Examining the Extent to Which Select Teacher Preparation Experiences

Inform Technology and Engineering Educators'

Teaching of Science Content and Practices

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Dissertation submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Doctor of Philosophy
In
Curriculum and Instruction

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March 19, 2015
Blacksburg, Virginia

Keywords: Pedagogical Content Knowledge, Technology and Engineering education, Integrative STEM Education, Mixed methods

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ABSTRACT

With the recent release of the *Next Generation Science Standards* (NGSS) (NGSS Lead States, 2014b) science educators were expected to teach engineering content and practices within their curricula. However, technology and engineering (T&E) educators have been expected to teach content and practices from engineering and other disciplines since the release of the *Standards for Technological Literacy* (ITEA/ITEEA, 2000/2002/2007). Requisite to the preparation of globally competitive STEM literate individuals is the intentional, concurrent teaching of science, technology, and engineering concepts. Many studies have examined the pedagogical content knowledge (PCK) (Shulman, 1987) of science and T&E educators, but none have examined the science PCK of T&E educators.

The purpose of this study was to examine the extent of the relationship between T&E educator's science and T&E preparation experiences, and their teaching of science content and practices. This study, which employed a fully integrated mixed methods design (Teddlie & Tashakkori, 2006), was conducted to inform the pre- and in-service preparation needs for T&E educators. A random sample of 55 Foundations of Technology (FoT) teachers across 12 school systems within one state participated in an online survey, leading to eight teachers being purposefully selected for classroom observations. Data collected from the surveys and classroom observations were analyzed through Spearman's rho tests to examine relationships between preparation factors and teaching of science content and practices. These data were corroborated with curriculum content analyses, classroom observations, and interview responses to validate the results.

Analyses of the data across all three methods revealed significant correlations between many preparation factors and the teaching of science content and practices. Specifically the amount of high school and undergraduate physics courses, and T&E and science in-service delivered were found to have statistically significant, strong positive correlations. These findings suggest T&E educators with increased amounts of these preparation experiences can be expected to teach science content and practices more proficiently. The findings and conclusions drawn from the data analyses provide implications for science and T&E educators, researchers, pre-service programs, and in-service professional development efforts. The discussion and implications suggest the need to conduct replication studies in different contexts.

Dedication

This dissertation is dedicated to Dr. Leon L. Copeland, Sr. and the late Dr. Gerald F. Day who planted the seed of pursuing a doctoral degree and ensured I was well prepared for this journey. Your passion and dedication toward the profession have inspired countless teachers and students. I am thankful to have had the opportunity to study under exceptional role models such as yourself, and hope that I can one day inspire others the way you have inspired me.

Acknowledgments

As educators we strive to make a difference in the lives of our students, and it is indisputable that the completion of my Ph.D. represents the influence that many educators have had on my life. I would like to first thank my parents, Kevin and Kimber-Leigh Love for their unconditional support and encouragement during this roller-coaster ride. From an early age you both taught me that anything is possible through hard work, which has served me well in my endeavors. To my brother Zach, your support and help as a fellow technology educator and sibling have been invaluable.

I owe a great deal of thanks to my committee chair and advisor Dr. John G. Wells for giving me the opportunity to study at Virginia Tech and dedicating countless hours to help me grow during my time in Blacksburg. Your tireless commitment to strive for perfection has pushed me to become a better student and researcher than I ever dreamed possible. To my committee member and professor Dr. Jeremy V. Ernst, your ability to provide feedback and advice on an array of items during my time at Virginia Tech has been fundamental in my development. In my view, and in the view of many others, you are a superb scholar who is critical to the future of our field. I would also like to thank my committee members Dr. Catherine L. Ulrich and Dr. Kelly A. Parkes. Your guidance in assisting me to narrow my research, develop the necessary instruments, and ask the right questions were extremely helpful. All of my committee members' patience and dedication throughout the dissertation process was greatly appreciated.

