three decades of metacognitive literature:

> Relating metacognition to developing one's self-knowledge and ability to 'learn how to learn' resulted in metacognition being awarded a high status as a feature of learning. The ground for developing such an interest proved particularly fertile, especially in view of a constantly changing technological world when not only it is impossible for individuals to acquire all existing knowledge, but it is also difficult to envisage what knowledge will be essential for the future. (p. 366)

Having an awareness of what one knows and does not know when approaching future situations will enhance learners ability to solve problems (Bransford et al., 1999;

Georghiades, 2004; and Lin, Schwartz, & Hatano, 2005) The National Research Council identified metacognition as one of three components central to learning and teaching (Bransford et al., 1999 as cited by Young, 2010). Teacher's metacognitive awareness is essential for effective planning, monitoring, organizing, adapting, and evaluating of their classroom practices (Bransford et al., 1999; Kramarski & Michalsky, 2009; and Pucheu, 2008).

Teacher's metacognitive awareness is also an essential part of their mental and environmental adaption to ill-defined problems, tasks, and broad variability that they encounter daily (Lin et al., 2005 and Pucheu, 2008). "Noted differences in adult strategy use and performance are directly linked to differences in metacognitive awareness rather than significant differences in intellectual abilities" (Corno, 1987; Palincsar & Brown, 1984; Schraw & Dennison, 1994; and Swanson, 1990 as cited by Pucheu, 2008, p. 7). Teachers with a greater metacognitive awareness are able to promote students' metacognitive awareness, self-regulation, higher-order thinking, enhanced learning, and problem-solving abilities (Bransford et al., 1999; Pintrich & DeGroot, 1990; Paris & Winograd, 1990; Pucheu, 2008; and Wenglinsky, 2000 & 2002). More often, researchers are measuring and evaluating students' metacognition (Reingold, Rimor, & Kalay, 2008; Tanner, 2012; and Young, 2010). Researching students' metacognition has indicated the importance of metacognition for student learning (Brown, 1978, 1987; Reingold, Rimor, & Kalay, 2008; Tanner, 2012; and Young, 2010).

Brown (1978) defined metacognition in terms of students' awareness and organization of thinking processes during learning and problem solving scenarios. Baker and Brown

(1980) defined metacognition as a theoretical structure with two components. The first component was a learner having accountability for their learning (Baker & Brown, 1980). The second component was the learner being aware of and managing their learning (Baker & Brown, 1980). Flavell (1979) studied children to determine if they had awareness of what controlled their memory and thinking. Flavell (1979) determined there was sufficient evidence to support his belief that children had the ability to reflect on their cognitive processes. Flavell (1987) indicated a concern for the separation of children's cognitive experiences and thorough understanding of these experiences. The literature debates whether young children are even capable of understanding their cognitive experiences (Brown, 1987 and Brown & DeLoache, 1978). Georghiades (2004) indicated, using Flavell's (1985 & 1987) reasoning, that it was not a question of children's metacognitive ability but rather a question of how they were taught to be metacognitive. "A 'metacognitive' approach to instruction can help students learn to take control of their own learning by defining learning goals and monitoring their progress in achieving them" (Bransford et al., 1999, p. 18).

More recently, research has shifted towards teacher's development of metacognition as a means to improve students' metacognition (Lin et al., 2005; Prytula, 2012; Pucheu, 2008; and Wilson & Bai, 2010). Teacher's metacognitive awareness will determine their ability to help students develop their metacognitive awareness (Kramarski & Michalsky, 2009). Teachers lacking metacognitive awareness will have difficulty modeling metacognitive behaviors for students during their development of metacognitive awareness (Schraw, 1998). Teacher professional development has received recent attention as an available method to strengthen teacher's metacognitive awareness (Prytula, 2012). However, teachers do not have the metacognitive awareness required to implement effective classroom practices received from professional development training (Bransford et al., 1999; Pucheu, 2008; and Schraw, 1998).

In order for teachers to effectively implement material from professional development in their classrooms they require knowledge and regulation of cognition (Bransford et al., 1999; Lin et al., 2005; Pucheu, 2008; and Schraw, 1998). The teacher must have the knowledge necessary to understand the type of environment that will improve student learning, the appropriate strategy based on the situation, the level of difficulty for a given task, students' level of understanding, and the ability to use their knowledge to benefit them (Bransford et al., 1999 and Lin et al., 2005). The ability to select and apply effective learning strategies is determined by teachers' knowledge of cognition (Leinhardt, 1990; Palincsar, 1986; Pucheu, 2008; Wilson & Bai, 2010; and Schraw, 2009). Additionally, teachers are often required to plan for the implementation of new material, organize learning, monitor themselves, debug what did not work, and evaluate the effectiveness of their classroom (Bransford et al., 1999; Lin et al., 2005; Prytula, 2012; and Pucheu, 2008). The varying complexity of the learning environment entails teachers having the ability to adapt their cognitive regulation to manage the environment (Lin et al., 2005) A teacher that focuses on their regulation of cognition will develop a classroom tenacity promoting life-long learning (Jonassen, Peck & Wilson, 1999; Stiggins, 2002; Wiggins, 1993; 1998).

## Metacognitive Measurement

Given the great importance of metacognition and metacognitive awareness, researchers have attempted for decades to establish quality measures of this ability.

Metacognition has been identified as ambiguous by many scholars (Akturk & Sahin, 2011). Metacognition's ambiguity implies the inherent difficulty with its measurement. Early studies concluded that metacognition was not an easily visible action, suggesting problematic measurement (Akturk & Sahin, 2011). Later studies argued that metacognition was not purely an internal process and could be more easily detected (Akturk & Sahin, 2011). Akturk and Sahin (2011) identified that the current metacognitive research is within one of three domains: (1) cognitive psychology (Hart, 1965 and Peters 2007), (2) cognitive development psychology (Piaget, 1950 and Steinbach 2008), or (3) social development psychology (Tsai 2001 and Vygotsky, 1962). Hart (1965) was the first to measure metacognition's existence (as cited by Peters, 2007). Hart (1965) first asked participants broad questions about general information. Hart (1965) then followed up by asking about participant's thoughts regarding solutions to various problems. Hart (1965) believed that the participants' thoughts about the solutions indicated correct answers to the general questions. Hart's (1965) research was followed by Underwood (1966). In Underwood's (1966) studies, participants were asked to indicate their perceived difficulty with various problems on a test. Underwood (1966) believed that the indicated level of difficulty expressed by the participant would reflect their level of difficulty in learning the concept covered by the question, implying the participant's inadvertent awareness. Arbuckle and Cuddy (1969) studied participants' judgments about their own learning. Their study determined that participant's judgments were highly accurate regarding their own understanding of material (Arbucle & Cuddy, 1969).

At present, various quantitative and qualitative methods have been used to measure metacognition. Common measurements of metacognition can be categorized into either self-reported or objective behavioral methods (Akturk & Sahin, 2011). The first category of self-reported measures, includes questionnaires and interviews. The second category of objective behavioral measurements, includes observations and think aloud protocols. Veenman (2005) further defined classifications for metacognitive measurements. Veenman's (2005) classifications related to the cognitive phase in which the measurement was implemented. Veenman's (2005) three classifications are probable, simultaneous, and retrospective. Probable classification suggests that the measurement happens before the cognitive task. Simultaneous classification stipulates measurement happens during the cognitive task. Retrospective characteristic indicates measurement happens after the cognitive task.

There are trade-offs associated with the use of each metacognitive measure. The two measurements most often used for simultaneous measurement are think aloud protocols and systematic observations (Rickey & Stacy, 2000 and Veenman, 2005). Think aloud protocols are used so that the researcher is able to hear and see what the participant is doing during a task. There are two main problems with using a think aloud protocol to measure metacognition (Akturk & Sahin, 2011). The first problem is that the participant may be more focused on thinking aloud rather than completing the cognitive task. While the second problem relates to the functional use of think aloud protocols. There is an appropriate time and place for think aloud protocols (Scott, 2008). Group settings often make the use of think aloud protocols inappropriate (Scott, 2008). In addition to think aloud protocols, observations also have trade-offs (Akturk & Sahin, 2011). Observations can be used to determine participants' metacognitive actions. Yet, observations are difficult and require time to implement even with a couple of participants. There may also be a disconnect between apparent internal and external processes when using observations.

Questionnaires are one of the most common tools used for measuring metacognition (Akturk & Sahin, 2011). Questionnaires can be used before, during, and after a cognitive task. There are also trade-offs with the use of questionnaires that should be considered. A major positive of a questionnaire is its ability to provide quick and objective measurement of metacognition, even with large sample sizes (Tobias & Everson, 1996). The negative aspects of a questionnaire relate to the participants' honesty, reluctance to answer, and ability to understand the questions (Baker & Cerro, 2000; cited by Scott, 2008). Questionnaires are often used because of their effectiveness and reliability in measuring metacognition (Akturk & Sahin, 2011; Schraw & Dennison, 1994; and Veenman, 2005).

Interviews are more appropriately used as a measure of metacognition before and after the cognitive task. Interviews are a self-reported measurement implying that participant's honesty, reluctance to share, and ability to understand the questions may be a problem. However, the ability to provide depth to the investigation is a positive reason for using interviews (Creswell, 2007 and Denzin & Lincoln, 1994). During an interview, the researcher has the ability to ask the participant to provide more detail about an idea that arises. This ability allows interviews to provide a more complete perspective of participant's metacognition (Bryman, 2006). The required time for the participant and researcher to complete adequate length interviews is a major consideration when determining if interviews are appropriate (Scott, 2008). In addition to the time required for the interview, is the time required to transcribe and code the interviews (Creswell, 2007 and Denzin & Lincoln, 1994). Aside from the time commitment, it is important for the researcher to create an environment that is comfortable for both the researcher and participant (Denzin & Lincoln, 1994).

The use of single method measurements of metacognition often lack sufficient detail (Baker & Cerro, 2000; Meichenbaum, Burland, Gruson & Cameron, 1985; Pintrich et al., 2000; and Schraw, 2000). Due to the multiple constructs of metacognition, there is currently no single method that allows comprehensive measurement of metacognition (Schraw, 2009). The complexity of metacognition has prevented efforts to relate metacognitive models to empirical data; as a result many of the single method metacognitive research studies measure metacognition generally (Akturk & Sahin, 2011). Schraw (2009) indicates that no single method will allow for a complete understanding of metacognitive levels and development. For this reason, research using quantitative and qualitative methods is recommended (Baker & Cerro, 2000; Bryman; 2006; Pintrich et al., 2000; and Schraw, 2000, 2009). For quantitative measurement purposes, Schraw and Dennison (1994) sought to create an instrument for measuring metacognitive awareness by combining constructs of metacognition. Schraw and Dennison’s (1994) efforts resulted in the metacognitive awareness inventory (MAI) (see Appendix A).

Schraw (2000) detailed six themes that emerged from the Buros Symposium. Theme four was “most available instruments that measure metacognition have unknown psychometric properties” (Schraw, 2000, p. 301). This fact creates two issues in the quantitative measurement of metacognition: (1) the instruments specific design and narrow usability and (2) lack of development background information (Baker & Cerro, 2000 and

Pintrich et al., 2000 as citied by Schraw, 2000). Learning and Study Strategies Inventory (LASSI), Motivated Strategies for Learning Questionnaire (MSLQ), and MAI are three instruments that have been proven to have psychometric reliability (Schraw, 2000). The LASSI is more appropriately used to measure cognitive skills and has not been thoroughly tested for use as a metacognitive measure (Schraw, 2000). Similarly, the MSLQ is more appropriately used to measure motivation and strategy subscales (Schraw, 2000). The MAI was designed to measure knowledge and regulation of cognition subscales and has high reliability (Schraw, 2000). The MAI is not normalized making it difficult to determine higher versus lower levels of metacognitive awareness (Pucheu, 2008 and Schraw, 2000). Schraw (2007) suggests that the MAI results can be normalized based on the results from the sample in the study. This allows for comparisons to be made within study samples (Pucheu, 2008 and Schraw, 2007).

The MAI instrument, developed by Schraw and Dennison (1994) consists of two components with five levels of awareness across eight subcomponents of metacognition. Each one of the 52 questions aligns with one of the eight subcomponents. Component one is Knowledge of Cognition and includes the subcomponents: Declarative Knowledge, Procedural Knowledge, and Conditional Knowledge. Component two is Regulation of Cognition and includes the subcomponents: Planning, Organizing (Information Management), Monitoring, Debugging, and Evaluation (see Table 3). Baker and Cerro (2000) identified the MAI as a "promising new instrument focusing more exclusively on metacognitive awareness" (p.113). The MAI is easy for individuals to use, practical, efficient, and reliable (Baker & Cerro, 2000 and Schraw and Dennison, 1994). Currently, the MAI is considered the only self-reported psychometric reliable ($\alpha = .90$, Schraw and Dennison, 1994) instrument for measuring metacognitive awareness (Schraw, 2000).

**Mixed Methods**

This section provides details from the literature behind the use of convergent complementarity mixed method designs (Creswell, 2007 and Creswell & Plano, 2007). Bryman (2006) details gaining a complete understanding of a researched entity by using mixed method designs. Researchers have indicated the importance of using a mixed methods design to investigate metacognition (Akturk & Sahin, 2011 and Schraw, 2009). In a convergent design the quantitative and qualitative data are gathered in parallel phases and then later analyzed in either one of two ways: (1) separately and then together or (2) together (Creswell, 2007). In a convergent design, the analysis of the combined data is used to describe the divergence and convergence of the results from each method (Creswell, 2007). The areas were the data converges indicates compelling connections between the measured components. For areas were the data diverges, there are often telling reasons that if determined can provide a greater understanding of the measured components.

In a complementarity design, quantitative and qualitative data are collected in different ways but are used to measure the same complex phenomenon (Creswell & Plano, 2007). The quantitative and qualitative data complement each another helping to provide a deeper understanding of a single complex phenomenon, like metacognitive awareness (Greene et al., 1989). The overlapping of the data from both methods during final convergent complementarity analysis provides a complete perspective and understanding of multifaceted components of a single complex phenomenon. Again, whether the data from both measures converges or diverges in the final analysis, complementarity designs offer an enhanced understanding of the phenomenon (Greene et al., 1989).

As research has demonstrated, metacognitive awareness--the ability to explain one's knowledge and regulation of cognition--is key to both learning and teaching. In order for teachers to be effective, they must have metacognitive awareness of their own, and they should foster this ability in students. Despite the importance of metacognitive awareness, literature has noted a lack of programming to foster this skill in teachers. The primary method for developing competencies in teachers, namely professional development opportunities, do not tend to focus explicitly on developing metacognitive awareness if at all. The research in this dissertation investigated the connection between teachers' metacognitive awareness and their participation in specific professional development programs. This section discusses research on professional development for teachers, in particular the goals of such programming, their essential components, their rationale, best practices, and limitations. As this section shows, professional development programs offer important opportunities for teachers to learn skills that will improve their teaching practice, but their effectiveness is limited by the fact that they often lack important characteristics, such as a focus on metacognition.

## Professional Development

Scholars generally agree that the primary goal of professional development is to enhance student learning by improving a teacher's knowledge, practices, collaboration, and recently metacognitive awareness (Avalos, 2011; Bransford et al., 1999; Guskey, 2003; Loucks-Horsley et al., 1998; Mundry, 2007; NCTAF, 1996; and WestEd, 2000). In short, professional development is intended to ensure that teachers receive essential skills aimed at improving student learning (WestEd, 2000). The literature presents numerous characteristics deemed essential for increasing the effectiveness of professional development (see Table 4) (Guskey, 2003; Mundry, 2007; Smylie et al., 2001; and WestEd, 2000). Based on Guskey's (2003) review of professional development literature, he determined that not all the literature agrees on specific characteristics of effective professional development. Additionally, Guskey (2003) indicates the lack of a direct connection between research-based characteristics of effective professional development and corresponding student achievement. Mundry (2007) points out that even without a consensus on characteristics of effective professional development, there is adequate knowledge about learning to "guide the design and implementation" of professional development programs (p. 1).

Professional development is widely agreed to be important for improving teacher practice. Professional development of teachers has been an increasing focus of school administrators and educational researchers. The focus from school administrators is a direct result of performance gains necessary for students to show improvements on high-stakes assessments (Pucheu, 2008). In order to improve students' scores, administrators seek out better ways to enhance student learning. Administrators frequently investigate ways for improving teacher's practices through implementation of professional development programs as a method for enhancing student learning. There are few options available for improving teacher practices other than professional development (Guskey, 2003). Research has shown that effective professional development of teachers has led to higher student achievement (Darling-Hammond, 1999; Guskey, 2003; Hirsh, 2003; Kelleher, 2003; and Scribner, 2003).

Literature, again suggests characteristics for effective professional development without directly linking specific characteristics to enhanced student learning (Guskey, 2003).

Table 4

*Components of Effective Professional Development*

| | Literature on Effective Professional Development | | | | |
|---|---|---|---|---|---|
| Components of Effective Professional Development | Smylie et al. (2001) | Mundry (2007) | Lock (2006) | Guskey (2003 & 1991) | WestEd (2000) |
| Clear and Challenging Goals | ✓ | ✓ | | ✓ | ✓ |
| Adequate Flexible Time that is well Structured and Organized | ✓ | ✓ | ✓ | ✓ | ✓ |
| Follow-up and Support | ✓ | ✓ | ✓ | ✓ | ✓ |
| Continuity and Coherence | ✓ | ✓ | ✓ | ✓ | ✓ |
| Research-based Learning | ✓ | ✓ | | ✓ | ✓ |
| Critical Reflection on Teacher Practices | ✓ | ✓ | ✓ | ✓ | ✓ |
| Evaluation and Feedback | ✓ | ✓ | | ✓ | ✓ |
| Engages Teachers (by focusing on how they learn) | ✓ | ✓ | ✓ | | ✓ |
| Collaboration (Learning Community) | ✓ | ✓ | ✓ | ✓ | ✓ |

Table 4 Continued

| | | | | | |
|---|---|---|---|---|---|
| Enhance Teacher Content Knowledge | ✓ | ✓ | ✓ | ✓ | ✓ |
| Enhance Teacher Pedagogical Knowledge | ✓ | ✓ | ✓ | ✓ | ✓ |
| Instills Change (Continuous Inquiry & Improvement) | ✓ | ✓ | ✓ | ✓ | ✓ |
| Focused on Student Improvement | ✓ | ✓ | | ✓ | ✓ |

**Technology and Engineering Professional Development**

The inclusion of engineering principles and problem solving has been a substantial modification to traditional industrial arts classes that focused on vocational skills (Avery, 2010; Clark, 1989; Hill, 2006; Lewis, 2004; & Sanders, 2001). The adaption of the field from manual arts to industrial arts, then to technology education, and more recently to technology and engineering education has been ongoing for the past century. New ideas, philosophies, attitudes, and remaining relevant in education have been the driving forces behind the adaption of the field. Custer, Daugherty, Zeng, Westrick, & Merrill, (2008); Lewis, (2004, 2005, & 2007); and Wicklein, (2006) along with many others highlighted the importance of teaching technology and engineering principles. However, teachers depend upon specific content knowledge and pedagogical content knowledge to successfully implement technology and engineering principles in their classroom (Bybee and Louks-Horsley, 2000; Custer et al., 2008; & Daugherty & Custer, 2012). According to Asunda and Hill (2007), teachers well trained in specific content and related pedagogy are able to effectively implement technology and engineering principles in their classrooms.

Technology and engineering professional development programs have typically focused on specific content knowledge and or pedagogical content knowledge (Avery, 2010; Bybee and Louks-Horsley, 2000; Custer et al., 2008; & Daugherty & Custer, 2012). According to Bybee and Louks-Horsley (2000) effective technology and engineering education teacher professional development should focus on four areas: (1) content knowledge; (2) pedagogical knowledge; (3) motivation, self-regulated learning; and (4) increased breadth and depth of professional development. In addition, the professional development should adhere to learners' diverse needs. "Such an approach should be informed by policy makers, teacher educators, school administrators, and the wider community by actively supporting such ventures through participation in research studies that seek to find out more on how we can improve teacher preparation practices as well as curriculum materials" (Asunda & Hill, 2007, p. 27). The technology and engineering education professional development literature describes many of the same characteristics recommended for effectiveness as less domain specific professional development literature. Again, technology and engineering education professional development literature tends to focus more on content knowledge and pedagogical knowledge for improving teacher's effectiveness than any other characteristic.