To the numerous faculty members in the School of Education and the Higher Education Administration program at Virginia Tech, especially Dr. Frank Shushok, Jr., Dr. Steven Janosik, and Dr. Claire Robbins, thank you for your assistance during this journey and for expanding my horizons as an educator. I am also grateful for the support from the School of Education at Virginia Tech, which allowed me to complete my Ph.D. without incurring much financial hardship.

Growing up I was fortunate to have two great technology educators, Mr. James Dunlop and Mr. Dale Ziegler, who supported my goal of becoming a technology educator and mentored me throughout my educational career. Thank you also to Mr. Larry Ryan, my cooperating teacher during my undergraduate student teaching internship who continues to provide guidance and advice. To my college baseball coach and mentor Guy Robertson, thank you for teaching me the importance of mind over matter and how to balance the difficult demands of being a student. These skills have helped me tremendously throughout my higher education studies.

I owe many thanks to the teachers that participated in this study and the school system supervisors who helped me recruit these individuals. Without their participation this study would not have been possible. Thank you to Mr. Avi Hadar, CEO of Kelvin® Educational, for supporting my research through the donation of prize packs that were raffled off to participants.

Lastly, to the countless family members, students, teachers, and faculty members I failed to mention, your support has not been unrecognized. My successes are a result of the great individuals who have supported me during my entire educational career. Your help and encouragement along the way is greatly appreciated. I am overwhelmed by the many blessings and opportunities God has bestowed upon me, which have led me to Virginia Tech to obtain this doctoral degree.

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CHAPTER ONE: INTRODUCTION

Overview

"Teaching is, essentially, a learned profession" (Shulman, 1987, p. 9). This quote describes the theoretical underpinning of pedagogical content knowledge (PCK) which Lee Shulman first introduced in his presidential address at the American Educational Research Association (AERA) in 1985. The theoretical framework for PCK was derived from John Dewey's *The Child and the Curriculum* (1902), which revealed the differences between logical understanding and psychological understanding necessary to teach (Shulman, 2008). Since its conception, PCK has been a popular research topic across many educational disciplines. It has also been a controversial topic leading experts to question its existence and how accurately it can be assessed. Studies have shown that teachers possess varying degrees of PCK based upon experience and training (Shulman & Hutchings, 2004; Williams & Lockley, 2012). However, there is a lack of research examining how preparation experiences influence technology and engineering (T&E) educator's science PCK to inform their teaching of science content embedded within T&E curricula. To help teachers, administrators, teacher educators, and state supervisors better understand and enhance the integrative teaching strategies of T&E educators, this study will examine some of the underlying theories of learning and select preparation experiences that contribute to teaching practices and impact student learning.

Nature of the Problem

Schools in the United States are the largest social service institution with expenditures for K-12 schooling costing over $500 billion a year and higher education expenditures totaling $300 billion (Orlich, Harder, Callahan, Trevisan, & Brown, 2007). Because of the emphasis the U.S. places on education and the amount of resources allocated to it, research on teaching and learning is needed to continually improve the teaching of educators and learning of students. Specifically, research in science, technology, engineering, and mathematics (STEM) education is needed to better prepare students with the necessary skills to be technologically literate 21st century citizens and help revive the United States' slipping competitiveness in a global economy.

The concept of STEM, in which these four disciplines are looked at collaboratively, has been around as early as 1989 when the American Association for the Advancement of Science (AAAS) developed *Project 2061* to help all Americans become literate in the STEM disciplines (1989). Leading up to the acronym STEM and the reform of integrative education were numerous educational reforms that helped pave the way for Integrative STEM Education. In the 1890s the Progressive Education Movement aimed to use school as an instrument for social reform. The launching of Sputnik in the 1950's brought the Progressive Education Movement to a close as the nation recognized a weakness in the United States' technological dominance (Wells, 2008). Sputnik also caused Robert Gagné to propose the conditions of learning, allowing the redesign of curricula to improve the STEM content being taught in schools (Gredler, 2005). What resulted were more teacher-centered curricula emphasizing science, mathematics, and foreign language. The 1960s and 1970s saw an Equity Reform Movement that focused on providing equal education to all Americans. The 1980s focused on a "back to the basics" movement, focusing strongly on content knowledge again. The Excellence Reform Movement beginning in the 1980s was the most recent educational reform movement, focusing primarily on curricular content (Wells, 2008).