## Online Professional Development

Dede, Ketelhut, Whitehouse, Breit, and McCloskey (2009) echo the importance of teacher professional development heard in the less domain specific professional development literature. Dede et al. (2009) seem to indicate that online professional development could be the solution to the problems that traditional professional development programs face. Much work is needed if online professional development is expected to become the new norm for teacher professional development (Dede et al., 2009). Dede et al. (2009) synthesized the online professional development literature and research to make suggestions about specific areas in need of further research. Dede et al. (2009) identified five themes in their review of the online teacher professional development literature: (1) studies lacked clear and concise research questions, (2) terminology and assumptions were not clearly defined, (3) newer; more relevant outcome measures are needed, (4) measurement of resulting student improvement is lacking, and (5) studies should focus on building a collective understanding. Dede et al. (2009) presented four suggestions to accomplish the building a theme of collective understanding: (1) studies should draw on previous research, (2) research designs should make use of data streams, (3) much can be learned on professional development research from other domains, and (4) all studies should reflect on and help revise professional development theories. Dede et al. (2009) used their literature review to make seven suggestions for online teacher professional development research: (1) ask questions regarding teacher change, (2) research strategies that respond to both marketed and theoretical needs, (3) use diverse and thorough methods for analyzing, (4) improve the clarity, explicitness, scope, and overall research design, (5) take advantage of the unique data from online professional development programs, (6) collaborate, and (7) conduct high quality research.

Lock (2006) describes teacher professional development as a personal and organizational issue. Lock (2006) believes that the time is right to reimagine teacher professional development due to the increasingly younger, more technologically savvy teacher population. Lock (2006) describes online teacher professional development with many of the same effective characteristics of less domain specific professional development (see Table 4). The challenges in designing effective online professional development are also similar to more traditional methods of professional development (Dede et al., 2009 & Lock, 2006). One of the challenges, developing a collaborative learning community, is especially problematic considering that teachers may be in different states, time zones, or countries. Schmoker (2004 & 2006) and Mundry (2007) discussed the importance of establishing a learning community that enables teachers to collaboratively think about and reflect on practice. The distinctive challenges in online professional development will entail reimagining professional development (Dede et al., 2009 & Lock, 2006). Lock (2006) further points out that reimagined teacher professional development is not about piling new technology onto traditional methods. Lock (2006) indicates that for professional development to be reimagined it will require significant changes in the "current beliefs, practices, and routines and [will] transform current notions of professional development" (p. 675).

## Effective Professional Development

Literature has proposed various characteristics considered to be essential for the effectiveness of professional development programs (Guskey, 1991 & 2003; Mundry, 2007; Smylie et al., 2001; and WestEd, 2000). When designing professional development, these essential characteristics can be divided into either macro- or micro- level. The macro-level characteristics are large-scale and necessitate consideration in the early design stages. The micro-level characteristics are specific details about the professional development's content. The idea is that the micro-level characteristics instill change and promote the participant's accomplishment of macro-level goals. Guskey (1991) identified that the process of designing professional development is particularly complicated. Mostly due to the difficulty in the process for instilling change (Guskey, 1991). There are a multitude of factors, both macro- and micro-, that make the professional development design process complex (Fullan, 1982; Guskey, 2003 and Huberman & Miles, 1984). Due to the complex nature of professional development design and the overall complexity of the educational environment, it has been difficult to identify precise elements that make professional development effective (Guskey, 2003). However, the literature does offer explanations of macro- and micro- level characteristics that entail consideration during design of professional development (Fullan, 1990; Humberman & Miles, 1984; and McLaughlin, 1990).

**Macro-level**

Guskey (1991) presents five macro-level characteristics for professional development design: (1) recognize that change is an individual process, (2) think big; start small, (3) work in teams, (4) include procedures for personal feedback on results, and (5) provide continued support and follow-up. Guskey (2003) also determined five macro-level characteristics by reviewing the literature on effective professional development: (1) enhance teachers' content and pedagogical knowledge, (2) organized; structured; and directed time, (3) collaboration,

(4) evaluation, and (5) analysis of student learning data. The characteristic of providing adequate time receives substantial attention in the literature. Organized, structured, and directed time should be used by teachers to practice material covered, collaborate, share, and align with colleagues (Blackwell, 2003; Hirsh, 2003; Kelleher, 2003; Paez, 2003; and Scribner, 2003). The professional development timeline should provide time for teachers to evaluate and discuss their current ideas, beliefs, and perceptions of new materials covered by the professional development (Behar-Horenstein, Pajares & George, 1996; Darling-Hammond, Ancess & Falk, 1995; Guskey, 1989, 2003; Richardson, 2003; Thompson, Warren & Carter 2004).

All of the macro-level characteristics presented are further supported by other scholars and research in the overall design of professional development programs (Bybee & Loucks-Horsley, 2000; Humberman & Miles, 1984; Lock, 2006; Loucks-Horsley et al., 1998; McLaughlin, 1990; Mundry, 2007; Smylie et al., 2001; and WestEd, 2000). There are two more macro-level design characteristics commonly suggested in the literature: (1) long-term goals and (2) active learning (Desimone et al., 2002 and Learning First Alliance, 2000). Most importantly, the professional development should relate to students' learning needs and teacher's ability to address those needs (Guskey, 2003 and Sykes, 1999). Professional development that is unrelated to the teacher's needs and the perceived needs of their students will not invoke active teacher participation (Guskey, 2003 and Pucheu, 2008). All of these macro-level characteristics relate to increasing the effectiveness of the professional development, improving teacher practices, and enhancing student learning.

## Micro-level Content

The process of selecting content for professional development has been addressed by several researchers (Ball, Thames, & Phelps, 2007; Bybee & Loucks-Horsley, 2000; Daugherty & Custer, 2012; Loucks-Horsley et al., 1998; Guskey, 2003; Haney, Jing, Keil, & Zoffel, 2007; Mundry, 2007; and Wenglinsky, 2000). “You can develop the most elegant design for your professional development program, including all the important features outlined above, but unless you include the right content for the professional development, your resources and efforts will be entirely wasted” (Mundry, 2007, p. 6). The content is the micro-level characteristics that will help promote teacher’s progress towards change and accomplishing long-term goals. The most commonly discussed content from the literature includes: (1) higher order thinking (Wenglinsky, 2000), (2) pedagogical content knowledge (Ball et al., 2007 and Bybee & Loucks-Horsley, 2000), (3) content knowledge (Bybee & Loucks-Horsley, 2000 and Mundry, 2007), (4) self-regulation and reflection (Loucks-Horsley et al., 1998; Mundry, 2007; Pucheu, 2008; Schmoker, 2004; and Smylie et al. 2001) and (5) metacognition (Prytula, 2012 and Pucheu, 2008).

## Higher-order Thinking

There is an emphasis in the literature on engaging students in problem solving requiring higher-order thinking (Wenglinsky, 2000). This has led to studies exploring the requirement for teachers to learn pedagogical skills for implementing higher-order thinking problems in their curriculum. In one of these studies, Wenglinsky (2000) examined data from the National Assessment of Educational Progress (NAEP) that considered how teacher quality would improve by enhancing teacher practices. The teachers’ development of higher order thinking skills was shown in the data to improve student learning and performance. The research also indicated that adding cultural diversity into professional development could result in higher math scores for students (Wenglinsky, 2000). In addition, the research presented that when teachers increased the use of higher order thinking skills by incorporating hands on activities the students' NAEP science test scores increased. However, the research also indicated that less focused professional development training did not result in a substantial drop in student performance (Wenglinsky, 2000).

**Pedagogical Content Knowledge.**

Bybee and Loucks-Horsley (2000), Daugherty and Custer (2012), and Ball, Thames, and Phelps (2007) all focus on the importance of professional development designed to improve teachers knowledge base related to pedagogy. Knowing the material is not the only part of being able to teach the material (Bybee and Loucks-Horsley, 2000). Professional development must involve both subject content knowledge as well as pedagogical content knowledge (PCK) (Ball et al., 2007). In order to effectively educate students, Shulman (1987) stated that a teacher must possess PCK. Having PCK allows the teacher to effectively convey knowledge and skills to students. When looking more specifically at the disciplines of science, technology, engineering, and mathematics (STEM), there is specific PCK associated with these disciplines (Shulman, 1987). In order for a teacher to successfully facilitate student learning, they must have a deep understanding of educational standards, subject content, and PCK (Shulman, 1987). While making material relevant to students, PCK also allows the teacher to instruct students with diverse learning needs (Shulman, 1987). Professional development is the mode through which essential elements like PCK could be made accessible to teachers (Ball et al., 2007; Bybee & Loucks-Horsley, 2000; and Daugherty & Custer, 2012).

### Content Knowledge

Many of the professional develop programs designed within STEM disciplines have a direct focus on content (Bybee & Loucks-Horsley, 2000; Custer, Daugherty, Zeng, Westrick, & Merrill, 2008; Daugherty & Custer, 2012; Loucks-Horsley et al., 1998 and Mundry, 2007). The focus on content is often due to the rate of change in technology. Furthermore, technology teachers often lack basic science and mathmatics content knowledge required to successfully implement STEM content (Wheeler, Ross, & Bayles, 2005). This lack of basic science and mathematics content knowledge provides challenges in the classroom during integration of the STEM disciplines. One of the goals of STEM education is to offer a pathway for students into STEM fields. For this pathway to exist, STEM professional development should have a focus on required content knowledge. The literature indicates that the professional development should focus on knowledge and skills absent from the teacher's formal training (Bybee & Loucks-Horsley, 2000; Daugherty & Custer, 2012; and Wheeler et al., 2005). With the required knowledge and skills, a teacher may be more comfortable discussing scientific and mathematical principles naturally inherent in the STEM disciplines (Wheeler et al., 2005).

### Self-regulation and Reflection

Zimmerman (2002) defined self-regulated learning as "the self-directive process by which learners transform their mental abilities into academic skills" (p. 65). Zimmerman (2002) identified three phases of self-regulated learning and each phase has two areas. The three phases are: (1) forethought phase, (2) performance phase, and (3) self-reflection phase. Each phase happens at a particular time during the learning process. The forethought phase happens before the performance phase and the self-reflection phase happens after the learning process and performance phase. The two areas of the forethought phase are task analysis (setting goals and planning) and self-motivated beliefs (having expectations based on your beliefs). The two areas of the performance phase are self-control (imagery, self-instruction, attention focusing, and task strategies) and self-observation (self-recording and self-experimentation). The final phase, self-reflection involves self-judgment (self-evaluation and causal attribution) and self-reaction (adaptive/defensive and self-satisfaction/affect). Zimmerman believed that self-regulation happened in varying sequences based on the current learning scenario.

Pintrich (2004) presented four phases of self-regulated learning that appear similar to Brown's (1987) three phases as well as Zimmerman's (2002) three phases. The four phases Pintrich (2004) presented are: (1) forethought, planning and activation, (2) monitoring, (3) control, and (4) reaction and reflection. Pintrich (2004) expressed that the major difference between his, Brown's, and Zimmerman's phases was that his phases may happen concurrently. Pintrich (2004) noted that it was not uncommon for at least two of the phases to happen simultaneously and dynamically. Pintrich (2004) further divided each of the four phases into four areas including: (1) cognition, (2) motivation and affect, (3) behavior, and (4) context. As an example, a teacher may regulate their learning while in the reaction and reflection phase by making connections between the new material and prior knowledge (cognition), researching more about a topic (motivation and affect), deciding how to use new knowledge (behavior), and evaluating if new material is appropriate for their classroom (context).

Critical reflection, as identified by Mundry (2007), is a component of professional development that helps develop teachers' metacognition. Research has also shown that when professional development encourages critical reflection and discussion about material implementation there is improved student learning (Birman, Desimone, Porter, & Garet 2000; Cohen & Hill, 1998; and Weiss, Gellatly, Montgomery, Ridgeway, Templeton, & Whittington, 1999). Mundry (2007) mentions that professional development designers need to be aware that not all teachers will be ready or able to reflect critically on their practice. Schmoker (2004) discusses the importance of professional development that focuses on enabling the teacher to think about and reflect on practice. Mundry (2007) recognizes professional development strategies including case discussions, lesson study, and examining student thinking. The use of these strategies will promote teacher collaboration to share, think, and reflect on what has and has not been successful in their classroom.

**Metacognition**

An increased focus on student's metacognition has promoted interest in teacher's metacognition. The interest is the result of a belief that when teachers have metacognitive awareness, they will be better able to help students develop their metacognitive awareness (Harskamp & Henry, 2009; Kramarski & Michalsky, 2009; and Prytula, 2012). If students' metacognition continues to be a focus of educational reform, then professional development focused on improving teachers' metacognition will also continue to be a focus of reform and research. The importance of professional development that has a focus on metacognition has been discussed in the literature (Prytula, 2012 and Pucheu, 2008). "The ability to self-regulate learning is essential for teachers' professional growth during their entire career as well as for their ability to promote these processes among students" (Kramarski & Michalsky, 2009, p. 161). Furthermore, a report from the National Commission on Teaching for America's Future (1996), indicates that professional development often fails to enable teachers with the ability to transfer material covered in a professional development back to the classroom. Due to teacher's deficiency in metacognitive awareness they are unable to implement ideas or material covered in the professional development (Bransford et al., 1999; Graber, 1998; Palincsar & Brown, 1984; and Pucheu, 2008). Professional development designed with a focus on metacognitive awareness will help address the teacher's ability to transfer material back into the classroom (Bransford et al., 1999; Prytula, 2012; and Pucheu, 2008).

## Evaluation of Professional Development

Evaluation of professional development and teachers that participated in the professional development are important in the design of future professional development. "Research indicates that, regardless of the quality of the professional development training …, staff development does not automatically translate into the implementation of effective practices" (Bransford et al., 1999; Mosenthal & Ball, 1992; Sykes, 1999; and Wenglinsky, 2002 as cited by Pucheu, 2008, p. 6). An evaluation should also provide feedback in many forms (Guskey, 2002). The feedback can be used as a tool to guide the design of future professional development programs. Additionally, feedback from long-term implementation of new practices and material can be used by the teachers to improve their instruction. The goal of feedback is to provide information on the effectiveness of components in professional development, the results teachers experienced, and levels of student achievement. Various evaluation methods have been proposed by scholars.

Guskey (2002) describes five critical levels of professional development evaluation. The five levels are: (1) participants' reactions, (2) participants' learning, (3) organization support and change, (4) participants' use of new knowledge and skills, and (5) student learning outcomes. Time is absent from Guskey's (2002) five levels of professional development evaluation. However, Guskey (2003) does go on to say that time is important, indicating time should be well organized, carefully structured, and purposefully directed. Additionally, Guskey (2000) stated that thoughtful planning, the ability to ask good questions, and how to find valid answers are important aspects in the evaluation of professional development.

## Difficulties and Limitations of Effective Professional Development

The literature identifies what constitutes effective professional development and its impact on student learning, although not all of the literature agrees on the importance of each and every characteristic of professional development (Guskey, 2003; Paez, 2003; and Wenglinsky, 2000; 2002). Compounding the problem is little empirical evidence showing what characteristics produce successful results (Guskey, 2003). There are currently only suggestions about what should and should not be in the professional development. Guskey (1991) noted that there is more known about why professional development is ineffective than why it is effective.

Guskey (1991) identified that the process of designing professional development is particularly complicated. The process of instilling change is difficult; and change is what makes professional development design so complicated (Guskey, 1991). Furthermore, there are an abundance of factors, other than change, that make the professional development design process complex (Fullan, 1982 and Huberman & Miles, 1984). Due to the complex nature of professional development design and other complexities in the educational environment, it is difficult to identify precisely what characteristics make professional development effective.

Even if the professional development is high quality, there is no guarantee that material covered will be effectively implemented by teachers (Bransford et al., 1999; Mosenthal & Ball, 1992; and Sykes, 1999). Even with evidence supporting better forms of professional development, schools usually offer, nonspecific, short term, and often only single day workshops. With a lower cost, these generic professional development programs have become the norm (Darling-Hammond & McLaughlin, 1995; Little, 1993; and NCES, 2001). As well as money, other factors including motivation, incentive, and time must be dealt with to ensure design of effective professional development (Porter, Birman, & Garet, 2000; Smylie et al., 2001; Wenglinsky, 2000; and WestEd, 2000). Little (1993) reveals that teachers' aversion to professional development is the result of it lacking in continuity and consistency. The continued separation of teachers from the planning stages of professional development often makes teachers notice a disconnect between the perception and reality of their classrooms (Glickman, Gordon, & Ross-Gordon, 2004).

More often, teachers attend generic professional development workshops that last a day or less with no form of follow up (NCES, 2001). These generic short term workshops are the specific reason that alternative methods of professional development are being explored.

These alternative methods are not seeking to change the goal of professional development, but rather they are seeking to enhance the outcomes of professional development programs. When discussing professional development outcome improvements, the National Center for Education Statistics (NCES) (2001) found that only 12 to 27 percent of teachers improved their teaching after a professional development program. According to NCES (2001), a mere eight percent of teachers could recall a linkage between generic professional development programs and any form of school improvement. Teachers also reported that they were not excited about attending professional development. This seems to be consistent with the known teacher apprehension to attend generic professional development programs.

Another reason for teacher apprehension is related to the content covered in these generic short term professional development programs. Often, someone or some organization from outside the school presents new ideas about teaching that are amiss with classroom reality. These ideas frequently are not relatable to the teachers (Glickman et al., 2004). In addition, short term professional development does not provide enough time or resources for the teachers to develop a detailed enough understanding of material covered (Glickman et al., 2004). At the end of the professional development there is no long term support plan used to assist and evaluate a teacher's use of new ideas.

Another limitation of professional development programs--including the one in this dissertation research--is that metacognition is usually only unintentionally cultivated. Much of the literature agrees on required components for effective professional development. One of the components receiving recent attention in the professional development literature is metacognition (Prytula, 2012 and Pucheu, 2008). Having effective professional development programs, like Transforming Teaching through Implementing Inquiry, are still not enough to instill lasting change and skill growth in teachers. There are factors, such as metacognitive awareness, in addition to the effectiveness of professional development that will determine teachers' development (Bransford et al., 1999; Mosenthal & Ball, 1992; Prytula, 2012; Pucheu, 2008; Sykes, 1999; and Wenglinsky, 2002).

## Chapter Summary

The review of literature analyzed and detailed the literature as it pertains to metacognition and teacher professional development. In the first part of the chapter, metacognitive literature was used to detail metacognition, metacognitive awareness, and measures of metacognition. The history of metacognition was presented to show its connection to the human experience. The review presented Flavell (1976) as the first to conceptualize metacognition. Metacognitive awareness, it components, and subcomponents were presented and detailed. The measurement of metacognition was expressed as difficult and the literature suggesting mixed method investigation was analyzed. Evidence was presented supporting metacognition as a focal characteristic of teacher professional development programs. The review then detailed professional development.

Literature was used to highlight the primary goal of teacher professional development, improving student achievement. Literature from general, technology and engineering education, and online professional development was used to highlight components of effective professional development. The review then examined macro- and micro- level characteristics needing consideration during the design of effective professional development. The review also presented the idea that some of literature does not agree upon all characteristic for effective professional development. Numerous characteristics of effective professional development were identified as suggestions, not guarantees that the professional development will result in improved teacher ability. Reviewing professional development literature indicated that one of the characteristics receiving more recent attention is metacognition. The importance of evaluation and feedback in professional development was also described, followed by the challenges and limitations of professional development. Finally, this chapter has provided a review of literature on metacognition and professional development essential to the research in this study.

# CHAPTER THREE: METHODOLOGY

Chapter three explains the methodology used in this convergent complementarity mixed methods study. The purpose of this study was to understand the impact of professional development on technology and engineering teachers' metacognitive awareness, as well as to measure the differences in teachers' metacognitive awareness based on their participation in either Transforming Teaching through Implementing Inquiry (T2I2) or National Board for Professional Teaching Standards (NBPTS) professional development. First, the chapter presents the research questions. Next, a rationale for and a description of the study design is presented; followed by a description of the domain and participants. Then, it presents the data collection procedures, including the instruments used for data collection: metacognitive awareness inventory (MAI) and semi-structured open-ended metacognitive awareness interview (see Appendix A & B). Finally, it describes the quantitative and qualitative techniques used to analyze the data.

The independent variable in this study was technology and engineering teachers' participation in professional development, and the measured dependent variable was participants' metacognitive awareness. The participants were divided into three groups based on their involvement in professional development. Group one was comprised of teachers who actively participated in the T2I2 professional development system; group two was comprised of teachers who were selected but did not actively participate in the T2I2 professional development system; and group three was comprised of teachers who had received National Board Certification (NBC) in career and technical education (CTE) from the NBPTS. The control variables were teaching experience, gender, certification path, highest degree earned, and grade level taught. Several extraneous variables that could have impacted participants' metacognitive awareness were not measured in this study.