A Nation at Risk (NCEE, 1983) opened the eyes of many Americans as it exposed the United States' rapidly slipping dominance as a global economic leader, "Our nation is at risk. Our once unchallenged preeminence in commerce, industry, science, and technological innovation is being overtaken by competitors throughout the world" (p. 1). It blamed the pedagogical practices of the American school system as part of the reason for the country's decline in global economic dominance, "Our society and its educational institutions seem to have lost sight of the basic purposes of schooling and of the high expectations and disciplined effort needed to attain them" (p. 1). *Science for All Americans* (AAAS, 1989) and the *Benchmarks for Science Literacy* (AAAS, 1993) provided the framework for science, mathematics, and technology to be taught in unison (Wells, 2008) and improve student interest and proficiency in STEM (Wells, 2013). The intent behind these AAAS publications was to encourage educators to envision teaching the STEM content areas in an integrative fashion (Wells, 2013) because these content areas were so closely related, "the ideas and practice of science, mathematics, and technology are so closely intertwined that we do not see how education in any one of them can be undertaken well in isolation from the others" (AAAS, 1993, pp. 321-322). In an effort to revive the United States' global economic dominance, research assessing PCK in STEM education is needed to better prepare students for 21st century.

In 2000 the *Standards for Technological Literacy* (ITEA/ITEEA, 2000/2002/2007) were developed to promote integration of various contents in technology education. Five years later, Sanders and Wells coined the term "Integrative STEM Education" and started the first Integrative STEM Education preparation program (Wells, 2013). Most recently, *The Next Generation Science Standards* (NGSS) (NGSS Lead States, 2014a) were published calling for the integration of engineering design concepts within science curricula. Although these reforms, standards, and frameworks have provided the support to integrate multiple curricula, the successful implementation of them is continually under scrutiny. Reformed education requires the recruitment and proper preparation of teachers that have both the content knowledge (CK) and PCK needed to implement integrative teaching strategies within their specific subject area (Mehalik, Doppelt, & Schunn, 2008; Wells, 2008; Zubrowski, 2002). The pedagogical practices used in Integrative STEM Education need to be continually researched and refined to improve teaching practices and student learning. Examining how to better implement STEM education in an integrative fashion, and showing that it increases student learning could help the United States prepare students to reclaim its global economic dominance. These factors serve as the basis for conducting research examining PCK of Integrative STEM Education teachers.

For the purpose of this study Wells and Ernst's (2013) definition of Integrative STEM Education will be used:

> The application of technological/engineering design based pedagogical approaches to *intentionally* teach content and practices of science and mathematics education concurrently with content and practices of technology/engineering education. Integrative STEM Education is equally applicable at the natural intersections of learning within the continuum of content areas, educational environments, and academic levels. (para. 2)

This definition suggested that there is no single method defined as the premier one to teach Integrative STEM Education, allowing instructors to choose from a variety of pedagogical practices. Teachers may be unsure of how to intentionally integrate the STEM content areas due to the lack of preparation in their teacher preparation programs or teaching experience. However, researchers have been advocating for integrative education for years, "Hence one of the weightiest problems with which the philosophy of education has to cope is the method of keeping a proper balance between the informal and the formal, the incidental and the intentional modes of education (Dewey, 1916, p. 10). Dewey recognized that students learn some concepts unintentionally, but teachers must assure they are intentionally integrating concepts in order to scaffold students toward the objectives of the lesson and help make relevant personal connections. Dewey (1916) also acknowledged the importance of relevance, "A curriculum which acknowledges the social responsibilities of education must present situations where problems are relevant to the problems of living together, and where observation and information are calculated to develop social insight and interest" (p. 226). Integrative STEM Education is rooted in these concepts of integration and relevancy, just as Shulman's concept of PCK was influenced by the work of Dewey.