## Research Questions

The primary goal of the study was to understand the role that professional development has in impacting technology and engineering teachers' metacognitive awareness. The secondary goal of the study was to measure the differences in technology and engineering teachers' metacognitive awareness based on their participation in two types of professional development. The final goal was to describe the essence of each group's metacognitive awareness. The central and secondary research questions were the following:

1. What effects did T2I2 online professional development system have on STEM teachers' metacognitive awareness?
    a. How did technology and engineering teachers who actively participated in T2I2 online professional development system compare to NBC technology and engineering teachers in terms of metacognitive awareness?
    b. How did technology and engineering teachers who did not actively participate in T2I2 online professional development system compare to NBC technology and engineering teachers in terms of metacognitive awareness?
    c. What is the essence of technology and engineering teacher's metacognitive awareness while performing established teacher practices?

The central research question was derived from research that indicated the need for professional development that focused on teachers' metacognition (Lin et al., 2005; Prytula, 2012; and Wilson & Bai, 2010). Metacognitive awareness is an important component of teacher professional development because when teachers are metacognitively aware, they are better able to help students develop metacognitive abilities (Harskamp & Henry, 2009; Kramarski & Michalsky, 2009; and Pucheu, 2008). According to Kramarski & Michalsky (2009), “The ability to self-regulate learning is essential for teachers’ professional growth during their entire career as well as for their ability to promote these processes among students” (p. 161). The secondary research questions *a* and *b* guided the comparisons among the three groups in order to further identify the impact of professional development on teachers’ metacognitive awareness. The final secondary research question was answered by compiling the results from the MAI and metacognitive awareness interview to describe the essence of the group’s metacognition during common teacher practices.

## Study Design and Rationale

The rationale for the design of the study was based primarily on two factors: the review of literature and the connection between T2I2 and NBPTS professional development as well as their hypothesized connection with metacognition. Together, these factors helped to form the essential elements of the study design.

The literature indicated that metacognitive research often focuses on students’ thinking and regulation, due to the belief that metacognitive awareness helps students to become better, more self-regulated learners (Harskamp & Henry, 2009; Perfect & Schwartz, 2002; and Robson, 2006). Recently, however, the focus of research on metacognition has shifted from the students to the teacher (Prytula, 2012 and Pucheu, 2008) because teachers who lack metacognitive awareness are unable to help students develop their metacognitive awareness (Harskamp & Henry, 2009; Kramarski & Michalsky, 2009; and Pucheu, 2008). If a teacher does not possess the required metacognitive awareness, they will be unable to instruct students through the development of their metacognitive awareness. Teacher professional development has received attention as an available method to strengthen teachers' metacognitive awareness (Bransford et al. 1999 and Prytula, 2012).

Research further indicates, however, that measuring metacognition is difficult (Akturk & Sahin, 2011 and Schraw, 2009). In designing this study, previous studies provided information on common methods for measuring metacognition (Akturk & Sahin, 2011; Prytula, 2012; and Pucheu, 2008). The literature comprising the foundation of these studies was used to weigh the strengths and weaknesses of different methods in measuring metacognition (Pintrich & De Groot, 1990; Schraw & Dennison, 1994; Thomas, 2003; Veenman et al., 2006; and Zimmerman & Martinez-Pons, 1992). Researchers have expressed that the use of more than one method for measuring metacognition may counteract the weaknesses in any one measure with the combined strengths of multiple measures (Akturk & Sahin, 2011; Creswell, 2014; and Veenman et al., 2006). Measuring metacognition using multiple methods provides a more complete understanding of the phenomenon (Bryman, 2006 and Schraw, 2009). Thus, this study used two different measures of metacognitive awareness.

The present study was informed not merely by the metacognitive literature, but also by research design literature. Specifically, this study used a convergent complementarity design, which is a type of mixed method study (Creswell, 2007 & 2014 and Creswell & Plano, 2007). In a complementarity study, quantitative and qualitative methods are used to strengthen the comprehension of a single complex phenomenon (Greene et al., 1989). The use of a complementarity design in this study allowed for an improved understanding of participants' metacognitive awareness. Other than complementarity, two types of mixed methods designs were originally considered, convergent and sequential; a convergent design was selected due to time constraints, as well as the expected outcomes, the integration of the data, and timing of the data collection (Creswell, 2014). As a convergent design, the analysis of the quantitative and qualitative data was performed separately, with the metacognitive awareness interviews conducted after the participants completed their MAIs. The quantitative and qualitative data were then merged for comparative analysis to determine the convergence and divergence of metacognitive awareness components measured by the interview and MAI (Creswell, 2014). The overlapping of the quantitative and qualitative measures provided a deeper, more complete understanding of the participants' metacognitive awareness (Bryman, 2006).

In addition to the literature, further justification for this study design was provided by the connection among T2I2 and NBPTS professional development as well as the hypothesized connection with metacognitive awareness. T2I2 professional development is aligned with the NBPTS, as demonstrated by alignment between T2I2 learning objects and NBPTS CTE standards as well as the teacher artifacts and rubrics used to evaluate the artifacts. Both T2I2 and the NBPTS professional developments are concerned with teachers' metacognition, even if the professional developments do not mention metacognition explicitly. The NBPTS measures teachers' metacognitive awareness using rubrics to evaluate teacher artifacts; these artifacts require the teacher to have a level of cognitive knowledge to complete cognitive tasks requiring critical reflection, self-evaluation, and self-regulation (CREDE, 2002). Thus the NBPTS evaluates teachers on their metacognition (CREDE, 2002 & Lustick & Syles, 2006). Due to T2I2 professional development using some of the NBPTS artifacts and having a national board evaluator rate the artifacts, T2I2 is also evaluating metacognitive components.

**Quantitative Rational**

The use of the MAI in this study was supported by research. In 2008, Pucheu evaluated teachers' ability to implement scoring rubrics by using the MAI, the Scoring Rubric Inventory (SRI), observations, and interviews (Pucheu, 2008). Pucheu (2008) believed that a teacher's metacognition determined their ability to implement scoring rubrics with student assignments. In Pucheu's (2008) study, the two research questions were as follows: (1) Is there a relationship between the SRI and MAI? (2) How do the self-reported levels of implementation compare to the actual levels of implementation as noted in observations and interviews? Comparisons were made between the MAI and SRI as well as the interviews and observations. Due to the MAI not being a normed instrument (Schraw, 2000 & 2007), SRI scores were converted to z-scores for comparison. Using 68 participants, Pearson Product Moment correlations were calculated and used to compare the SRI to the MAI. At an alpha level of .05, there were five significant correlations, including the following: SRI to MAI ($p < .253$); SRI to MAI Knowledge of Cognition ($p < .279$); SRI to MAI Procedural Knowledge (.331); SRI to MAI Conditional Knowledge ($p < .268$); and SRI to MAI Evaluation ($p < .283$) (Pucheu, 2008). The significant pairings did not have strong correlations between the MAI and SRI. Pucheu (2008) indicated that during the qualitative portion, 11 of 12 randomly selected participants from the original 68 had accurately self-reported their implementation of scoring rubrics.

The Kruskal-Wallis one way analysis of variance by ranks was used to compare grouped participant's metacognitive awareness. The Kruskal-Wallis test was selected based primarily on three reasons: (1) ability to compare two or more independent groups, (2) small sample size of this study resulting in non-normally distributed data, and (3) the ranking of data to decrease impact of outliers (Sheskin, 2004). The Kruskal-Wallis test is designed to be used with two or more independent samples. The Kruskal-Wallis is consider an extension of the Mann-Whitney U test for comparing two independent samples (Sheskin, 2004). The result of comparing two independent samples using the Kuskal-Wallis will be equivalent to the result of the Mann-Whitney U test comparing the same samples (Sheskin, 2004). The Kruskal-Wallis test operates under the assumptions of randomized selection of participants, group independence, continuous variable, and homogeneity of variance. When using a nonparametric statistic like the Kruskal-Wallis test many researchers believe there is an increased importance placed on validating the assumptions (Sheskin, 2004). However, the continuous variable assumption is frequently not adhered to (Sheskin, 2004). Additionally, researchers commonly fail to check homogeneity of variance. There are several statistical tests that measure homogeneity of variance. Most commonly with a Kruskal-Wallis test is the nonparametric Levene's test (Sheskin, 2004). The null hypothesis of the Kruskal-Wallis one way analysis of variance by ranks is that the mean rank scores of group one equals the mean rank scores of group two equals… continued for all *k* groups (Sheskin, 2004).

In order to test homogeneity of variance in the context of the Kruskal-Wallis test, the nonparametric Levene's test was used. The two most common tests for homogeneity of variance are the Levene's test and the Brown-Forsythe test (Sheskin, 2004). The Levene and the Brown-Forsythe test would have similar results. The Brown-Forsythe test is sometimes selected due to being less impacted by the violation of the normality assumption (Sheskin, 2004). The nonparametric Levene's test compares the absolute difference of the ranked scores of each participant's metacognitive awareness and the mean of the rank scores. The nonparametric Levene's test is considered the most powerful and robust test for homogeneity of variance with non-normal distributed data (Nordstokke & Zumbo, 2010). The null hypothesis of the nonparametric Levene's test is that the variances are equal.

**Qualitative Rational**

The metacognitive awareness interview was designed to gather a more complete perspective of the participant's metacognitive awareness (Bryman, 2006; Creswell, 2007; and Denzin & Lincoln, 1994). The semi-structured and open-ended characteristics of the interview enabled participants to provide an uninfluenced depth to their responses and promoted emergence of themes and patterns stated by the interviewee (Akturk & Sahin, 2011; Creswell, 2007; and Denzin & Lincoln, 1994). Using interviews with broad open-ended questions to investigate metacognition was supported by the literature (Akturk & Sahin, 2011 and Prytula, 2012). The metacognitive awareness interview consisted of nine primary questions (see Appendix B). Additional questions were only used as guidance for the interviewee if the interviewer felt they were straying from the focus of the question. Literature supported listening to the interviewee with as few interruptions to their responses as possible (Denzin & Lincoln, 1994; Creswell, 2007; and Prytula, 2012).

The use of the phenomenological component was, like the use of the MAI, supported by research. In 2012, Prytula used interviews in a phenomenological qualitative study to gain understanding of how teachers in a professional learning community (PLC) described their metacognition, their development of metacognition, and the impact of metacognition on their work (Prytula, 2012). Prytula (2012) believed that metacognitive experiences happened during PLCs and were impacting teachers' metacognitive abilities. Successful PLCs offer an environment where teachers can have metacognitive experiences (Prytula, 2012). The purpose of the PLCs in the study was to transform teachers' knowledge, growth, and practice (Prytula, 2012). The PLCs involved teacher collaboration in problem-solving scenarios. In order to solve the problems, teachers had to communicate, reflect, work together, and consider implementation of possible solutions. The phenomenological approach was selected to achieve a comprehensive understanding of teachers' experience with metacognition during the PLCs. Prytula conducted pre-interviews, semi-structured interviews, and several other forms of informal contact with three participants. The focus on three participants allowed for a more complete understanding of each teacher's metacognition. Prytula (2012) found that an effective PLC was an environment for teachers' metacognitive development. Prytula (2012) also determined that a teacher's metacognition impacted their ability to learn as well as to influence the learning of others.

A phenomenological approach was selected for the qualitative portion of this study to describe the essence of the participant's metacognitive awareness related to their teacher practices. (Creswell, 2007). As a complementarity study, both the quantitative and qualitative methods measure the same complex phenomenon (Creswell, 2007). To ensure that the qualitative interview complemented the MAI, the interview was modeled based on the MAI and its components. Questions from the metacognitive awareness interview, asked the participants to detail the essence of their thinking during cognitive tasks including planning, monitoring, organizing, information management, debugging, and evaluating. Participant's ability to describe their mental phenomenon was used to indicate a level of metacognitive awareness (Georghiades, 2004, p. 374). The metacognitive awareness coding rubric was used to determine each participant's level of knowledge and regulation of cognition based on their answers to the interview questions. The coding rubric was also generated based on the metacognitive awareness subcomponent definitions from literature surrounding the MAI. The qualitative portion was used to offer breadth and depth to the analysis of participant's metacognitive awareness (Akturk & Sahin, 2011; Creswell, 2003; and Denzin & Lincoln, 1994).

## Domain and Participants

The study was conducted in the fall of 2014 with technology and engineering teachers from three states: Illinois, North Carolina, and Virginia. A total of 73 state-certified technology and engineering teachers were initially identified for possible participation in the study; each teacher was connected to either T2I2 or NBPTS professional development. Of the 73 teachers who were initial identified, 30 were randomly selected to participate. The 30 teachers received an email explaining the study and requesting their participation. A total of 21 teachers responded with interest in participating with the study (N=21). Of the 21 teachers, 3 completed just the MAI and 18 completed both the MAI and the metacognitive awareness interview (N=18).

The participants formed three groups: (1) teachers who actively participated in the T2I2 professional development system, (2) teachers who had been selected for but did not actively participate in the T2I2 professional development system, and (3) teachers who had received NBC in CTE from the NBPTS. Group one had eight teachers; group two had six teachers; and group three had seven teachers. Each group had six participants that completed both the MAI and the metacognitive awareness interview. Participants in groups one and two applied and were randomly selected for participation in the T2I2 professional development pilot years one or two. The participants in group three were identified through the NBPTS's website. All NBC teachers, their states, counties, certification areas, and certification expiration dates were listed. Teachers on the list were filtered by state and by CTE certification area. The researcher determined that teachers certified by NBPTS in CTE may not have a technology and engineering state teacher certification. Included in the list of 73 possible participants were teachers with valid NBPTS certification in CTE and who were currently teaching technology and engineering education in one of the three states.

The reason for including groups one and two in this study was that the literature indicated a gap in research on teacher metacognition, especially in terms of professional development (Bransford et al., 1999; Pucheu, 2008 and Prytula, 2012). This study's investigation of T2I2 and NBC teachers was based on the nearness of the connection between T2I2, NBPTS, and teachers' metacognitive awareness. Group three, which was comprised of teachers who had received NBC, was included in the comparisons of this study for two reasons. First, T2I2's 17 learning objects are aligned with the 13 CTE standards from the NBPTS (Ernst et al., 2013). Teachers who participate in T2I2 professional development system are asked to complete shorter versions of six NBPTS teacher artifacts required for NBC; these artifacts submitted by T2I2 participants are evaluated by a national board assessor using rubrics provided by the national boards (Ernst et al., 2013). The second reason for this study's inclusion of teachers who had received NBC was that since 1987, NBC has been the highest measures of teacher quality and certification (Lustick & Sykes, 2006).

The demographics considered in the study were years of teaching experience, gender, grade level taught, certification path, highest degree earned, and percentage of T2I2 completed. Fifty-seven percent of the subjects in the study were male, and 43% were female. Sixty-seven percent of the subjects in the study were lateral-entry certified teachers, and 33% had been traditionally state certified as technology and engineering teachers. Sixty-one percent of the subjects in the study taught high school, and 39% taught middle school. In addition to each participant having a bachelor's degree, 78% had received master's degrees, and one participant from group three had received a doctorate. The participants' amount of teaching experience ranged from 5 years to 34 years. Group one had an average of 20 years of experience, group two had an average of 17.3 years of experience, and group three had an average of 21.5 years of experience. Group one teachers had completed anywhere from 20% to 100% of T2I2. Seventy-five percent of group one teachers had completed 100% of T2I2. Group two teachers had completed 0 to 11 percent of T2I2. Seventy-five percent of group two teachers had completed 5% or less of T2I2.

## Data Collection Procedures

The study was conducted over a sixteen-week period during the fall 2014 semester. The quantitative data was collected using Schraw and Dennison's (1994) self-reported questionnaire, the MAI. The qualitative data was collected using a semi-structured interview (Creswell, 2007). The MAI and a metacognitive awareness interview were used to measure participants' metacognitive awareness. The research timeline is shown in Table 5.

Table 5

*Research Timeline*

| | | | |
|---|---|---|---|
| Week 1 | Tuesday | September 23rd | IRB Approval |
| | Wednesday | September 24th | Solicit Participants |
| Week 2 | Monday | September 29th | Start Collecting Quantitative Data |
| Week 3 | Thursday | October 9th | Start Collecting Qualitative Data |
| | Friday | October 10th | Begin Transcribing Interviews |
| Week 8 | Friday | November 14th | Finish Collecting Qualitative Data |
| | Saturday | November 15th | Finish Transcribing Interviews |
| Week 9 | Monday | November 17th | Begin Open-Coding |

Table 5 Continued

| | | | |
|---|---|---|---|
| Week 11 | Wednesday | December 3rd | Finish Collecting Quantitative Data |
| Week 12 | Monday | December 8th | Retrain Coders<br><br>Begin Axial-Coding<br><br>Begin Analysis of Data |
| Week 16 | Friday | January 8th | Finish Coding<br><br>Finish Analysis of Data |

**Informed Consent**

The study began with the Institutional Review Board (IRB) approval on September 23, 2014, and continued until January 8, 2014 (see Table 5 & Appendix C). In compliance with the IRB Human Subjects Committee guidelines, this study was conducted under the supervision and approval of the North Carolina State University (NCSU). As the guidelines for human subjects require, the risks to subjects participating in the study were minimal. The risks to the subjects were reasonable in relation to expected benefits. The selection of all participants was equitable. Participants were identified based on their participation in either T2I2 or NBPTS professional development. A total of 73 possible participants were identified, 36 possible from T2I2 professional development and 37 possible from NBPTS professional development. The subjects were autonomous, and efforts were made to ensure the protection, rights, and welfare of all participants. Additionally, all subjects were provided with an informed consent email in regards to their participation in this study (see Appendix D). The participants were informed that they could stop participation at any point. Participation in the study was optional.

**Overview of Data Collection Process**

After participants made an informed decision to participate, each was assigned a unique identifying number. The participant's MAI, interview recording, and interview transcript were encrypted with the unique number. The participants were sent the MAI in an email. In the email, the participants were asked to specify a phone number, date, and, time for the one-hour interview. Once all the MAIs were returned, the analysis of the quantitative data began with the entering of participants' self-reported values on the MAI into Statistical Package for the Social Sciences (SPSS). After entering the data, it was checked to determine whether it violated the assumptions of the Kruskal-Wallis test. The randomized selection of participants, group independence, and continuous variable assumptions were easily verifiable. The assumption of homogeneity of variance required the use of the nonparametric Levene's test (Sheskin, 2004). The Kruskal-Wallis test was then used to compare the groups' metacognitive awareness. After the participants completed and returned the MAI, they were called at the date and time they specified. In four cases, attempts to reach the participant failed. Each of the four participants were sent an email asking them to reschedule the interview.

In this study, the quantitative data collection was proceeded by qualitative data collection. At the beginning of the interview, each participant was informed that the interview would be audio recorded. In an attempt to build rapport with the interviewee, the interviewer started by asking questions about the participant's background and experience (Burke & Miller, 2001). The interview was open-ended and semi-structured, allowing the interviewee to answer the nine primary questions with detailed explanations (Creswell, 2007 & 2014). Additional guiding questions were used to help the interviewee provide sufficient detail regarding aspects of their metacognitive awareness (Glesne, 2010 & Patton, 1990). The following sections describe the quantitative and qualitative data collection procedures in greater detail.

**Metacognitive Awareness Inventory**

The MAI consists of two main components and eight sub-components of metacognition, rated at five levels of awareness. Each one of the 52 questions aligns with one of the eight sub-components.  One main component is Knowledge of Cognition and includes the following sub-components: Declarative Knowledge, Procedural Knowledge, and Conditional Knowledge. The other main component, Regulation of Cognition, includes the following components: Planning, Organizing, Monitoring, Debugging, and Evaluating. The five levels of awareness are "Always True" (5), "Sometimes True" (4), "Neutral" (3), "Sometimes False" (2), and "Always False" (1).

In 1994, Schraw and Dennison explained the purpose, development, and testing of the MAI in the article, "Assessing Metacognitive Awareness" (Schraw & Dennison, 1994). Prior to the MAI, nearly all experimental research that focused on identifying metacognitively aware individuals required extensive time due to the use of observations, questionnaires, and interviews.  Schraw and Dennison (1994) sought out a faster and more reliable measure of metacognitive awareness. The result was the MAI, an easy-toadminister, self-reported, 52-question inventory. After generating the MAI, Schraw and Dennison (1994) performed two experiments to check the reliability of the instrument. The first experiment asked 197 college students to complete the MAI. The average completion time was roughly ten minutes. A two factor analysis was used to compare the data to the two metacognitive components, Knowledge of Cognition (Jacobs & Paris, 1987) and Regulation of Cognition (Brown, 1987). The two factor analysis revealed that both knowledge and regulation of cognition components were highly correlated, $r = .54$, coefficient α for item loading on each component reached .91 and the coefficient α for the entire instrument reached .95 indicating a high degree of internal consistency. The results of the first experiment indicated that the MAI measured both metacognitive components reliably. The second experiment asked 110 college students to take the MAI. A two-factor analysis revealed that both components were again correlated at $r = .45$, and the coefficient α reached .88 for both the knowledge and regulation of cognition components, and the coefficient α for the entire instrument reached .93 indicating a high degree of internal consistency. Schraw and Dennison (1994) stated that their results suggested the components knowledge of cognition and regulation of cognition function concurrently.