Bonser and Mossman (1923) also realized the value of Dewey's work and applied it to industrial arts (now T&E education):

> Children have a strong impulse to manipulate materials, and this impulse may be turned to good account in the development of values altogether higher than those of mere manipulation. In the study of industrial arts the hand work should always be rated as subordinate to the brain work, and supplementary to it. Hand work often serves as a means of carrying industrial studies forward with greater interest, understanding, and personal appreciation of meanings and values. (p. 17)

If the hands-on approach that Bonser and Mossman described is used to increase interest, understanding, and personal meanings, the popular Design Based Learning (DBL) approach widely used today in T&E education could also be viewed as an invaluable pedagogical method. DBL should not be kept just in the T&E education classroom, but shared with other subject areas such as science and mathematics education. Bonser and Mossman (1923) found that children have a strong impulse to manipulate materials, giving the rationale to use these manipulation instincts and skills in STEM education. The STEM subject areas have a strong relationship, as recognized by the NGSS (NGSS Lead States, 2014a). Integrating the closely intertwined STEM disciplines using the DBL pedagogy further enhances the learning environment, “Research in cognitive science supports the belief that integrative practices using hands-on/minds-on methods creates a learning environment where students make connections in a manner that suits how the brain organizes information and constructs knowledge” (Wells, 2010, p. 203). Using T&E DBL activities as the vehicle to intentionally integrate STEM concepts helps evoke student participation in a relevant and engaging educational experience. Teachers are products of their environment and rely on episodic storage to teach the way they were taught, which may not have been in an integrative fashion (Humphreys, Post, & Ellis, 1981; Nespor, 1987; Wells, 2008). Shulman (2004) describes this observation of learning to teach “a seventeen year apprenticeship” (p. 119) in which teachers learn to teach from their experience as a student. He also contests that instructors of content have a greater impact by modeling how to teach a topic than that of a teaching methods professor who has a very brief period to discuss pedagogical methods with future educators. Integrative education can be effective if implemented using the correct pedagogical practices and learning theories. The standards and frameworks of some STEM disciplines are integrative in nature, allowing instructors to intentionally teach STEM content and practices using an integrative approach.

The educational reforms and initiatives discussed in this section exemplify the strong connection between STEM subject areas and the need to teach them in an integrative fashion. Examining the science PCK of T&E educators could expose weaknesses in the methods used to prepare them and help promote integrative pedagogical practices in T&E classrooms. Despite the call for integrative pedagogical methods for the past 30 years, the STEM disciplines in public education still practice in isolation from one another (Wells, 2013). As Shulman and Hutchings (2004) described this experience, “We close the classroom door and experience pedagogical solitude, whereas in our life as scholars, we are members of active communities…to exchange our findings" (p. 140). The world outside of the school walls does not distinguish between content areas, which Integrative STEM Education continues to emphasize for the benefit of increased student learning.

Rationale for the Study

Traditionally research has found that teacher quality is the most effective predictor of student achievement in the classroom (Just for the Kids and The Southeast Center for Teaching Quality, 2002; McCray & Chen, 2012; National Commission on Teaching and America's Future, 1996; Rice, 2003; Wright, Horn, & Sanders, 1997). Darling-Hammond (2000) and Ferguson (1991) found that teachers' expertise, especially teacher qualifications, accounted for more gains in student achievement than socioeconomic status. Additionally, Podgursky (2002) found that teachers with proper credentials, professional development, and classroom practice could offset the effect socioeconomic disadvantage has on student achievement.