In this study, the purpose of the MAI was to collect quantitative data on participants' current level of metacognitive awareness. The data was used to compare the three groups on their metacognitive awareness. Additionally, the groups were compared based on the two components and eight subcomponents of metacognitive awareness. Schraw and Dennison (1994) indicated that the MAI provided a "reliable initial test of metacognitive awareness" when used with adults (p. 472). The MAI has been identified as the only currently available, reliable psychometric measure ($\alpha = .90$, Schraw and Dennison, 1994) that focuses on metacognitive awareness (Baker & Cerro, 2000 and Pucheu, 2008).

The positive attributes of the MAI are its practicality, reliability, compactness, efficiency, and ease of use (Baker & Cerro, 2000; Pucheu, 2008; and Schraw, 2000). However, the challenges of using a self-reported questionnaire such as the MAI include the potential for participants' dishonesty, reluctance to share, and inability to fully understand the questions (Baker & Cerro, 2000). Despite these challenges, questionnaires remain the most frequently used metacognitive data collection technique due to their usability and participant normalization (Akturk & Sahin, 2011). Questionnaires allow researchers to collect reliable data from larger groups of individuals in less time, even in difficult situations (Pintrich & DeGroot, 1990 and Tobias & Everson, 1996). Questionnaires, unlike interviews, help normalize the individuals, thus allowing for more direct comparisons between and within groups (Akturk & Sahin, 2011).

**Metacognitive Awareness Interview**

For the qualitative portion of the study, a phenomenological approach was used (Creswell, 2007). As with all phenomenological research, the goal was to describe the essence of an event (Creswell, 2007). During the metacognitive awareness interview, participants were asked to detail the essence of their thinking while completing fundamental teacher responsibilities. The participant's ability to describe their mental phenomena was used to indicate the level of their metacognitive awareness (Georghiades, 2004). The nine questions in the metacognitive awareness interview focused on participants' knowledge and regulation of thinking during the planning, organizing, monitoring, debugging, and evaluating of tasks.

The semi-structured and open-ended qualities of the interview enabled participants to provide in-depth responses (Akturk & Sahin, 2011 and Creswell, 2007). Additionally, these qualities allowed the interviewer to direct the interviewee towards addressing concepts that required more breadth or depth (Denzin & Lincoln, 1994). Using the interview to gather a more complete perspective of the participants' metacognitive awareness promoted the emergence of themes and patterns stated by the interviewee during coding (Bryman, 2006; Creswell, 2007; and Denzin & Lincoln, 1994).

A positive attribute of the qualitative portion was to offer breadth and depth to the data (Akturk & Sahin, 2011; Creswell, 2003; and Denzin & Lincoln, 1994). The interviewer's ability to determine when to direct the interviewee toward a broader or more in-depth explanation was essential to gathering pertinent data (Creswell, 2007; Burke & Miller, 2001). Knowing the appropriate time to direct the interviewee with a guiding question or when to listen was a challenge for the interviewer (Burke & Miller, 2001). Another challenge was the time that interviews required of the researcher and the participants (Scott, 2008). The participants had to contribute their own time, often outside of their normal classroom time (Scott, 2008). The researcher had not only to complete the interview, but also the analysis, which added considerable additional hours of work (Creswell, 2007). The analysis of an interview often requires transcribing the interview and coding specific patterns

(Creswell, 2007). The time requirement innate in collecting and analyzing interview data is a negative aspect of interviews.

The metacognitive awareness interview in this study consisted of nine primary questions. Questions 1 and 2 were about planning for instruction and assessment. Question 3 dealt with the participant's organization. Question 4 was broken into three questions dealing with information management: one question about information management in general, and two questions that were specific to a scenario entailing information management. In the metacognitive awareness literature, information management falls under organization (Schraw & Dennison, 1994). However, the complexity of both information management and organization led the researcher to decide that there should be two separate questions on these concepts. Questions 5 and 6 asked the participant about monitoring during instruction and assessment. Question 7 dealt with the teacher's debugging and adjusting during instruction. Question 8 required only a yes or no answer. Question 9 was about the teacher's reflection and self-evaluation. Additional questions were used to guide the interviewees whenever the interviewer felt they were straying from the focus of the question at hand.

## Data Analysis Procedures

The quantitative and qualitative data were first analyzed separately. The analysis of the quantitative data from the MAI was conducted in SPSS, using the Kruskal-Wallis test to compare the three groups. The Mann-Whitney U test was considered for comparing one group to another. However, it was determined that the result from the Kruskal-Wallis one-way analysis of variance by ranks, when the number of groups is equal to two, would be equivalent to the results from the Mann-Whitney U test (Sheskin, 2004). The analysis of the qualitative data occurred in two stages. First, the interviews were read, open-coded, and then axial-coded by two trained coders (Creswell, 2007). The participants' responses were ranked by the coders using the coding rubric. Second, SPSS was used to analyze the inter-rater reliability. Cohen's kappa was used to determine the agreement between rater one and rater two (Sheskin, 2004). Cohen's kappa was used for its inclusion of chance in the calculation of the resulting value and because Cohen's kappa is appropriate when two raters are present (Sheskin, 2004). After the quantitative and qualitative data were analyzed, the analyses were merged with a comparative analysis. During the analysis, quantitative and qualitative results of metacognitive awareness, its components and sub-components were analyzed to determine whether they converged or diverged. The comparison added to the profundity of the understanding of each group's metacognitive awareness.

**Quantitative Analysis**

The participants' level on the MAI were determined by the mean of their responses to the 52 items. Each participant's metacognitive awareness was the mean of their responses to the 52 items on the inventory. To determine participant's awareness of their knowledge of cognition, the mean value was calculated based on the person's answers to the 17 questions that aligned with the knowledge component (see Appendix A). The participant's awareness in the regulation of cognition component was the mean value of the other 35 items on the inventory that aligned with the regulation component (see Appendix A). The mean value was also determined for each sub-component based on the aligned questions. The groups were compared on metacognitive awareness, its components, and sub-components using the Kruskal-Wallis test.

The data was checked to verify the validity of each assumption in the Kruskal-Wallis test. The participants were randomly selected. Each group was independent from other groups. Metacognitive awareness is not a continuous variable when using the MAI; the continuous variable assumption is often not adhered to during the Kruskal-Wallis test (Sheskin, 2004). The final assumption was homogeneity of variance. The nonparametric Levene's test was used to validate the homogeneity of variance assumption (Sheskin, 2004).

The Kruskal-Wallis test was used to compare the groups on eleven items from the MAI, including the following: (1) metacognitive awareness, (2) regulation of cognition, (3) knowledge of cognition, (4) planning, (5) monitoring, (6) organizing, (7) evaluating, (8) debugging, (9) declarative knowledge, (10) procedural knowledge, and (11) conditional knowledge. The Kruskal-Wallis test was used four times for the different group combinations: (1) groups 1, 2, and 3; (2) groups 1 and 2; (3) groups 2 and 3; and (4) groups 1 and 3. Using SPSS to calculate Kruskal-Wallis produced a chi-square value that could be used to calculate an effect size estimate also known as eta-squared. The effect size estimate determined the percent of variability in the rank scores from the Kruskal-Wallis test, and it accounted for differences in the teachers' metacognitive awareness based on their participation in professional development. In this study, the effect size was used to represent the strength of the relationship between the independent and dependent variables.

## Qualitative Analysis

After the interviews, the audio recordings were transcribed for two purposes. The first was to make the inquiry into participant's metacognition more efficient. The second was to check the inter-rater reliability of the coded transcriptions. Personal or identifying information was removed from each transcript. Based on the question number, the transcripts were bracketed for coding purposes. Each transcript was open and axial coded by two trained coders with the use of a coding rubric (see Appendix B) (Creswell, 2007). The coders first read and then open-coded the interviews using a pink highlighter. The researcher read the open coding and determined that additional training was required for the coders axial-coding. During axial-coding, blue highlighters were used to code the regulation of cognition components, and a yellow highlighter was used to code the knowledge of cognition components. Pens were used to take notes, indicate participants' level, and to write a synopsis about each participants overall apparent level of metacognitive awareness.

Two coders were selected based on their experience in teaching and qualitative research. Coder one has taught for several years including at elementary, middle, and high school as well as at the collegiate level. Coder one has also been involved numerous times in the analysis of qualitative research data. The second coder spent the majority of their teaching career at the elementary and middle school level. The second coder frequently performed qualitative data collection and analysis, usually involving their students.

The complementarity portion of the design was selected due to the quantitative and qualitative methods complementing each other. This included the focus of the metacognitive awareness interview and the coding rubric. The interview and coding rubric were designed based on the metacognitive literature. The descriptions of evaluated items from the interview were listed in the rubric. These descriptions are the definitions of each of the subcomponents of metacognitive awareness presented by Schraw and Dennison (1994). The coding rubric was organized according to the questions in the metacognitive awareness interview and the components of metacognitive awareness. The rubric had five levels of awareness: “High Level” (5), “High to Medium” (4), “Medium” (3), “Medium to Low” (2), and “Low” (1). Although the rubric did not have a “No Level” (0) of metacognitive awareness, the coders both used a zero at times to indicate no level of awareness.

The processes for analyzing the transcribed interviews began by reading the interviews. The coders had to be taught the techniques to use for open- and axial-coding. The coders were given background information about metacognition. The information included the definitions for metacognitive awareness and its components. Additionally, examples of words were given as something the participant might say or be discussing when they are being metacognitive. The words were action verbs from the Revised Bloom’s Taxonomy (Anderson & Krathwohl, 2001). The coders were then asked to open-code the interviews. Each coder spent about two hours open-coding each interview. During open coding, the coders were asked to code sections that they thought indicated metacognitive items. The open coding helped the coders to become familiar with each participant. As teachers, the coders often focused on sections of the interviews where the participants described familiar or enthralling teaching techniques. Not much was learned in terms of metacognition during open-coding due to the coders focusing more on attractive concepts rather than metacognitive awareness.

To help prevent the coders from focusing on items outside of metacognitive awareness, additional training was implemented. The coders were assisted in axial coding two interviews. The training of the coders was done by letting them code one question and component at a time. The assistance involved discussing what the coder was coding and whether it aligned with the coding rubric. Before a level was assigned to a participant's response, the coders were asked to determine if the level from the rubric aligned the each participant's response. The process of discussing assigned levels was done for two of the interviews. During the discussion of assigned levels on the second interview, it was determined that the coders were adequately trained. The coders then began axial coding the interviews independently using the coding rubric. The coders were still able to ask questions during their coding for the rest of the interviews.

The axial coding took at least two hours for each interview. During the axial coding, each coder had a different technique for coding. One coder would read each response to a question and code the regulation of cognition followed by the knowledge of cognition. The other coder would code the entire interview for regulation of cognition and then start back at the beginning, coding for knowledge of cognition. The coding rubric was used as a guide for what items should be coded during the axial coding. After each question in the interview was coded, a level from zero to five was assigned by the coder to the participant's response based on the rubric. To help prevent miscoding a participant's response, the coders wrote a description based on the coding rubric of areas the participant did and did not address in their answer to each question. The description was used to help identify if a participant's response was correctly assigned a level based on the rubric. After the axial coding, the coders wrote a short synopsis about each participant's overall metacognitive awareness, again using terms from the coding rubric. Additionally, notes were taken about any participant responses that were assigned higher levels based on the coding rubric, or that answered the question uniquely.

Inter-rater reliability was determined using Cohen's kappa, using the assigned level from each coder on each interview question. Coder one's assigned levels for all 18 participants and 10 scored sections in each interview were compared to the same from coder two. The ten sections included questions one through nine, with question four having three parts, and question eight being excluded. Not every participant was asked each question because the interviewer attempted to keep the interviews to one hour each, and participants' response times varied. Thus, the total number of compared items was 173, not 180. The inter-rater reliability analysis started by confirming that there were no miscodes on the transcripts. A miscode was when the coder's assigned level and reason for that level did not match. The miscodes required the coder to verify their level and reason. Once the miscodes were addressed, the data was entered into SPSS. The Cohen's kappa statistic was then used to analyze the data for inter-rater reliability.

The researcher also compiled the coders' synopsis of each participant into their respective group. Each synopsis consisted of the participant's assigned level of awareness on each of the 10 scored sections of the interview and their responses that characterized the assigned level of awareness. The combination of each participant's synopsis into their group helped assimilate the essence of each group's metacognitive awareness. Once the group's synopsizes were combined, each group's unique metacognitive phenomenon was evident.

## Chapter Summary

The purpose of this convergent mixed methods study was to determine the impact of professional development on teachers' metacognitive awareness. This chapter detailed the rationale and design of this study, including the domain and participants, the quantitative and qualitative data collection procedures, and the data analysis procedures. To support the methodology of this study, previous studies using metacognitive data collection methods were described. The 21 teachers who participated were divided into groups based on their participation in professional development. Participants were asked to complete the MAI and metacognitive awareness interview. The data was used to compare groups of teachers' metacognitive awareness as well as to discover the essence of their metacognitive phenomena during common teacher tasks. The three groups' MAI results were compared using the Kruskal-Wallis test. The three groups were also compared using the coded transcriptions of the metacognitive awareness interviews. The assigned levels on the participants' interview questions from the two coders were compared using Cohen's kappa to test inter-rater reliability. In the next chapter, the results from the quantitative and qualitative analyses of metacognitive awareness will be presented and analyzed.

# CHAPTER FOUR: FINDINGS

The primary goal of this study was to understand the impact that professional development has on teachers' metacognitive awareness. The metacognitive awareness inventory (MAI) (see Appendix A) and metacognitive awareness interview (see Appendix B) were the two measures used for data collection. The MAI was used to quantitatively measure the participants' existing levels of metacognitive awareness (Schraw & Dennison, 1994). The metacognitive awareness interviews were used to gain a deeper understanding of participants' metacognitive awareness (Creswell, 2014).

This chapter describes both the quantitative, statistical results from the MAI and the qualitative results from the metacognitive awareness interview. Participants are compared within their respective groups. In the first section of the chapter, the participants' demographics and the control variables are delineated. The second section describes the results of the quantitative, qualitative, and comparative data analyses. An alpha level of .05 is used to test the significance of the quantitative data. The qualitative section uses portions of interviews from each group to detail that group's metacognitive awareness.

## Demographic Data

The collected demographic data was considered controlled variables in the study. The professional development literature expressed the importance of controlling variables, as there are numerous variables that could impact the dependent variable within the study (Flecknoe, 2002; Garet, Porter, Desimone, Birman, & Yoon, 2001; and Ingvarson, Meiers, & Beavis, 2005). As with Garet et al. (2001), this study included gender, grade level, certification, and experience as control variables. Participants' metacognitive awareness was compared using the Kruskal-Wallis analysis of variance by ranks test based on participants' gender, experience, teacher path to certification, and grade level taught. The variable of highest degree earned was not tested because nearly all of the participants ($N$=18, 78%) had their master's degrees. Additionally, all teachers were state certified in technology and engineering education. In each section below, the significance of results from the Kruskal-Wallis tests are detailed. Table 6 was used to show the descriptive demographic data. The number sign (#) in Table 6 was used to indicate number of participants in each group for the performed Kruskal-Wallis tests.

Each group had different gender demographics. Table 6 shows the amount and percentage of females and males in each group as well as a combined amount and percentage. The combined total of the three groups indicates that 57% of the subjects ($N$ = 21) in the study were male, and 43% were female. Group two had the greatest difference in males to females. Each group had a different average for years of teaching experience (see Table 6). Calculating the combined mean and standard deviation of each group provided the grand mean of 19.6 and standard deviation of 8.9 ($N$ = 18). Table 6 also shows the individual mean and standard deviation for each group's teaching experience. The certification path for groups one and two (the teachers who participated in Transforming Teaching through Implementing Inquiry and the teachers who were selected but did not participate) demonstrated that teachers certified to teach technology and engineering often received certification through lateral entry (see Table 6). The combined total of the three groups specified that 67% of the subjects ($N$ = 18) in the study were lateral entry, and 33% were traditionally certified. As Table 6 shows, groups one and three had an equal number of middle and high school teachers. However, the combined total of the three groups showed that 61% of the participants (*N* = 18) in the study were high school teachers, and 39 percent were middle school teachers.

Table 6

*Demographics*

| Group | Variables | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Gender | | | Experience | | | Certification | | | Grade Level Taught | | | |
| 1 | | # | % | # | *M* | *SD* | | # | % | | # | % | |
| | M | 5 | 62.5 | 6 | 20 | 11 | Lat. | 4 | 66.7 | Mid. | 3 | 50 | |
| | F | 3 | 37.5 | | | | Trad. | 2 | 33.3 | Hi. | 3 | 50 | |
| 2 | | | | | | | | | | | | | |
| | M | 4 | 66.7 | 6 | 17.3 | 8.5 | Lat. | 5 | 83.3 | Mid. | 1 | 16.7 | |
| | F | 2 | 33.3 | | | | Trad. | 1 | 16.7 | Hi. | 5 | 83.3 | |
| 3 | | | | | | | | | | | | | |
| | M | 3 | 42.9 | 6 | 21.5 | 8.2 | Lat. | 3 | 50 | Mid. | 3 | 50 | |
| | F | 4 | 57.1 | | | | Trad. | 3 | 50 | Hi. | 3 | 50 | |
| Combined | | | | | | | | | | | | | |
| | M | 12 | 57.1 | 18 | 19.6 | 8.9 | Lat. | 12 | 66.7 | Mid. | 7 | 38.9 | |
| | F | 9 | 42.9 | | | | Trad. | 6 | 33.3 | Hi. | 11 | 61.1 | |

**Control Variables**

The Kruskal-Wallis one way analysis of variance by ranks was used to test if gender, teaching experience, path to certification, or grade level taught impacted the teacher's metacognitive awareness. First, the Kruskal-Wallis test was used to determine whether the participants' gender impacted metacognitive awareness. The analysis compared the males' metacognitive awareness to the females' metacognitive awareness. The Kruskal-Wallis test using gender as the independent variable resulted in chi-square = 2.79, 1 degree of freedom, and a p-value = .095 (see Table 7). Based on these findings, the null hypothesis that males' metacognitive awareness equaled females' metacognitive awareness was supported. This means that, based on data from the MAI, gender did not impact participants' metacognitive awareness.

Next, the Kruskal-Wallis test was used to determine whether the participants' teaching experience impacted their metacognitive awareness. The difference in means between groups two and three—the non-Transforming Teaching through Implementing Inquiry (T2I2) completers and the National Board Certification (NBC) groups—was initially a concern for the impact of experience on metacognitive awareness. The Kruskal-Wallis test compared three reformed groups based on experience. For this test the groups ranged from (1) participants with 5 to 14 years of teaching experience, (2) 16 to 23 years of experience, and (3) 27 to 34 years of experience. The Kruskal-Wallis test using experience as the independent variable resulted in chi-square = .947, 2 degrees of freedom, and a p-value of .623 (see Table 7). Based on these findings, the null hypothesis, that groups based on years of experience are equal in terms of their metacognitive awareness, was supported. This indicated that, based on data from the MAI, a group's teaching experience did not impact its members' metacognitive awareness.

Then, the Kruskal-Wallis test was used to signify whether the teacher's path to certification impacted participants' metacognitive awareness. The analysis compared lateral-entry teachers' metacognitive awareness to traditionally certified teachers' metacognitive awareness. The Kruskal-Wallis test using certification path as the independent variable resulted in chi-square = .316, 1 degree of freedom, and a p-value of .574 (see Table 7). Based on these findings, the null hypothesis that lateral entry teachers' metacognitive awareness equaled traditionally certified teachers' metacognitive awareness was supported. This means that, based on data from the MAI, the teachers' certification path did not impact the participants' metacognitive awareness.

Then, the Kruskal-Wallis test was used to determine whether the grade level taught impacted teachers' metacognitive awareness. The analysis compared middle school teachers' metacognitive awareness to high school teachers' metacognitive awareness. The Kruskal-Wallis test using grade level taught as the independent variable resulted in chi-square = .461, 1 degree of freedom, and a p-value of .497 (see Table 7). Based on these findings, the null hypothesis that middle school teachers' metacognitive awareness equals high school teachers' metacognitive awareness was supported. This means that, based on data from the MAI, grade level taught did not impact participants' metacognitive awareness.

**T2I2 Amount Completed**

The primary research question of this study was based on the premise that groups one and two completed different amounts of T2I2 professional development. Group one completed from 20% to 100% of T2I2.  It is also worth noting that the majority (75%) of group one participants completed 100% of T2I2. Group two had a range of T2I2 completed from 0% to 11%. The majority (75%) of group two participants completed 5% or less of T2I2. The Kruskal-Wallis test was used to determine whether the difference in the amount of T2I2 completed between groups one and two was significant. The Kruskal-Wallis test using amount of T2I2 completed as the independent variable resulted in chi-square = 10.4, 1 degree of freedom, and a p-value of .001 (see Table 7). Based on these findings, the null hypothesis that the amount of T2I2 completed by group one equals the amount of T2I2 completed by group two was rejected. The result indicates that there was a significantly different amount of T2I2 completed by groups one and two. Group three was not involved with T2I2 professional development and therefore was not involved in this analysis. Additionally, in order for group three participants to have NBC, they were required to complete 100% of the National Boards for Professional Teaching Standards (NBPTS) professional development.

Table 7

*Kruskal-Wallis Test for Control Variables*

| Variables | Group | *N* | *Mean Rank* | *Chi-Squared* | *df* | *Sig.* |
|---|---|---|---|---|---|---|
| Gender | | | | 2.793 | 1 | .095 |
| | Male | 12 | 13.81 | | | |
| | Female | 9 | 4.00 | | | |
| Experience | | | | .947 | 2 | .623 |
| (in years) | 5 to 14 | 6 | 8.00 | | | |
| | 16 to 23 | 6 | 9.50 | | | |
| | 27 to 34 | 6 | 11.00 | | | |

Table 7 Continued

| | | | | | | |
|---|---|---|---|---|---|---|
| Certification | | | | .316 | 1 | .574 |
| | Traditional | 6 | 10.50 | | | |
| | Lateral | 12 | 9.00 | | | |
| Grade Taught | | | | .461 | 1 | .497 |
| | Middle | 7 | 10.57 | | | |
| | High | 11 | 8.82 | | | |
| Amount of T2I2 | | | | 10.40 | 1 | .001 |
| Completed | 1 | 8 | 10.50 | | | |
| | 2 | 6 | 3.50 | | | |

## Data Analysis

The focus of this section is the analysis of the quantitative and qualitative data. The quantitative portion presents results from the comparisons of the groups using the Kruskal-Wallis one-way analysis of variance by ranks. The results from the analysis of the quantitative data are delineated in this order: (1) groups one, two, and three; (2) groups one and two; (3) groups two and three; and (4) groups one and three. The statistical analysis of the quantitative data precedes the discussion of findings from the qualitative data. The results of the interviews are reported in order of groups and interview questions.

### Quantitative Analysis

As stated in chapter three, an assumption of the Kruskal-Wallis one-way analysis of variance is homogeneity of variance. Homogeneity of variance means that the spread of each group’s metacognitive awareness is equal. The Kruskal-Wallis test does not require a normal distribution of data, but does require an equally similar distribution of data in all groups (Sheskin, 2004). In order to test homogeneity of variance in the context of the Kruskal-Wallis test, the nonparametric Levene's test was used. The nonparametric Levene's test compares the absolute difference of the ranked scores of each participant's metacognitive awareness and the mean of the rank scores. The nonparametric Levene's test is considered the most powerful and robust test for homogeneity of variance with non-normal distributed data (Nordstokke & Zumbo, 2010). The null hypothesis of the nonparametric Levene's test is that the variances of each group are equal. The nonparametric Levene's test resulted in an F-statistic = 2.249 and a p-value of .134. This indicated that the homogeneity assumption was valid for the metacognitive awareness data collected with the MAI.

Table 8 shows the result of the omnibus Kruskal-Wallis analysis, which included all three groups. In this case, the Kruskal-Wallis test looked for any difference in metacognitive awareness among the groups. Table 8 displays the mean rank scores for each group in each component of metacognitive awareness. Group two had the lowest mean rank score in each component of metacognitive awareness. In all components, except procedural and conditional knowledge, groups one and three were at least double the mean rank score of group two. In Table 14, the significance column illustrates that eight of the eleven components were statistically significant at an alpha level of .05. Based on the results of the Kruskal-Wallis test; the subcomponents of evaluating (chi-square = 5.327, 2 *df,* and $p$ = .07), procedural (chi-square = 4.393, 2 *df,* and $p$ = .111), and conditional knowledge (chi-square = 3.346, 2 *df*, and $p$ = .188) indicated similarity between the groups' metacognitive awareness. In this test, the analysis did not indicate which group was different from another group. Later tests directly compared one group to another group.

Also shown in Table 8 is the eta-squared value for each component. Eta-squared quantifies the amount that the groups differed for each component of metacognitive awareness. In Table 8, eta-squared for metacognitive awareness was .535, signifying that 53.5% of the variability in the rank scores for metacognitive awareness was accounted for based on the groups' participation in professional development.

Table 8

*Kruskal-Wallis test for Metacognitive Awareness all Three Groups*

| Component | Group | *N* | *Mean Rank* | *Chi-Squared* | *Eta-Squared* | *Sig.* |
|---|---|---|---|---|---|---|
| Metacognitive | | | | 10.705 | .535 | .005 |
| Awareness | 1 | 8 | 13.81 | | | |
| | 2 | 6 | 4.00 | | | |
| | 3 | 7 | 13.79 | | | |
| Regulation of | | | | 11.239 | .562 | .004 |
| Cognition | 1 | 8 | 13.63 | | | |
| | 2 | 6 | 3.83 | | | |
| | 3 | 7 | 14.14 | | | |
| Knowledge of | | | | 6.299 | .315 | .043 |
| Cognition | 1 | 8 | 13.50 | | | |
| | 2 | 6 | 5.67 | | | |
| | 3 | 7 | 12.71 | | | |
| Planning | | | | 11.425 | .571 | .003 |
| | 1 | 8 | 13.56 | | | |
| | 2 | 6 | 3.83 | | | |
| | 3 | 7 | 14.21 | | | |
| Monitoring | | | | 8.367 | .418 | .015 |
| | 1 | 8 | 13.25 | | | |
| | 2 | 6 | 4.83 | | | |
| | 3 | 7 | 13.71 | | | |

Table 8 Continued

| | | | | | | |
|---|---|---|---|---|---|---|
| Organizing | | | | 9.973 | .499 | .007 |
| | 1 | 8 | 12.94 | | | |
| | 2 | 6 | 4.33 | | | |
| | 3 | 7 | 14.50 | | | |
| Evaluating | | | | 5.327 | .266 | .070 |
| | 1 | 8 | 12.94 | | | |
| | 2 | 6 | 6.08 | | | |
| | 3 | 7 | 13.00 | | | |
| Debugging | | | | 11.460 | .573 | .003 |
| | 1 | 8 | 14.19 | | | |
| | 2 | 6 | 3.83 | | | |
| | 3 | 7 | 13.50 | | | |
| Declarative | | | | 6.877 | .344 | .032 |
| Knowledge | 1 | 8 | 11.69 | | | |
| | 2 | 6 | 5.83 | | | |
| | 3 | 7 | 14.64 | | | |
| Procedural | | | | 4.393 | .22 | .111 |
| Knowledge | 1 | 8 | 14.06 | | | |
| | 2 | 6 | 7.17 | | | |
| | 3 | 7 | 10.79 | | | |
| Conditional | | | | 3.346 | .167 | .188 |
| Knowledge | 1 | 8 | 13.44 | | | |
| | 2 | 6 | 7.42 | | | |
| | 3 | 7 | 11.29 | | | |

Table 9 shows a direct comparison between groups one and two using the Kruskal-Wallis test. In this case, the Kruskal-Wallis looked for a difference in the eleven components between groups one and two. Group two again had the lowest mean rank score in metacognitive awareness and each of its components. In all components except for procedural, conditional, and declarative knowledge, group one had at least double the mean rank score of group two. The significance of those three items was also above the alpha of

.05 (see Table 9). Knowledge of cognition was the combination of those three subcomponents that did not have a significant p-values. However, the knowledge of cognition component indicated significance with a chi-square = 5.127, 1 degree of freedom, and a p-value of .024. The results of the Kruskal-Wallis test comparing groups one and two indicated that group one had a higher level of metacognitive awareness, especially in the regulation of cognition component.

In this case, the comparison between the eta-squared for knowledge of cognition and regulation of cognition was important. Table 9 shows the eta-squared for regulation of cognition at .680, whereas the eta-squared for knowledge of cognition was .394. Eta-squared signified that the variance in group two's regulation of cognition was different than their variance in the knowledge of cognition component when compared to group one based on participation in the T2I2 professional development.

Table 9

*Kruskal-Wallis test for Metacognitive Awareness Groups One and Two*

| Component | Group | *N* | *Mean Rank* | *Chi-Squared* | *Eta-Squared* | *Sig.* |
|---|---|---|---|---|---|---|
| Metacognitive | | | | 8.817 | .678 | .003 |
| Awareness | 1 | 8 | 10.38 | | | |
| | 2 | 6 | 3.67 | | | |
| Regulation of | | | | 8.836 | .680 | .003 |
| Cognition | 1 | 8 | 10.38 | | | |
| | 2 | 6 | 3.67 | | | |
| Knowledge of | | | | 5.127 | .394 | .024 |
| Cognition | 1 | 8 | 9.69 | | | |
| | 2 | 6 | 4.58 | | | |

Table 9 Continued

| | | | | | | |
|---|---|---|---|---|---|---|
| Planning | | | | 8.934 | .687 | .003 |
| | 1 | 8 | 10.38 | | | |
| | 2 | 6 | 3.67 | | | |
| Monitoring | | | | 6.057 | .466 | .014 |
| | 1 | 8 | 9.88 | | | |
| | 2 | 6 | 4.33 | | | |
| Organizing | | | | 6.711 | .516 | .010 |
| | 1 | 8 | 10.00 | | | |
| | 2 | 6 | 4.17 | | | |
| Evaluating | | | | 4.650 | .358 | .031 |
| | 1 | 8 | 9.56 | | | |
| | 2 | 6 | 4.75 | | | |
| Debugging | | | | 8.193 | .630 | .004 |
| | 1 | 8 | 10.25 | | | |
| | 2 | 6 | 3.83 | | | |
| Declarative | | | | 3.607 | .277 | .058 |
| Knowledge | 1 | 8 | 9.31 | | | |
| | 2 | 6 | 5.08 | | | |
| Procedural | | | | 3.682 | .283 | .055 |
| Knowledge | 1 | 8 | 9.31 | | | |
| | 2 | 6 | 5.08 | | | |
| Conditional | | | | 3.559 | .274 | .059 |
| Knowledge | 1 | 8 | 9.31 | | | |
| | 2 | 6 | 5.08 | | | |

Table 10 shows a comparison between groups two and three using the Kruskal-Wallis test. The results of this test were not unlike the group one and two comparison; due to group one and three having similar mean rank scores and group two having the lowest mean rank scores. The Kruskal-Wallis was again testing to determine whether the differences in mean rank scores was significant between groups two and three. The significance of evaluating, procedural, and conditional knowledge was above the alpha of .05 (see Table 10). The results of the Kruskal-Wallis test comparing groups two and three indicated that group three had a higher level of metacognitive awareness with chi-square = 7.388, 1 degree of freedom, and a p-value of .007 (see Table 10).

Table 10

*Kruskal-Wallis test for Metacognitive Awareness Groups Two and Three*

| Component | Group | *N* | *Mean Rank* | *Chi-Squared* | *Eta-Squared* | *Sig.* |
|---|---|---|---|---|---|---|
| Metacognitive | | | | 7.388 | .616 | .007 |
| Awareness | 2 | 6 | 3.83 | | | |
| | 3 | 7 | 9.71 | | | |
| Regulation of | | | | 8.186 | .682 | .004 |
| Cognition | 2 | 6 | 3.67 | | | |
| | 3 | 7 | 9.86 | | | |
| Knowledge of | | | | 4.315 | .360 | .038 |
| Cognition | 2 | 6 | 4.58 | | | |
| | 3 | 7 | 9.07 | | | |
| Planning | | | | 8.231 | .686 | .004 |
| | 2 | 6 | 3.67 | | | |
| | 3 | 7 | 9.86 | | | |
| Monitoring | | | | 6.649 | .554 | .010 |
| | 2 | 6 | 4.00 | | | |
| | 3 | 7 | 9.57 | | | |
| Organizing | | | | 8.186 | .682 | .004 |
| | 2 | 6 | 3.67 | | | |
| | 3 | 7 | 9.86 | | | |
| Evaluating | | | | 3.507 | .292 | .061 |
| | 2 | 6 | 4.83 | | | |
| | 3 | 7 | 8.86 | | | |
| Debugging | | | | 9.100 | .758 | .003 |
| | 2 | 6 | 3.50 | | | |
| | 3 | 7 | 10.00 | | | |

Table 10 Continued

| | | | | | | |
|---|---|---|---|---|---|---|
| Declarative | | | | 5.649 | .471 | .017 |
| Knowledge | 2 | 6 | 4.25 | | | |
| | 3 | 7 | 9.36 | | | |
| Procedural | | | | 1.525 | .127 | .217 |
| Knowledge | 2 | 6 | 5.58 | | | |
| | 3 | 7 | 8.21 | | | |
| Conditional | | | | 1.046 | .087 | .306 |
| Knowledge | 2 | 6 | 5.83 | | | |
| | 3 | 7 | 8.00 | | | |

The previous Kruskal-Wallis tests showed that groups one and three had a higher level of metacognitive awareness than group two based on the data from the MAI (see Tables 8, 9, & 10). Table 11 shows a comparison between groups one and three using the Kruskal-Wallis test. In Table 11, the significance column shows that all of the 11 components were above the alpha of .05. This use of the Kruskal-Wallis tested the null hypothesis that group one's metacognitive awareness was equal to group three's metacognitive awareness. Based on the p-values in Table 11, group one's metacognitive awareness was similar to group three's metacognitive awareness. In fact, metacognitive awareness had a chi-square = .003, 1 degree of freedom, and a p-value = .954, indicating a significant similarity (see Table 11).

Table 11

*Kruskal-Wallis test for Metacognitive Awareness Groups One and Three*

| Component | Group | *N* | *Mean Rank* | *Chi-Squared* | *Eta-Squared* | *Sig.* |
|---|---|---|---|---|---|---|
| Metacognitive | | | | .003 | .000 | .954 |
| Awareness | 1 | 8 | 7.94 | | | |
| | 3 | 7 | 8.07 | | | |
| Regulation of | | | | .054 | .004 | .817 |
| Cognition | 1 | 8 | 7.75 | | | |
| | 3 | 7 | 8.29 | | | |
| Knowledge of | | | | .085 | .006 | .771 |
| Cognition | 1 | 8 | 8.31 | | | |
| | 3 | 7 | 7.64 | | | |
| Planning | | | | .087 | .006 | .768 |
| | 1 | 8 | 7.69 | | | |
| | 3 | 7 | 8.36 | | | |
| Monitoring | | | | .014 | .001 | .907 |
| | 1 | 8 | 7.88 | | | |
| | 3 | 7 | 8.14 | | | |
| Organizing | | | | .273 | .020 | .602 |
| | 1 | 8 | 7.44 | | | |
| | 3 | 7 | 8.64 | | | |
| Evaluating | | | | .014 | .001 | .907 |
| | 1 | 8 | 7.88 | | | |
| | 3 | 7 | 8.14 | | | |
| Debugging | | | | .172 | .012 | .678 |
| | 1 | 8 | 8.44 | | | |
| | 3 | 7 | 7.50 | | | |
| Declarative | | | | 1.157 | .083 | .282 |
| Knowledge | 1 | 8 | 6.88 | | | |
| | 3 | 7 | 9.29 | | | |
| Procedural | | | | 1.410 | .101 | .235 |
| Knowledge | 1 | 8 | 9.25 | | | |
| | 3 | 7 | 6.57 | | | |

Table 11 Continued

| | | | | | | |
|---|---|---|---|---|---|---|
| Conditional | | | | .350 | .025 | .554 |
| Knowledge | 1 | 8 | 8.63 | | | |
| | 3 | 7 | 7.29 | | | |

**Qualitative Analysis**

The open- and axial- coding of the participants' transcribed interviews is presented in this section. The open coding did not result in an evaluation of the participants' metacognitive awareness. Due to inadequate training, the open-coding resulted in evaluating participants' instructional and assessment techniques based on the coders' interest. However, the open-coding did allow the coders to become familiar with the participants. The focus of this section is the results of axial-coding using the coding rubric and inter-rater reliability between the two coders.

Inter-rater reliability provided an indication of the accuracy in the coded results from one coder by using two coders. Cohen's kappa was used to measure the inter-rater reliability of the two coders using the coding rubric. Cohen's kappa is a chance-corrected measure indicating the agreement between two raters (Sheskin, 2004). Cohen's kappa indicated that coders one and two had a beyond-chance moderate agreement of 73%, standard error of .03, and a p-value less than .001 in their assigned levels for the participants' responses to the interview.

During axial coding, the coders used a coding rubric. The rubric had the same description for all interview questions for a high level of knowledge of cognition. The description was, "The participant describes a strategy, how to use the strategy, why the strategy was used in cognitive terms, and how they knew that was the strategy to use in cognitive terms." Only one of the participants belonging to group three received consecutive high levels in the knowledge of cognition component. Other than that one participant, based on the interviews, each group had a slightly different but overall medium level of metacognitive awareness in the knowledge of cognition component based on the coding rubric. The participants frequently discussed their strategies and how to use the strategies for planning, organizing, monitoring, debugging, and evaluating. Occasionally a participant from groups one and three would also discuss why the strategy was used in terms of cognition. Listed below are representative examples of responses to interview question three (which dealt with organization) that were coded for the knowledge of cognition component:

- "Right now, the way I do things primarily is I will introduce the topic, and I can either be just showing slides, or a presentation, or I like to if I can show an audio or a video."…"Once they know the information then we will kind of go back and revisit all of that, but in the applicable sense where they're actually going to be performing the task or the skill." (group 3)
- "I sit down with the standard course of study, create a pacing guide, roughly when I'm going to teach what, how much time it's going to take, and then create lessons for each day." (group 2)
- "Typically, what I'll do is I have a PowerPoint slide that I'll throw up. It'll give the day's agenda for the three different sections I've been teaching for that period, and it'll give specific warm ups…" (group 1)

The participants from groups one and two focused on a strategy and how to use the strategy. The participant from group three was selected due to having a conditional reason why the strategy was used in terms of cognition. However, when comparing each group's knowledge of cognition, as a whole, the groups were similar.

The group's answers to interview questions based on the regulation of cognition component were more distinguishably different. Group three participants were assigned more high and high-to-medium levels; group two received levels ranging from medium to low; and group one received more high-to-medium and medium levels. In two cases, a participant from group one and two received a level of zero. The zero level was not on the coding rubric, but both coders in both cases recorded a zero for those participants' responses. For questions one and two, coders were looking for the participant to describe planning, goal setting, and allocation of resources. Listed below are representative examples of the regulation of cognition coded responses from interview question one dealing with the planning of instruction:

- "With this unit, I used what the state had provided, but I also sought additional resources by using an opportunity to participate in a grant program. This program provided additional resources for the students to use." (group 3)
- "One of the methods I use for planning instruction is called the 5 Es, and it's engagement, evaluation, and it's a couple more." (group 2)
- "I draw on my past experience quite a bit. I take a look at what has worked in the past and maybe what hasn't worked so well and then I formulate my lecture, my demonstrations based on that information." (group 1)

The passage from the group three participant exemplifies how group three members, those who had NBC, often discussed goals or allocation of resources in addition to planning. Group three participants would often focus on two items from the rubric and only provide some detail on the third. The group one passage is primarily focused on planning. Group one, the teachers who participated actively in T2I2, often focused on planning, with brief descriptions of either goal setting or allocation of resources. The passage from group two, the teachers who did not participate actively in T2I2, exemplifies an average answer from participants in group two. The combination of incomplete thoughts and little detail on one or two of the rubric items resulted in low assigned levels of metacognitive awareness in the regulation of cognition component for interview questions one and two.

Questions three and four were focused on organization. Question four was specific to information management, an aspect of organization. In question three, coders were looking for the participant to describe implementation of techniques based on an understanding of cognition for the purpose of planning. Listed below are representative examples of the responses to interview question three (which dealt with the cognitive organization of instruction techniques or strategies) that were coded regulation of cognition:

- "I would begin with some type of bell ringer. Something to get the students interested in what the topic is for that particular day." … "The overall objective for the lesson [was] to draw the kids interest, to help them make connections to the real world" (group 3)
- "I try to make them aware of where we are today, where we've come from, and hopefully where we're going to go in the future." (group 2)

- “I usually start the class out with some sort of bell ringer, to get them thinking about what it is that we’re going to do that day.” … “By taking it further and possibly doing a hand-on or application project with it, they’re involved.” (group 1)

Group three participants, the NBC teachers, were focused on organization, attending to the cognitive needs of the students in order to keep them interested. Group two participants responded to question three in general terms. The coders had difficulty highlighting any significant responses from group two participants. Due to group two’s generalized responses to question three, their focus seemed to be at the macro level of organization. Group one participants’ answers to question three were similar to those of group three. Occasionally, participants in group one, the T2I2 teachers, lacked the high level of detail shown in group three’s responses.