Wells (2010) cited Shluman's seven categories of teacher knowledge as having significant impacts on student learning. A logical extension to improve student learning is to ensure teachers are adequately prepared to teach STEM content and practices in an integrative fashion as a result of pre- and in-service preparation programs. T&E educators have been expected to deliver Integrative STEM Education concepts through engineering design since the *Standards for Technological Literacy* were released in 2000. Many science educators are prepared with the knowledge to deliver science content in engineering content and practices, but how well prepared they are to teach engineering content and practices has yet to be discovered. Given the longer span of time that T&E educators have been expected to deliver engineering content and practices, they are the more reasonable population to investigate in regards to Integrative STEM Education teaching strategies.

Current national reform of standards, curricula, and tests have impacted the need for teacher quality and increased student achievement. The *Standards for Technological Literacy* called for technology and engineering educators to teach STEM concepts through an engineering design and problem solving approach (pp. 8-9). More recently, the NGSS (NGSS Lead States, 2014b) have called upon science educators to incorporate the teaching of engineering content and practices within the science curriculum (p. 1). In both T&E education and science education, there has been a push for educators to teach STEM concepts in an integrative fashion (Merrill, 2001). Curricula geared toward engineering education, such as Engineering byDesign (EbD) and Project Lead the Way (PLTW), are heavily embedded with science concepts that teachers must present to students for them to produce solutions to engineering problems. From a national perspective, standardized testing has placed more emphasis on teacher quality to increase student achievement scores. The NAEP is releasing a Technological and Engineering Literacy assessment in 2014, which could be used to measure student gains and compare student achievement scores from teacher to teacher. All of these factors have called for STEM educators to increase their PCK of integrative teaching and use engineering DBL as the vehicle to teach naturally embedded science and mathematics concepts. Additionally, higher levels of PCK for integrative teaching could help improve student achievement (e.g., NAEP scores) in Technological and Engineering Literacy. From this rationale it can be concluded that examining the level of science PCK of T&E educators is of utmost importance. Because of recent educational reform and how tightly interwoven science is within T&E education, examining this aspect of their PCK is needed for T&E education teacher preparation programs to determine how to better train teachers to deliver STEM content and practices in an integrative manner.

Purpose of the Study

To address the growing body of evidence regarding the PCK of T&E educators, various researchers suggest additional studies are needed to fully develop this topic (Jones & Moreland, 2004, 2005; Love, 2013c; Phillips, De Miranda, & Shin, 2009; Rohaan, Taconis, & Jochems, 2011; Williams & Lockley, 2012). T&E educators have been delivering engineering content and practices for almost 15 years, and it would be expected that they have developed and refined their engineering PCK over that time. Unfortunately there remains little evidence to support or refute this claim. T&E educators have been tasked with delivering engineering content and practices in their daily repertoire; concurrent with this delivery of T&E content and practices is science and mathematics content and practices. Unlike T&E education's experience with delivering engineering content and practices using an integrative approach, science education has only been expected to address this topic since the NGSS (NGSS Lead States, 2014a) were released this past year.

Examining the PCK that T&E educators have developed to teach multiple contents in an integrative fashion affords many benefits from which the science education community can learn, as they begin to develop engineering PCK recently required by the NGSS (NGSS Lead States, 2014b). Science education should learn specifically from the methods and processes T&E education used to develop this unique knowledge over time. By studying the science PCK of T&E educators, T&E education can show that it posses a unique knowledge which can help deliver the engineering content and practices that science educators are still developing. The framework of the *Standards for Technological Literacy* affords room to deliver science, engineering, and other subject areas concurrently within the context of an integrative design-based problem solving approach. Given the framework of T&E education and the fact that it has been tasked with delivering engineering content and practices for almost 15 years, T&E educators are the logical population to study. Therefore, the purpose of this study was to examine the level of science PCK that T&E educators possess to better inform pre- and in-service teacher preparation programs; and allow T&E education to show that it possesses a unique set of knowledge to deliver engineering content and practices not yet developed by teachers in other subject areas. To document this level of PCK the researcher collected data to address the following research questions and sub-questions.