Question four was split into three scenarios dealing with information management. The first scenario was a general question about information management. The second scenario was specific to information management of nonverbal feedback from students. The third scenario related to information management of new teaching techniques learned from another teacher or from a professional development program. In all three scenarios, coders were looking for the participant to describe their cognitive organization, elaboration, summarization, and selective focus on important information. Listed below are representative examples of the responses to interview question four (which dealt with the participants’ general information management) that were coded as regulation of cognition:

- “When I receive information, I try to make it relevant to what the situation is as far as my perspective, how I’m going to view it.” … “When I receive information, I try to internalize it and fully understand the whole concept without just judgment about the information." … "I try to sometimes put myself in the position of being someone else." … "I get information and sometimes I try to apply it to a project, maybe, the kids are working on." (group 3)

- "Based on your experience or based on your colleagues that you're working with or talking to about it, you can evaluate some of the things as yeah, this is really important piece of information that they need to know, or maybe this particular piece of information is not as critical." (group 2)
- "I try to put it into some type of situation that I'm maybe familiar with. What am I going to do with this information, how am I going to apply it to something I already know or something that I need to know." (group 1)

Group three participants discussed how they organized information, focused on the important information, and either summarized or elaborated on the information they received. The group two participants mostly talked about one item specifically, and talked about the other aspects of information management more generally or not at all. In the group two passage above, the participant's entire response was specific to focusing on important information, but the participant neglected any real detail about other aspects of information organization. The group one participant's answers were more associated with the elaboration and summarization of information as well as the general management of information.

In questions five and six, the coders were looking for the monitoring subcomponent of cognitive regulation. The high-level column in the rubric for questions five and six stated, "The participant describes cognitive assessment of themselves, someone else, and their strategy." For a participant to receive a high level, they needed to describe cognitive assessment of each item in detail. All of the participants at least described the monitoring of their students. However, group two often did not describe the cognitive assessment portion. Group two discussed general monitoring of their students. Only a few participants described the cognitive assessment of themselves or their methods. Only three participants, one from group one and two from group three, described in detail the cognitive assessment of themselves, someone else, and their strategy. Listed below are representative examples of the responses coded regulation of cognition from interview question five, which dealt with the monitoring of cognition during instruction:

- "One team was asking the same question and another team was asking the same question, even though they're two different ability levels then that means I missed it somewhere and I need to go back and cover that." … "I will need to change my lesson plan just for that one level and I can remediate with them later or right at that moment…" (group 3)
- "I walk my classroom and make sure that the students are doing individual work, or if they are working in learning teams then I know what they are doing." (group 2)
- I kind of monitor myself because if what I'm saying doesn't make sense to me… but I've already said something that after I say that, 'wait a minute, what did I just say?'" (group 1)

Question seven focused on the debugging or adjustment of the teacher's strategy during instruction. The coders were looking for the participant to describe a strategy used to correct performance errors and false assumptions that they had made about the task or strategy being used. None of the participants described the correction of both performance errors and false assumptions with enough detail for both coders to assign a high level of cognitive regulation in the debugging subcomponent. Group one provided the most detailed descriptions of their adjustments. Group one focused on either errors or assumptions, with brief reference to the other aspect of the component. Group two received the lowest levels on this component. Both coders wrote that the responses of group two participants were general and sometimes did not seem to provide a direct answer to question seven. Group three answered similarly to group one, but lacked the same level of detail. The coders considered group three participants to be more at the medium level of metacognitive awareness for the debugging subcomponent based on the coding rubric. Listed below are representative examples of the regulation of cognition coded responses from interview question seven, which dealt with the debugging or adjusting during instruction:

- "I adjust my teaching during the lesson based on how I think the lesson is going… whether it's contextual feedback or if it's a spoken-type of feedback or body language. I adjust my lesson just based on what I see if it's working or not …" (group 3)
- "I'm trying to make sure that I'm not losing some of them. If I do I try to back up and show a different way to do a particular thing." (group 2)
- "I might backtrack and re-explain something. I might try a different way of explaining something… switch people to different groups… I might try to find a totally different way to explain something. Some groups, I might do hands-on

activities. Other groups, I might show a video or see a PowerPoint, just depending on the dynamics." (group 1)

Question nine was about the participants' cognitive self-evaluation and reflection. The coders were looking for the participants to describe their own post-hoc analyses of their performance and strategy effectiveness. Based on the coding of their responses, the groups all had similar metacognitive awareness on question nine; they were all basically assigned at a medium level of metacognitive awareness. Some of the participants provided somewhat more detail than others, resulting in a slightly higher levels. The participants focused on reflecting either about their performance or their strategy effectiveness. The participants described how, when, and why they tended to reflect on their cognition. Some of the participants even described what they did based on decisions made during their self-evaluation. Listed below are representative examples of the regulation of cognition coded responses from interview question nine, which dealt with the participants' self-evaluation after instruction:

- "I go back and look at what didn't work, what I need to change." … "The next time I teach this lesson, I'm going to do this. I might leave this part off. That's basically how I plan." (group 3)
- "You have to look back on it, and say, 'well, that really didn't go well that way, next time I can try it this way." … "A lot of times driving home I'll think about what I did that day. Did it work? How can I do something a little different? Make it a little better, make it a little more interactive." (group 2)

- “I try to make little notes to myself about what went right, what went wrong, come up with ideas on how I could change things and do thing differently.” (group 1)

## Chapter Summary

This chapter presented collected data from the three groups of technology and engineering teachers using two measures of metacognitive awareness, the MAI and the metacognitive awareness interview. The participants were placed into three groups based on their participation in one of two professional development programs, T2I2 and NBC. The demographics showed that the participants were 57% male, that 67% were lateral entry, and that 78% had master’s degrees. The mean teaching experience of each group was 20 years (group one), 17 years (group two), and 21.5 (group three). The majority of group one teachers had completed 100% of T2I2, while the majority of group two had completed less than 5% of T2I2. The quantitative data from the MAI was compared using the Kruskal-Wallis test. Results from the MAI indicated that groups one and three had similar levels of metacognitive awareness. Additionally, based on the MAI, groups one and three had higher levels of metacognitive awareness than group two.

The metacognitive awareness interviews were coded by two coders using a coding rubric (see Appendix B). The inter-rater reliability of the coded data was analyzed using Cohen’s kappa. The analysis of the interviews was used to provide more depth to the understanding of the participants’ metacognitive awareness. The analysis of the interviews indicated that in the subcomponents of planning, monitoring, organizing, evaluating, debugging, and conditional knowledge, the groups had different levels of metacognitive awareness. However, in the component of knowledge of cognition and the subcomponent of declarative and procedural knowledge, the groups had similar levels of metacognitive awareness. Chapter five will answer the primary and secondary research questions, analyze the implications of the findings, relate the findings to the literature, and identify the role of metacognition in professional development.

# CHAPTER FIVE: CONCLUSIONS AND IMPLICATIONS

Chapter five answers the primary and secondary research questions based on the findings as well as discusses the implications of those findings. The chapter starts by reviewing the primary and secondary research questions. Then, detailed answers to each research question are provided. Next, the results of this study are used to explain additional implications. In the implications section, literature is used to discuss the impact of professional development on technology and engineering teachers' metacognitive awareness as revealed in this study. Finally, the chapter concludes with suggestions for future research based on the findings of this study.

The primary research question of this study focused on understanding the role that Transforming Teaching through Implementing Inquiry (T2I2) professional development had in impacting technology and engineering teachers' metacognitive awareness. The first two secondary research questions of the study are focused on detailing the similarities and differences in technology and engineering teachers' metacognitive awareness based on their participation in two types of professional development. The final secondary research question was answer by a comparative analysis of the quantitative and qualitative results. The comparative analysis helped the researcher to develop a more complete perspective of the participants' metacognitive awareness (Bryman, 2006 and Greene et al., 1989). The central and secondary research questions were as follows:

1. What effects did T2I2 online professional development system have on technology and engineering teachers' metacognitive awareness?
    a. How do technology and engineering teachers who actively participated in

T2I2 online professional development system compare to NBC technology and engineering teachers in terms of metacognitive awareness?

b. How do technology and engineering teachers who did not actively participate in T2I2 online professional development system compare to NBC technology and engineering teachers in terms of metacognitive awareness?

c. What is the essence of technology and engineering teacher's metacognitive awareness while performing established teacher practices?

## Analysis of Research Questions

The purpose of this study was to investigate and understand the role professional development has in impacting technology and engineering teachers' metacognitive awareness. Further emphasizing the role of metacognition in professional development, this study measured the differences in teachers' metacognitive awareness based on their participation in two types of professional development. Data was collected using the metacognitive awareness inventory (MAI) and metacognitive awareness interviews (see Appendix A & B). The results of the quantitative, qualitative, and comparative analysis were used to answer the primary and secondary research questions.

### Research Question #1

What effects did T2I2 online professional development system have on technology and engineering teachers' metacognitive awareness?

Research question one was answered by the results of the MAI data from groups one and two. The participants in both groups were selected for T2I2 professional development.

As represented in Table 7, group one participants completed a significantly greater amount of T2I2 than group two participants. The results from the MAI indicated that participants in group one had a significantly greater metacognitive awareness than group two with a chi-square of 8.817, 1 degree of freedom, and a p-value of .003 (see Table 9). Additionally, group one had significantly greater self-reported awareness in both components of metacognitive awareness, as well as five subcomponents (see Table 9). The three subcomponents that did not show significant difference were declarative, procedural, and conditional knowledge (see Table 9). The metacognitive awareness interview results converged with the results of the MAI data indicating there was similarity between groups one and two's knowledge of cognition subcomponents. The results of the MAI analysis indicated that group one was statistically more metacognitively aware in the knowledge of cognition component. The interview data diverged, revealing that group one's knowledge of cognition was only noticeably better during their discussion of the planning aspect, based on the coding rubric.

The regulation of cognition component and its five subcomponents from the MAI illustrated that group one's metacognitive awareness was significantly greater than group two's metacognitive awareness (see Table 9). The interview data converged indicating group one's higher level of metacognitive awareness in the subcomponents of planning, information management, and debugging. However, the interview data results also diverged from the MAI results by indicating group one's similarity to group two in regulation of cognition subcomponents of organizing, monitoring, and evaluating. Ultimately, based on the comparative analysis, participants from group one and two were similar in some subcomponents of metacognitive awareness and different in others.

The understanding of convergence and divergence between the MAI and metacognitive awareness interview provided a more complete perspective of each group's metacognitive awareness. The convergence of the MAI and metacognitive awareness interview results indicated that group one had great levels of metacognitive awareness, specifically in the subcomponents of planning, information management, and debugging. Again, the convergence indicated that groups one and two were similar in the knowledge of cognition subcomponents. The MAI and metacognitive awareness interview results also diverged. The MAI results indicated statistical difference in the subcomponents of organizing, monitoring, and evaluating (see Table 9). Although, the interview results indicated groups one and two were similar in the subcomponents of organizing, monitoring, and evaluating. There were extraneous variables that could have impacted the similarities and differences seen between groups one and two, such as the participants' teaching experience, gender, certification path, and grade level taught; however, these variables were controlled and showed no statistically significant impact on the groups' metacognitive awareness.

**Secondary Research Question #1**

How do technology and engineering teachers who actively participated in T2I2 online professional development system compare to NBC technology and engineering teachers in terms of metacognitive awareness?

Secondary research question one was answered by the results of the MAI data from groups one and three. Seventy-five percent of the participants in group one had completed

T2I2 professional development. The other two participants in group one had completed 20% and 40% of T2I2 professional development. Group three participants had earned NBC by completing the NBPTS professional development. The quantitative results from the analysis of the MAI data indicated that participants in groups one and three had significantly similar metacognitive awareness with a chi-square of .003, 1 degree of freedom, and a p-value of .954 (see Table 11). All subcomponents showed a significant similarity except for declarative, conditional, and procedural knowledge subcomponents (see Table 11). The metacognitive awareness interview results converged with the results of in MAI data analysis. The MAI mean rank scores and coded interview results showed that group one was slightly more metacognitively aware than group three in the subcomponent of debugging (see Table 11). Based on the mean rank scores and the levels indicated by the coders, group three was slightly more metacognitively aware than group one in all other subcomponents (see Table 11). There was also divergence between the MAI and metacognitive awareness interview results. The MAI results indicated groups one and three were significantly similar in the planning and monitoring subcomponents. The interview results diverged by indicating groups one and three had different levels of awareness in the planning and monitoring subcomponents. Overall, based on the MAI and interview results, both groups one and three had similar metacognitive awareness.

**Secondary Research Question #2**

How do technology and engineering teachers who did not actively participate in T2I2 online professional development system compare to NBC technology and engineering teachers in terms of metacognitive awareness?

Secondary research question two was answered by the results of the MAI data from groups two and three. The participants in group two were selected for T2I2 professional development. Group two participants did not actively participant in T2I2 professional development program, completing less than 11 percent of the program. Group three participants received NBC in career and technical education from the NBPTS. The results of the quantitative data indicated that participants in group three had a significantly greater metacognitive awareness than group two with a chi-square of 7.388, 1 degree of freedom, and a p-value of .007 (see Table 10). Additionally, the results of the MAI indicated group three had a higher level of self-reported awareness than group two in both components of metacognitive awareness and five of the subcomponents (see Table 10). With p-values above .05, the three subcomponents that did not indicate a significant difference were evaluating, procedural knowledge, and conditional knowledge (see Table 10).

The results of the metacognitive awareness interview converged with the results of the MAI. In the subcomponents of evaluating and procedural knowledge, the convergence between the MAI and interview results indicated similarity between groups two and three (see Table 10). In the subcomponents of planning and organizing, the convergence between the MAI and interview results indicated differences between groups two and three (see Table 10). There was also divergence between the MAI and metacognitive awareness interview results for groups two and three. The MAI results indicated that group three had significantly greater metacognitive awareness than group two in the subcomponents of monitoring, debugging, and declarative knowledge (see Table 10). The interview results diverged with the indication that groups two and three had similar levels of monitoring, organizing, and declarative knowledge. Additionally, the MAI results indicated that groups two and three were significantly different in their knowledge of cognition. The metacognitive awareness interview results diverged indicating that groups two and three had similar knowledge of cognition levels.

The convergence and divergence between the results of the MAI and metacognitive awareness interview provided a more complete perspective of groups' two and three metacognitive awareness. The convergence of the MAI and metacognitive awareness interview results indicated that group three had higher levels of metacognitive awareness, specifically in the subcomponents of planning and organizing. The convergence also indicated that groups two and three were similar in the subcomponents of evaluating and procedural knowledge. Extraneous variables could have impacted the similarities and differences observed between groups two and three. The controlled variables included the participants' teaching experience, gender, certification path, and grade level taught. The controlled variables were shown to have no statistically significant impact on either group's metacognitive awareness.

**Secondary Research #3**

What is the essence of technology and engineering teacher's metacognitive awareness while performing established teacher practices?

Based on the quantitative and qualitative results, as well as the additional perspective gained by the comparative analysis, each group was found to have its own unique metacognitive awareness phenomenon while performing their teacher practices. The purpose of the phenomenological portion of the study was to understand and then describe the essence of each group's unique metacognitive awareness. The metacognitive phenomena of the three groups related to the many facets of the group members' respective teacher practices. The researcher's challenge was to collect an adequate amount of data from the participants to completely describe the essence of their metacognitive awareness during their teacher practices. Each group's distinctive metacognitive awareness is described below.

**Group One**

Teachers in group one, who participated actively in T2I2, had a distinctive form of thinking regarding planning for instruction and assessment. These teachers would start by analyzing their own knowledge and ability for the particular area they would be covering in class. According to a group one participant, "When I say I developed a lesson or an idea, I think that it's foolproof, but that's because I'm understanding it from my side and from my kind of level of knowledge and expertise." Group one considered the use of various instructional methods before determining the appropriate way for the students to develop the requisite knowledge and abilities. Group one's awareness of goals in their planning was obscured by the focus on their ability to transfer knowledge to students. According to another group one participant, "I'll start out with an idea or plan … by the end of the day I've completely authored that plan because what I think is going to work and what actually works sometimes is two different things."

When organizing their instruction, group one teachers thought about the use of instructional tools that could aid them in their organization. They made decisions about the appropriate use of these tools. A group one participant stated, "I have the ability to demonstrate things electronically, either to the entire class, or I can just demonstrate something to individual students, [or I can] demonstrate the concept through actual physical … demonstration." Group one participants thought of their instructional techniques as vital to building students' knowledge and abilities throughout the course. One group one participant stated, "I start out with smaller concepts, smaller ideas, then gradually build into bigger ideas and concepts which require [the students] to understand the previous" items covered.

When presented with new information, group one participants either cognitively elaborated or summarized the information based on previous experiences. A group one participant explained, "I try to put it into some type of situation that I'm familiar with. What am I going to do with this information, how am I going to apply it to something I already know or something I need to know." These teachers' cognitive elaboration and summarization required more time, indicating that in situations demanding quicker responses, those responses could be misguided.

Group one cognitively monitored themselves and their students. A group one participant said, "I have to … think how they're thinking so that I can understand what they're trying to do." Another group one participant stated, "You definitely have to keep the question in your mind, whether or not you've given the kids the right information or you've done everything it takes to allow them to be safe, to be successful." When group one participants saw students struggling, they analyzed several possible reasons. The students were watched by group one participants to determine their progression while solving problems. This gave group one participants' time to complete their analysis of possible issues aiding or hindering problem solving. To help complete their analysis, group one participants asked their students cognitive, probing questions.

Group one participants focused on their students during their debugging of performance errors or false assumptions that they had made related to a lesson. However, the participants indicated an understanding that changes to their performance errors or assumptions would require them to change. Group one participants analyzed the use of other instructional methods to correct their instructional errors. Based on their experience and the information from the situation, group one participants made decisions to implement different instructional methods that they believed would correct errors. Group one participants also considered learning styles and how learning styles might impact students' learning during the use of a specific instructional techniques.

Group one teachers asked themselves questions during their post-hoc reflection and evaluation of their performance and effectiveness. A group one participant thought, "Did I try to do too much? Did I not give them enough information? Am I going at a pace that is too fast, or am I going too slow? Is there a different way that I can teach this? Is there something that they can relate to?" Group one participants used the answers to such questions to guide their thinking related to planning and organizing. Group one participants believed that student success meant that they were effective. Group one's post-hoc evaluation could be performed rapid if they believed the students were successful.

### Group Two

The teachers in group two, who did not participate actively in T2I2, began their planning for instruction and assessment by thinking about and reviewing standards and objectives for the course. According to a group two participant, “I look at the standards that are required for whatever I am teaching, and … I research and look at my standards.” Then, group two teachers reviewed information gathered from previous experiences or research. Finally, group two participants constructed their curricula, lessons, or activities based on the standards and the gathered information. Group two participants identified the varying content that they taught as the reason for differences in the selected planning and instructional techniques. Participants in group two did not indicate cognitive awareness of goals during the interviews. The focus on standards seems to indicate group two’s use of standards or objectives as targeted accomplishments for the students. Group two thought about planning broadly and did not seem to narrow their thinking to specific details during the planning process.

Again, group two’s thinking about instructional organization was described with general beliefs, ideas, and principles. When organizing their instruction, group two thought about the start, middle, and end of the instructional process. They focused on using established classroom organization techniques. Stated one group two participant, “I really prefer to lecture at the beginning, give them guided practice time, and then sum it up at the end.” Group two participants specified that they organized their classrooms so that groups of students worked together to complete one part of an activity, while at the same time another group was completing a different part of the same activity. According to a group two participant, “I try to teach and set up the course so that I have covered people working, doing stuff on paper, people doing stuff in software, people that may do stuff with physical equipment.”

When presented with new information, group two participants used multiple methods to reflect on and reiterate the information to ensure that they would have the necessary understanding to use the information when instructing their students. A group two participant stated, “I think about how it works. I listen to people … doodle and write down the information … think about what they’ve done or said.” Their cognitive focus on important details and summarization required them to review and reflect on the information. The reflection process took time, making information management a lengthy process for group two participants. Their broad focus on the information could impact their understanding and future implementation of the information.

Group two was primarily focused on monitoring their students. The methods that group two used for monitoring made the cognitive monitoring of their students more difficult. Occasionally, however, group two participants would ask students questions to check their understanding. Group two’s focus on multiple items within their classroom made their monitoring of themselves and strategies infrequent. Group two participants identified the importance of monitoring their students so that each student benefitted from the learning experience. A group two participant gave the following response when asked the reason for monitoring students: “So that you can pull the best out of the students. When students feel [forgotten], they shut down.”

Group two participants indicated that their students were the reason that they made adjustments during instruction. A group two participant stated, “I’m trying to make sure that I’m not losing some of them. If I do I try to back up and show a different way.” Another group two participant said, “I adjust my teaching during a lesson based on feedback from the students.” Group two’s focus on the students obstructed cognitive analysis of their own performance errors or assumptions, although several group two participants seemed to indicate that their performance errors were reflected in feedback from the students. Group two’s selection of remediation techniques seemed to be based on the situation. However, group two participants identified that they relied on previous experiences to make decisions about appropriate techniques to use.

During post-hoc analysis, group two participants examined which aspects of their performance effectiveness were acceptable and which aspects needed improvement. Group two participants either did short-term post-hoc analysis frequently or large-scale analysis a few times per year. Group two participants made decisions about their performances based on how the students performed on assessments or during a semester. Group two participants indicated that even when the students were successful, they, the teachers, might make changes. Based on whether the participants in group two performed frequent or infrequent post-hoc analysis, they had different levels of thoroughness and amounts of time required.

**Group Three**

Group three had a focus on several items regarding their planning for instruction and assessment. All participants discussed the processes they used for planning, addressing state standards and objectives, and conducting research related to planning. Group three’s thinking about planning related to the research that they did to prepare for and plan units, lessons, and activities. A group three participant said, “[I] look at research, what the research says, especially current trends in the field and what people are doing to help educate better and more efficiently … Research has really been a big part of how I teach.” Group three participants identified reasons for the importance of planning related to the students, including the following: background, skill level, learning needs, and motivation. Group three participants also analyzed instructional methods and learning styles to determine what they must plan for and accomplish in order for their students to successfully learn the material. Group three participants were aware of their students' goals as well as their own goals. They combined these goals to plan a more student-centered classroom. Group three participants also planned for unexpected situations. The participants often discussed planning for students to complete more than was expected. One group three participant said, "A lot of times, many of the students go beyond the goal, so I have to plan for extra stuff. In addition to regular planning, [I plan additional] challenges" for the students.

Group three participants thought about several attributes during organization, including the planning of organization, the setting of objectives and goals, attending to student learning needs, the use of appropriate instructional techniques, and efficient use of time. Group three participants also thought specifically about the organization of each lesson. They began instruction with a prompt to get the students started and interested in the topic; then, they shared the objectives and vocabulary for the lesson with the students; next, they used an instructional technique specifically selected based on the material, students, and time; and finally, at the end of the lesson, there was time for reflection on the material that had been presented.

Group three participants cognitively summarized, focused on important information, and explained their organization of new information. A group three participant stated, "If I find it interesting and/or I think it will be important, I investigate it further, see how it will apply, whether it's in my personal life or apply it to my teaching." Group three used their selective focus on important information to decrease the time required to process new information. One group three participant described what happens cognitively when receiving new information: "I'm making a connection. 'Okay, this is something I can use.'… Can I use this? … I'm basically trying to figure out when I would use it, how I would use it? How can I change it? What would I do differently? … Would this benefit my students?"

Group three cognitively monitored their students, as well as either themselves or their strategies. A group three participant stated, "I've had to change either speed, or how I present the content, or the fashion I present the content." Group three participants adjusted their instructional strategy when students were struggling. Group three participants watched and evaluated students to determine ways that they could remediate the difficult information. Group three participants thought about using assessment data to perform post-hoc monitoring of the students' learning and areas their instruction could be improved.

Group three participants thought about their students' reactions and used that information to guide necessary instructional changes. A group three participant said, "Sometimes it's that blank look, nobody is getting it, and everybody is avoiding eye contact, so then I know," that changes must be made. Group three participants thought about personal learning styles and the impact that had on their instructional designs. Group three participants recognized that using their own preferred learning style was not always the best way to indicate the appropriate instructional technique.

Group three participants used a more continual self-evaluation. They reflected on either performance or strategy effectiveness before school, during class, after class, and after school. In response to a question about self-evaluation, a group three participant said, “In essence, [I] determine, review, [and] come to a conclusion about how well the activity, project, [and] specific objective got through to the kids.” Another group three participant said, “I do a lot of thinking about that. I have a 40-minute drive home and then I’m home alone by myself through the week, so I spend a whole lot of time trying to figure out if I’m a good instructor or not.” Group three participants used their reflection to determine what they could do better to help the students. One group three participant shared, “I wanted to be sure I was doing everything I could for my students … Basically when I make decisions about how I teach and why I teach, it is based on what is best for the students.” Group three participants communicated with other teachers about their instruction and even reflected together on whether instructional topics were similar. A group three participant said, “Sometimes when you’re teaching a class that someone else is teaching, you can reflect with them. [I am] the only one teaching it, so that forces me into the realm of looking at it in my own mind, and reflecting upon did it go well, or not go well.” Group three participants believed that self-evaluation led to continual improvement. They made changes even when the lesson or activity had gone well. A group three participant said, “I’m always self-evaluating. I’m always changing. I’ve never taught the same lesson in the exact same way twice … I’m always self-evaluating whether I need to learn more about the particular topic at hand.”

## Implications

Several implications can be drawn from the results of this study. The results of the study indicated that all three groups’ metacognitive awareness in the knowledge of cognition component were similar, even though the researcher had expected each group to have different levels in the knowledge of cognition component based on the teachers' participation in either T2I2 or NBPTS professional development. The results of the study also indicated that all three groups had varying levels of metacognitive awareness in different regulation of cognition subcomponents. The quantitative, qualitative, and phenomenological results each had implications as well.

The results from the quantitative and qualitative portions of the study indicated that all three groups had similar levels of metacognitive awareness in the knowledge of cognition component. Based on coded interview results, all participants described their procedural knowledge; group two and on some questions group one did not described their conditional knowledge; and, only three participants from group three described their declarative knowledge on some questions. Coders using the coding rubric indicated that participants, other than the three participants from group three, ranged from medium to low levels of cognitive knowledge. The literature in professional development, especially in technology and engineering related professional development, has discussed the importance of content and pedagogical knowledge in professional development (Asunda & Hill, 2007; Bybee & Louks-Horsley, 2000; Custer et al., 2008; Daugherty & Custer, 2012; Mundry, 2007; and WestEd, 2000). Content knowledge and pedagogical content knowledge are often considered foundational characteristics of effective professional development (Asunda & Hill; 2007; Ball et al., 2007; Bybee & Louks-Horsley, 2000; and Mundry, 2007).

Effective professional development in technology and engineering education should address teachers' development of content and pedagogical knowledge (Bybee and Loucks-

Horsley, 2010). Technology and engineering education professional development's focus on content and pedagogical knowledge is most likely due to the rate of change in technology and engineering education (Avery, 2010). As technology and engineering education continues to include increasingly complex, cognitively demanding concepts like engineering principles and problem solving, teachers' and students' metacognitive awareness will be important for their self-regulated learning (Asunda & Hill; 2007; Bransford et al., 1999; Kramarski & Michalsky, 2009; Pintrich, 2004; Pucheu, 2008; and Young, 2010). With technology and engineering education professional development's focus on content knowledge, there is also an apparent need for the professional development to focus on metacognitive awareness to enable teachers with the ability to transfer learned content from professional development back into their classrooms (Bransford et al., 1999; Graber, 1998; and Palincsar & Brown, 1984). According to Bybee and Locks-Horsley (2000), "Professional development will provide the opportunities for technology teachers and other educators to learn what they need to know and be able to do as they assist students" (p. 32) with learning; only if the professional development provides teachers with the "cognitive self-awareness necessary for the kinds of metacognitive capabilities required to transfer professional development training into effective classroom practices" (Bransford et al., 1999; Graber, 1998; and Palincsar & Brown, 1984 as cited by Pucheu, 2008, p. 7). Having a focus on metacognition at the beginning of professional development would allow teachers to develop adequate metacognitive awareness specific to the cognitive reasoning behind the application of learning strategies (Guskey, 2003; Leinhardt, 1993; Palincsar, 1986; and Pucheu, 2008).

Wilson and Bai (2010) further detailed the importance of the knowledge of cognition component in teachers' pedagogical understanding of metacognition. Wilson and Bai (2010) determined that a teacher's ability to develop students' metacognition was dependent on the teacher's knowledge of cognition. In this study, teachers were purposefully selected based on the understanding that they needed metacognitive awareness if their goal was to develop students' metacognitive awareness (Pucheu, 2008 and Wilson & Bai, 2010). Based on the results of this study and Wilson and Bai's (2010) study, even after completing professional development with a focus on improving pedagogy, teachers will have difficulty in developing students' metacognition if their own knowledge of cognition is not improved. Teachers' knowledge of cognition determines their ability to select and apply effective learning strategies (Leinhardt, 1990; Palincsar, 1986; and Pucheu, 2008). It is difficult to identify one component of metacognitive awareness as being more important than another; however, students' development of metacognition seems to rely on teachers' knowledge of cognition (Wilson & Bai, 2010 and Schraw, 2009). This suggests that teacher professional development should focus on metacognitive awareness, especially knowledge of cognition, as it will have positive impacts on student's development of metacognition (Darling-Hammond, 1999; Schraw, 2009; and Wilson & Bai, 2010).

Another implication of this study was determined from the findings, in both quantitative and qualitative portions. The findings are that the groups had different levels of metacognitive awareness in the subcomponents of regulation of cognition. The teachers in this study self-reported their metacognitive awareness for each of the cognitive regulation subcomponents. Regulation of cognition has been identified as a substantial component in the learning process (Pintrich & DeGroot, 1990; Pintrich et al., 2000; and Pucheu, 2008).

This again implies the importance of metacognitive awareness as a focus in professional development if teachers are to benefit from professional development programs. The regulation of cognition entails teachers' ability to solve problems involving complex information management and reasoning during planning, monitoring, debugging, organizing, and evaluating tasks (Corno, 1987; Pucheu, 2008; and Schraw & Dennison, 1994). The problems that teachers are exposed to each day vary greatly and necessitate the teacher's ability to regulate their cognition (Lin et al., 2005). Due to the complexity of problems that teachers encounter, their ability to cognitively adapt will help develop successful solutions (Lin et al., 2005). A teacher's inability to regulate their cognition can negatively impact the teacher's planning, monitoring, debugging, organizing, or evaluating (Corno, 1987 and Schraw & Dennison, 1994). Professional development with a focus on metacognitive awareness may be the only option to improve teachers' regulation of cognition (Bransford et al., 1999; Graber, 1998; Guskey, 2003 Prytula, 2012; and Pucheu, 2008).

Specifically in technology and engineering education, teachers engage students in problem solving and design activities comprised of science, technology, engineering, and mathematics content that requires thoughtful planning, information management, and critical reflection on practice (Avery, 2010; Asunda & Hill, 2007; and Mundry, 2007). The complexity of content and pedagogical knowledge required for the interdisciplinary approach to technology and engineering education requires teachers to cognitively adapt and self-monitor the learning environment (Lin et al., 2005 and Barak, 2010). As recommended by the literature, professional development in technology and engineering education should present this intricate content and pedagogical knowledge (Bybee and Louks-Horsley, 2000;

Custer et al., 2008; & Daugherty & Custer, 2012). Technology and engineering teachers in these professional development programs require the ability to collaborate, organization, and manage new information as well as reflect on practices, beliefs, and social implications related to the presented content and pedagogical knowledge (Barak, 2010; Petrina, Feng, & Kim, 2008; and Mundry, 2007). The importance of content and pedagogical knowledge expressed in the technology and engineering professional development literature (Asunda & Hill, 2007; Bybee and Louks-Horsley, 2000; Custer et al., 2008; & Daugherty & Custer, 2012) implies the importance of professional development programs being designed to incorporate regulation of cognition components discussed in the literature (Barak, 2010; Lin et al., 2005; and Petrina, Feng, & Kim, 2008).

When comparing the quantitative and qualitative results of this study, both divergent and convergent results were found. The quantitative results indicated that there was a more significant difference between group two and the other two groups, one and three. The quantitative data from the MAI was considered by Schraw and Dennison (1994) to be a "reliable initial test of metacognitive awareness" (p. 472). In this study, in addition to the MAI, the metacognitive awareness interview was used to provide a more complete understanding of the participants' metacognitive awareness (Bryman, 2006; Creswell, 2007; and Denzin & Lincoln, 1994). The qualitative analysis provided a more complete understanding of the participants' metacognitive awareness, revealing similarity in their knowledge of cognition and varying differences in their regulation of cognition. When planning to study metacognition, there are a variety of possible measures (Akturk & Sahin, 2011). Each metacognitive measure has strengths and weaknesses that can impact the received data. Using one method to measure provides a narrow perception of participants' metacognition (Akturk & Sahin, 2011). The literature recommends using multiple methods when investigating metacognition to develop a more complete understanding of it (Akturk & Sahin, 2011; Schraw, 2000; and Veenman et al., 2006).

The intent of this study was to measure technology and engineering teachers' metacognitive awareness. The focus on teachers' metacognition has historically been considerably less of a focus in research than students' metacognition; however, researchers' focus on teachers' metacognition, especially within professional development, has been increasing in recent years (Bransford et al., 1999; Prytula, 2012; and Pucheu, 2008). The findings of this study are applicable to future work in the professional development of teachers. An increase in teachers' metacognitive awareness, provided by professional development focused on metacognition, could positively impact teachers' planning, organizing, monitoring, debugging, and evaluating as well as students' higher-order thinking, problem-solving, self-assessment, self-regulated learning, and self-awareness (Corno, 1987; Guskey, 2003; Leinhardt, 1990; Mundry, 2007; Palincsar, 1986; Paris & Winograd, 1990; Prytula, 2012; Pucheu, 2008; and Wenglinsky, 2000).

## Future Research

The literature on professional development and metacognition points out several aspects of professional development that require further investigation. One of the aspects that should be further investigated is the numerous possible impacts of professional development on teachers, in particular the connection between the professional development's impact on teachers and the experiences of students. Additionally, research should be conducted on how a focus on metacognition in professional development programs impacts the programs' effectiveness. Research addressing the strengths and weaknesses of professional development could further advance the understanding of metacognition's role in professional development effectiveness. Similarly, research on teachers' levels of metacognitive awareness before and after professional development, as well as the resulting gains from professional development, would add to literature on metacognition's potential to increase professional development effectiveness.

Admittedly, there are challenges in measuring the impact of professional development on teachers (Flecknoe, 2002 and Garet et al., 2001). As with this study, there are extraneous variables that potentially alter the measurable impacts. One of the extraneous variables that should be considered in future professional development research is motivation. Lack of motivation may be a reason that group two participants did not complete the T2I2 professional development system and or self-reported lower levels of metacognitive awareness. Barak (2010) considered motivation one of three characteristics essential for self-regulated learning within technology education. The other two characteristics considered by Barak (2010) as essential for self-regulated learning are cognition and metacognition. As this study has only focused on metacognition, motivation and cognition should be addressed in future self-regulated professional development research.

Additionally, when researching, the focus must be on measurable impacts of the professional development program on teacher's practice. The impact on the teacher's practice seems to indicate a pre- and post- measurement of the teachers. The suggested measures for professional development's impact on teachers' practices are observations and interviews

(Flecknoe, 2002). The suggested qualitative design would be either case study or phenomenology (Creswell, 2007; Flecknoe, 2002). For an improved analysis, the aspects that are identified in the literature for influencing the professional development's effectiveness could be controlled (Guskey, 2003). As part of adding to the literature on professional development impacting teachers' practice, research connecting teacher gains and resulting student gains is also suggested.

Guskey (2003) pointed out that much of the research and literature on professional development effectiveness does not further investigate the connection between teacher and student improvements. Guskey (2003) does indicate that occasionally research connects the results of professional development on teachers' practice to student achievement, but research is still lacking in this area. Research indicates strategies for effective professional development but leaves out the direct focus on professional development to increase student achievement. In Wenglinsky's (2002) study, he determined that professional development is one of three characteristics that most impacts student achievement. Wenglinsky's (2002) study indicated that teacher professional development in higher-order thinking skills and diversity positively impacted student achievement. However, more research is needed in this area.

If metacognitively aware teachers continue to be a focus of educational reform, research on professional development that is designed to improve teachers' metacognition will be needed (Prytula, 2012 and Pucheu, 2008). As previously stated, much of the current research focuses on students' metacognition. However, with the understanding that students' metacognitive awareness would be the result of teachers' metacognitive awareness, the focus is shifting towards the teachers' professional development (Harskamp & Henry, 2009; Kramarski & Michalsky, 2009; Lin et al., 2005; Prytula, 2012; and Wilson & Bai, 2010). Metacognition has been only indirectly included in professional development programs. This means that the benefits of having a direct focus on metacognition as a characteristic of professional development are as yet unidentified. However, the benefits of metacognitive students have been studied, and the numerous benefits of metacognitively aware students indicates the importance of metacognitively aware teachers. Teacher professional development is one of a few ways for improving teachers' metacognitive awareness (Guskey, 2003 and Prytula, 2012). Research on the role of metacognition in teacher professional development is needed. Additionally, more research on the impact of metacognition as part of professional development on teacher's practices is needed.

A future study of the impact of professional development on a teachers' metacognitive awareness could include both a pre- and post- measurement, which would add extensive detail to the analysis. As with this study, some teachers may have had higher levels of metacognitive awareness than other teachers before participating in the professional development. The pre- and post- measurement would help control for the extraneous variable of metacognitive levels before and after the professional development program. Thus, the pre- and post- measurement of the teacher's metacognition would enable a more accurate determination of the impact of the professional development. Characteristics of professional development that could be better controlled in future research include focus on metacognition, time, goals, and collaboration; controlling for these variables would enable researches to determine the relative importance of each characteristic. Additionally, measuring other variables, like motivation, that may impact teachers' metacognitive awareness, self-regulated learning, and or performance in professional development programs would provide more comprehensive understanding of professional development's impact on teachers.

## Conclusions

The rationale for measuring the impact of professional development on metacognitive awareness was based on the review of literature as well as the connection among T2I2 professional development, NBPTS professional development, and metacognition. The literature emphasized the importance of teachers' metacognitive awareness in influencing students' metacognitive adaptation, knowledge of how to learn, self-regulated learning, and self-assessment (Lin et al., 2005; Paris & Winograd, 1990; and Pucheu, 2008). The literature also indicated that teachers do not have many available options for becoming more metacognitively aware other than professional development (Bransford et al., 1999; Kramarski & Michalsky, 2009; and Prytula, 2012). The literature identified the MAI and semi-structured interview as effective measures of teachers' metacognitive awareness (Akturk & Sahin, 2011; Prytula, 2012; and Pucheu, 2008).

The intent of the study was to investigate the impact of professional development on technology and engineering teachers' metacognitive awareness, in particular the differences in teachers' metacognitive awareness based on their participation in either T2I2 or NBPTS professional development. The MAI and metacognitive awareness interview were used for data collection. The analysis of the data included using the Kruskal-Wallis analysis of variance, Cohen's kappa, and two independent coders who used a coding rubric to code the transcribed interviews. Results of the data analysis indicated differences in participants' metacognitive awareness based on their involvement in professional development. Results from the quantitative and qualitative methods were compared side-by-side. The comparison indicated both divergence and convergence in the subcomponents of participants' metacognitive awareness. Results from the comparison were used to describe the essence of the participants' metacognitive awareness during common teacher practices.

The combination of quantitative and qualitative data provided a more complete understanding of teachers' metacognitive awareness than would have been possible with a single data type. Comparing the groups indicated impacts of professional development on teachers' metacognitive awareness. From the comparisons of the participants, three findings emerged. First, all participants were at a similar level in the knowledge of cognition component of metacognitive awareness; the participants' knowledge of cognition was at a medium level, indicating that the participants had room to improve their knowledge of cognition. The second finding was that all participants' regulation of cognition could also be improved; participants ranged from a component level to a low level in the regulation of cognition component. The third finding was that group three participants had the highest metacognitive awareness, group one participants were similar to group three, and group two participants were less metacognitive than the other two groups.

The results from this study contribute to the scholarly literature on effective professional development, which offers a theoretical basis for the training of in-service teachers. Further research may be conducted on the impact of teacher professional development on student achievement, as well as on how professional development that is focused on metacognition impacts both teacher and student achievement. The findings from this study indicate the importance of metacognition as a central characteristic in teacher professional development, but future research is essential to determining metacognition's role in professional development.

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# APPENDICES

## Appendix A

## METACOGNITIVE AWARENESS INVENTORY

## METACOGNITIVE AWARENESS COMPONENTS AND SUBCOMPONENTS

## QUESTIONS BY SUBCOMPONENT

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# METACOGNITIVE AWARENESS INVERNTORY

Please use the rating scale provided to respond to each question below by indicating how true or false each statement is about you. Your responses will be kept confidential, so please answer as truthfully as you can.

| ALWAYS FALSE | SOMETIMES FALSE | NEUTRAL | SOMETIMES TRUE | ALWAYS TRUE |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

_____ 1. I ask myself periodically if I am meeting my goals.

_____ 2. I consider several alternatives to a problem before I answer.

_____ 3. I try to use strategies that have worked in the past.

_____ 4. I pace myself while learning in order to have enough time.

_____ 5. I understand my intellectual strengths and weaknesses.

_____ 6. I think about what I really need to learn before I begin a task.

_____ 7. I know how well I did once I finish a test.

_____ 8. I set specific goals before I begin a task.

_____ 9. I slow down when I encounter important information.

_____ 10. I know what kind of information is most important to learn.

_____ 11. I ask myself if I have considered all options when solving a problem.

_____ 12. I am good at organizing information.

_____ 13. I consciously focus my attention on important information.

_____ 14. I have a specific purpose for each strategy I use.

_____ 15. I learn best when I know something about the topic.

_____ 16. I know what the teacher expects me to learn.

_____ 17. I am good at remembering information.

_____ 18. I use different learning strategies depending on the situation.

_____ 19. I ask myself if there was an easier way to do things after I finish a task.

_____ 20. I have control over how well I learn.

_____ 21. I periodically review to help me understand important relationships.

_____ 22. I ask myself questions about the material before I begin.

_____ 23. I think of several ways to solve a problem and choose the best one.

_____ 24. I summarize what I've learned after I finish.

_____ 25. I ask others for help when I don't understand something.

_____ 26. I can motivate myself to learn when I need to.

_____ 27. I am aware of what strategies I use when I study.

_____ 28. I find myself analyzing the usefulness of strategies while I study.

_____ 29. I use my intellectual strengths to compensate for my weaknesses.

_____ 30. I focus on the meaning and significance of new information.

_____ 31. I create my own examples to make information more meaningful.

_____ 32. I am a good judge of how well I understand something.

_____ 33. I find myself using helpful learning strategies automatically.

_____ 34. I find myself pausing regularly to check my comprehension.

_____ 35. I know when each strategy I use will be most effective.

_____ 36. I ask myself how well I accomplished my goals once I'm finished.

_____ 37. I draw pictures or diagrams to help me understand while learning.

_____ 38. I ask myself if I have considered all options after I solve a problem.

_____ 39. I try to translate new information into my own words.

_____ 40. I change strategies when I fail to understand.

_____ 41. I use the organizational structure of the text to help me learn.

_____ 42. I read instructions carefully before I begin a task.

_____ 43. I ask myself if what I'm reading is related to what I already know.

_____ 44. I re-evaluate my assumptions when I get confused.

_____ 45. I organize my time to best accomplish my goals.

_____ 46. I learn more when I am interested in the topic.

_____ 47. I try to break studying down into smaller steps.

_____ 48. I focus on overall meaning rather than specifics.

_____ 49. I ask myself questions about how well I am doing while I am learning something new.

_____ 50. I ask myself if I learned as much as I could have once I finish a task.

_____ 51. I stop and go back over new information that is not clear.

_____ 52. I stop and reread when I get confused.

## METACOGNITIVE AWARENESS COMPONENTS AND SUBCOMPONENTS

KNOWLEDGE OF COGNITION SUBCOMPONENTS:

1. Declarative Knowledge: knowledge about learning and one's cognitive skills and abilities
2. Procedural Knowledge: knowledge about how to use strategies
3. Conditional Knowledge: knowledge about when and why to use strategies

REGULATION OF COGNITION SUBCOMPONENTS:

1. Planning: planning, goal setting, and allocating resources.
2. a) Organizing: implementing strategies and heuristics that help one manage information

   b) Information Management: organizing, elaborating, summarizing, and selectively focusing on important information
3. Monitoring: on-line assessment of one's learning or strategy use
4. Debugging: strategies used to correct performance errors or assumptions about the task or strategy used
5. Evaluation: post-hoc analysis of performance and strategy effectiveness

QUESTIONS BY SUBCOMPONENT

Declarative Knowledge Questions: 5, 10, 12, 16, 17, 20, 32, 46

Procedural Knowledge Questions: 3, 14, 27, 33

Conditional Knowledge Questions: 15, 18, 26, 29, 35

Planning Questions: 4, 6, 8, 22, 23, 42, 45

Organizing Questions: 9, 13, 30, 31, 37, 39, 41, 43, 47, 48

Monitoring Questions: 1, 2, 11, 21, 28, 34, 49

Debugging Questions: 25, 40, 44, 51, 52

Evaluating Questions: 7, 19, 24, 36, 38, 50

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from: Andrew Hughes <ajhughe2@ncsu.edu>

to: Gregory Schraw <gschraw@unlv.nevada.edu>

date: Sat, Jan 24, 2015 at 8:52 PM

subject: metacognitive awareness inventory

mailed-by: ncsu.edu

Hello Dr. Schraw,

I am completing a doctoral dissertation at North Carolina State University that compares groups of teachers' metacognitive awareness based on their participation in professional development. It is a mixed methods study, using the Metacognitive Awareness Inventory and an interview I developed. I am asking for your permission to use and reprint the MAI in my dissertation?

Thank you
Andrew Hughes

from: Gregory Schraw <gschraw@unlv.nevada.edu>

to: Andrew Hughes <ajhughe2@ncsu.edu>

date: Thu, Jan 29, 2015 at 9:32 AM

subject: Re: metacognitive awareness inventory

mailed-by: unlv.nevada.edu

Hi Andrew,

This is fine....feel free to use and reprint the MAI.

Gregg

## Appendix B

## METACOGNTIIVE AWARENESS INTERVIEW

## METACOGNTIIVE AWARENESS INTERVIEW CODING RUBRIC

METACOGNITIVE AWARENESS INTERVIEW

This interview is being recorded.

This interview, as part of my dissertation, is to help understand a teacher's metacognitive awareness. No one, including me will be able to connect your identity with the information you provide. I want to tell you that there is no right or wrong answers to the questions. Listen to the question carefully and then describe what comes to mind. Your answers should be based on experiences related to your teaching.

How many years have you taught?

Were you originally trained and certified as a teacher?

Have you received a masters or doctorate?

What level do you currently teach?

Where all (# of years) at the (level) level?

1. Describe a method you use for planning instruction.

2. Describe a method you use for planning assessment.

3. Describe how you organize your instruction.

4.1. Remembering that there are multiple types of information: Describe how you inwardly interpret information?

4.2. How do you inwardly interpret unspoken information from your students?

4.3. How do you inwardly interpret a new technique learned from another teacher or a professional development?

5. Describe how you monitor during instruction.

6. Describe how you monitor during assessment.

7. Describe how you adjust your teaching during a lesson.

8. Do you self-evaluate after the instructional process?

9. Describe how you self-evaluate after the instructional process.

## METACOGNITIVE AWARENESS INTERVIEW CODING RUBRIC

| Question Focus: Subcomponent | Component of Metacognitive Awareness | High Level of Metacognitive Awareness | High to Medium Level of Metacognitive Awareness | Medium Level of Metacognitive Awareness | Medium to Low Level of Metacognitive Awareness | Low Level of Metacognitive Awareness |
|---|---|---|---|---|---|---|
| **planning: Question 1 and 2** | Regulation | The participant describes planning, goal setting, and allocation of resources | The participant describes 2 of the items in detail and 1 item generally in the column “High Level of Metacognitive Awareness”. | The participant describes 2 of the 3 listed in the column “High Level of Metacognitive Awareness”. | The participant describes 1 of the items in detail and 2 item generally in the column “High Level of Metacognitive Awareness”. | The participant describes 1 of the 3 listed in the column “High Level of Metacognitive Awareness”. |
| | Knowledge | The participant describes a strategy; how to use the strategy, why the strategy was used in cognitive terms, and how they knew that was the strategy to use in cognitive terms. | The participant describes 3 of the 4 listed in the column “High Level of Metacognitive Awareness”. | The participant describes 2 of the 4 listed in the column “High Level of Metacognitive Awareness”. | The participant describes 1 of the 4 listed in the column “High Level of Metacognitive Awareness”. | The participant does not describe any of the 4 listed in the column “High Level of Metacognitive Awareness”. |
| **organization: Question 3** | Regulation | The participant describes the implementation of techniques based on an understanding of cognition for the purpose of organization. | The participant describes the implementation of techniques based on an understanding of cognition for the purpose of organization. | The participant describes the implementation of techniques for the purpose of organization. | The participant describes generally the implementation of techniques for the purpose of organization | The participant does not describe the implementation of techniques for the purpose of organization. |
| | Knowledge | The participant describes a strategy; how to use the strategy, why the strategy was used in cognitive terms, and how they knew that was the strategy to use in cognitive terms. | The participant describes 3 of the 4 listed in the column “High Level of Metacognitive Awareness”. | The participant describes 2 of the 4 listed in the column “High Level of Metacognitive Awareness”. | The participant describes 1 of the 4 listed in the column “High Level of Metacognitive Awareness”. | The participant does not describe any of the 4 listed in the column “High Level of Metacognitive Awareness”. |

| | | | | | | |
|---|---|---|---|---|---|---|
| **information management:**<br><br>**Question 4** | Regulation | The participant describes their cognitive organization, elaboration, summarization, and selective focus on important information. | The participant describes 3 of the 4 items listed in the column "High Level of Metacognitive Awareness". | The participant describes 2 of the 4 listed in the column "High Level of Metacognitive Awareness". | The participant describes 1 of the 4 listed in the column "High Level of Metacognitive Awareness". | The participant does not describe any of the 4 listed in the column "High Level of Metacognitive Awareness". |
| | Knowledge | The participant describes a strategy; how to use the strategy, why the strategy was used in cognitive terms, and how they knew that was the strategy to use in cognitive terms. | The participant describes 3 of the 4 listed in the column "High Level of Metacognitive Awareness". | The participant describes 2 of the 4 listed in the column "High Level of Metacognitive Awareness". | The participant describes 1 of the 4 listed in the column "High Level of Metacognitive Awareness". | The participant does not describe any of the 4 listed in the column "High Level of Metacognitive Awareness". |
| **monitoring:**<br><br>**Question 5 and 6** | Regulation | The participant describes cognitive assessment of themselves, someone else, and their strategy | The participant describes 2 of the items in detail and 1 item generally in the column "High Level of Metacognitive Awareness" | The participant describes 2 of the 3 listed in the column "High Level of Metacognitive Awareness". | The participant describes 1 of the items in detail and 2 item generally in the column "High Level of Metacognitive Awareness". | The participant describes 1 of the 3 listed in the column "High Level of Metacognitive Awareness". |
| | Knowledge | The participant describes a strategy; how to use the strategy, why the strategy was used in cognitive terms, and how they knew that was the strategy to use in cognitive terms. | The participant describes 3 of the 4 listed in the column "High Level of Metacognitive Awareness". | The participant describes 2 of the 4 listed in the column "High Level of Metacognitive Awareness". | The participant describes 1 of the 4 listed in the column "High Level of Metacognitive Awareness". | The participant does not describe any of the 4 listed in the column "High Level of Metacognitive Awareness". |

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|---|---|---|---|---|---|---|
| **debugging:**<br><br>**Question 7** | Regulation | The participant describes a strategy used to correct performance errors and assumptions they made about a task or strategy used. | The participant describes 1 of the items in detail and 1 item generally in the column "High Level of Metacognitive Awareness". | The participant describes a strategy used to correct performance errors or assumptions they made about a task or strategy used. | The participant generally describes 1 of the 2 aspects in the column "High Level of Metacognitive Awareness". | The participant does not describe a strategy used to correct performance errors or assumptions they made about a task or strategy used. |
| | Knowledge | The participant describes a strategy; how to use the strategy, why the strategy was used in cognitive terms, and how they knew that was the strategy to use in cognitive terms. | The participant describes 3 of the 4 listed in the column "High Level of Metacognitive Awareness". | The participant describes 2 of the 4 listed in the column "High Level of Metacognitive Awareness". | The participant describes 1 of the 4 listed in the column "High Level of Metacognitive Awareness". | The participant does not describe any of the 4 listed in the column "High Level of Metacognitive Awareness". |
| **evaluating:**<br><br>**Question 9** | Regulation | The participant describes their own post hoc analysis of their performance and strategy effectiveness. | The participant describes 1 of the items in detail and 1 item generally in the column "High Level of Metacognitive Awareness" | The participant describes their own post hoc analysis of either their performance or strategy effectiveness. | The participant generally describes 1 of the 2 aspects in the column "High Level of Metacognitive Awareness". | The participant does not describe their own post hoc analysis of either their performance or strategy effectiveness. |
| | Knowledge | The participant describes a strategy; how to use the strategy, why the strategy was used in cognitive terms, and how they knew that was the strategy to use in cognitive terms. | The participant describes 3 of the 4 listed in the column "High Level of Metacognitive Awareness". | The participant describes 2 of the 4 listed in the column "High Level of Metacognitive Awareness". | The participant describes 1 of the 4 listed in the column "High Level of Metacognitive Awareness". | The participant does not describe any of the 4 listed in the column "High Level of Metacognitive Awareness". |

## Appendix C

## INSTUITIONAL REVIEW BOARD REQUEST FOR EXEMPTION

North Carolina State University
Institutional Review Board for the Use of Human Subjects in Research
REQUEST FOR EXEMPTION (Administrative Review)

**GENERAL INFORMATION**

| | |
|---|---|
| 1. | **Date Submitted:** 9/15/14 |
| 2. | **Title of Project:** Impact of Online Self-regulated Professional Development on Technology and Engineering Educators Metacognitive Awareness |
| 3. | **Principal Investigator:** Andrew Hughes |
| 4. | **Principal Investigator Email:** ajhughe2@ncsu.edu |
| 5. | **Department:** STEM Education |
| 6. | **Campus Box Number:** N/A |
| 7. | **Phone Number:** 8145911183 |
| 8. | **Faculty Sponsor Name if Student Submission:** Cameron Denson |
| 9. | **Faculty Sponsor Email Address if Student Submission:** cddenson@ncsu.edu |
| 10. | **Source of Funding** (Sponsor, Federal, External, etc): None<br>*If Externally funded, include sponsor name and university account number:* |
| | **RANK:**<br>Faculty: ☐; Student: ☐Undergraduate ☐ Masters ☐ PhD; Other: X |

*As the principal investigator, my signature (or electronic submission) testifies that I have read and understood the University Policy and Procedures for the Use of Human Subjects in Research. I assure the Committee that all procedures performed under this project will be conducted exactly as outlined in the Proposal Narrative and that any modification to this protocol will be submitted to the Committee in the form of an amendment for its approval prior to implementation.*

***Electronic submissions to the IRB are considered signed via an electronic signature***

**Principal Investigator:**

Andrew Hughes 8/18/2014

(typed/printed name) (signature) (date)

*As the faculty sponsor, my signature (or electronic submission) testifies that I have reviewed this application thoroughly and will oversee the research in its entirety. I hereby acknowledge my role as the* ***principal investigator of record****.*

**Faculty Sponsor:**

Cameron Denson 9/15/2014

(typed/printed name) (signature) (date)

*PLEASE COMPLETE AND E-MAIL TO:* **irb-coordinator@ncsu.edu**

********************************************************************************************

*For SPARCS office use only*

**Regulatory Compliance Office Disposition**

Exemption Granted ☑; Exempt Under: ☐ b.1 ☑ b.2 ☐ b.3 ☐ b.4 ☐ b.6

Not Exempt, Submit a full protocol ☐

North Carolina State University is a land-grant university and a constituent institution of the University of North Carolina

**Office of Research and Innovation**
Division of Research Administration

NC STATE UNIVERSITY

Campus Box 7514
Raleigh, North Carolina 27695-7514

919.515.8754 (phone)
919.515.7721 (fax)

From: Jennifer Ofstein, IRB Coordinator
North Carolina State University
Institutional Review Board

Date: September 23, 2014

Title: Impact of Online Self-regulated Professional Development on Technology and Engineering Educators Metacognitive Awareness

IRB#: 5241

Dear Andrew Hughes,

The research proposal named above has received administrative review and has been approved as exempt from the policy as outlined in the Code of Federal Regulations (Exemption: 46.101. b.2). Provided that the only participation of the subjects is as described in the proposal narrative, this project is exempt from further review. This approval does not expire, but any changes must be approved by the IRB prior to implementation.

NOTE:

1. This committee complies with requirements found in Title 45 part 46 of The Code of Federal Regulations. For NCSU projects, the Assurance Number is: FWA00003429.

2. Any changes to the research must be submitted and approved by the IRB prior to implementation.

3. If any unanticipated problems occur, they must be reported to the IRB office within 5 business days.

Please forward a copy of this letter to your faculty sponsor, if applicable.
Thank you.

Sincerely,

Jennifer Ofstein

Jennifer Ofstein
NC State IRB

## Appendix D

## INFORMED CONSENT EMAIL

**Hello Participant,**

The purpose of this email is to ask for your participation in a research study. Your participation in this study is voluntary. You have the right to be a part of this study, to choose not to participate or to stop participating at any time without penalty. I am student at North Carolina State University and this research study is for the completion of my dissertation. The purpose of this study is to compare the impact of professional development on groups of teachers' metacognitive awareness. You will be financially compensated for your time if you chose to participate in this study. Every effort has been made to reduce any possible risk in your participation. At any time, if you do not understand something you have the right to ask the researcher for clarification or more information.

If you have read and understood this email and would like to participate, please respond to this email with "yes, I would like to participate".

**<u>What will happen if you take part in the study?</u>**

If you agree to participate in this study, you will be asked to complete the Metacognitive Awareness Inventory (MAI). The MAI should take between 5 and 10 minutes to complete. After the MAI is returned, a follow up interview will be conducted at a date and time agreed upon. The interview is only 9 questions and will take less than 45 minutes.

**<u>Compensation</u>**

Each participant will receive 5 dollars for completing and returning the MAI. Additionally, each participant will receive 20 dollars for completing the interview. The total for completing both the MAI and interview is 25 dollars.

**<u>What if you have questions about this study?</u>**

If you have questions at any time about the study or the procedures, you may contact the researcher, Andrew Hughes, at ajhughe2@ncsu.edu. Alternately, you can also contact either of the researcher's faculty advisors, Aaron Clark, at aaron_clark@ncsu.edu or Cameron Denson, at cddenson@ncsu.edu.

Thank you

Andrew Hughes

# Appendix E

## NATIONAL BOARD for PROFESSIONAL TEACHING STANDARDS EVALUATED ITEMS ALIGHNED with METACOGNITIVE AWARENESS SUBCOMPONENTS

| NBPTS Evaluated Items | Aligned Metacognitive Awareness Subcomponents |
|---|---|
| Evidence that the teacher has worked collaboratively with colleagues to improve teaching and learning, either within the school or in the wider professional community. | planning and organizing |
| Evidence that the teacher treats parents and other interested adults as valued partners in the child's education, and uses thoughtfully chosen, appropriate strategies for reaching out to the families of his or her students. The selected strategies may or may not be original to the teacher, but they are implemented with skill and enthusiasm and are effective in engaging parents and other interested adults in communication that is highly interactive, fostering extensive two-way dialogue focused primarily on substantive teaching and learning issues and individual student progress. | procedural, conditional, and declarative knowledge |
| Evidence that the teacher accurately analyzes and thoughtfully reflects on the significance of all accomplishments taken together, and can appropriately plan for future opportunities to impact student learning. | planning, information management, evaluating, declarative knowledge, conditional knowledge, and procedural knowledge |
| Evidence that the teacher's demonstration lesson illustrates important career and technical learning that is directly linked to appropriate and challenging learning goals. | planning |
| Evidence that the teacher is able to use appropriate technologies to enhance student learning. | planning, procedural, and conditional knowledge |
| Evidence that the teacher is proficient with the demonstrated skill. | procedural knowledge |
| Evidence that the teacher's instructional strategies meaningfully engage students in the process of skill exploration and acquisition and support students' critical thinking and problem-solving abilities. | organizing and declarative knowledge |
| Evidence that the teacher monitors student performance and provides constructive feedback to students that furthers student learning. | monitoring, information management, and conditional knowledge |
| Evidence of the teacher's ability to use knowledge of students to design assessments that evaluate students' understanding of important career and technical education concepts and skills. | planning, information management, declarative, and conditional knowledge |

**Appendix E (continued)**

| | |
|---|---|
| Evidence that the teacher is able to design assessments that foster students' problem-solving and critical thinking skills and further challenging learning goals that support student learning. | planning, procedural, and conditional knowledge |
| Evidence that the teacher links career and technical content with appropriate instruction and reflects on his or her current practice to evaluate, modify, and shape future practice. | planning, evaluating, procedural, and conditional knowledge |
| Evidence that the featured team activity(ies) and related instructional goals are important, challenging, and appropriate for students and that the teacher guides students in the development of their problem-solving skills. | planning, monitoring, and declarative knowledge |
| Evidence that the teacher reflects on his or her current practice to accurately describe, analyze, inform, and shape future practice. | evaluating |
| Evidence that the teacher is able to thoroughly describe, analyze, and evaluate classroom interactions and insights into student learning. | information management |