Research Questions and Sub-Questions

The following research questions were developed from the problem statement and the review of literature, and also provided the framework for this study. Research Question 1 and its respective sub-questions focus on the preparation experiences that influence the teaching of science content, while Research Question 2 and its sub-questions examine the teaching of science practices.

RQ1 – To what extent do select teacher preparation factors inform in-service secondary level technology and engineering (T&E) educators how to teach *science* ***content*** in T&E education classrooms?

In the context of teaching the Foundations of Technology (FoT) unit of the Engineering byDesign (EbD) curriculum:

RQ1, SQ1- To what extent do select *science-related* preparation experiences inform in-service secondary level T&E educators how to *teach science content* embedded within the FoT unit?

RQ1, SQ2- To what extent do select *T&E-related* preparation experiences inform in-service secondary level T&E educators how to *teach science content* embedded within the FoT unit?

RQ2 – To what extent do select teacher preparation factors inform in-service secondary level T&E educators how to teach *science **practices*** in T&E education classrooms?

In the context of teaching the Foundations of Technology (FoT) unit of the Engineering byDesign (EbD) curriculum:

RQ2, SQ1- To what extent do select *science-related* preparation experiences inform in-service secondary level T&E educators how to *teach science practices* embedded within the FoT unit?

RQ2, SQ2- To what extent do select *T&E-related* preparation experiences inform in-service secondary level T&E educators how to *teach science practices* embedded within the FoT unit?

Delimitations

1. The participants in the observation and interview portion of this study were purposefully selected based upon mode rankings of all survey responses. By purposefully selecting individuals for the observation and interview, it allowed the researcher to examine those that reported unique preparation experiences but may have excluded many with the median experiences.
2. A Mid-Atlantic state was specifically chosen due to it having the most FoT teachers in the country. This allowed the researcher a greater opportunity to obtain the most participants possible. Even though FoT is a uniform national curriculum, by only selecting participants from one state it may not capture the various other influences that state and school systems may have on how to teach FoT.
3. Despite the RTOP being found reliable for a single observer to rate one lesson (Lomas & Nicholas, 2009) and the researcher establishing inter-rate reliability above the preferred 80% threshold (Howell, 2007) with science and T&E education experts, the reported RTOP scores in this study are the opinion of one researcher. The RTOP

instrument is reliant upon raters' opinions and knowledge of teaching science and T&E content and practices.

4. Teachers were observed for one class period in this study; therefore, the researcher could only rate them based on what he observed during that period.

Limitations

1. This study contained a small homogenous sample for both the survey (Table 17) and the classroom observations (Table 6). The researcher had no control over this factor since the study was limited to those who voluntarily participated from school systems that agreed to partake in this study.
2. The results of this study may not be generalizable beyond high school T&E educators and students participating in the FoT curriculum within the consortium state where this study took place.
3. This study was limited to assessment of the PCK levels as indicated by the TEES-PCK survey, RTOP, and interview questions.

Definition of Terms

Achievement

Measures of student learning and performance such as student scores on state assessments, pre-tests and end-of-course tests, and other measures that are rigorous and comparable across classrooms (U.S. Department of Education, 2012a).

Conceptual Understanding

Theoretical comprehension.

Content Knowledge (CK)

The knowledge about a subject (Shulman, 1995).

Design-based learning (DBL)

A teaching method that, “enables students to experience the construction of cognitive concepts as a result of designing and making individual, inventive, and creative projects, to initiate the learning process in accordance to their own preference, learning styles, and various skills” (Doppelt, Mehalik, Schunn, Silk, & Krysinski, 2008, p. 23).

Detailed Explanations

Thorough descriptions better explaining content or practices.

Elements of Science

Critical components of science.

Fundamental Science/T&E Concepts

Essential content topics needed to learn more complex ones.

General Pedagogical Knowledge (GPK)

“those broad principles and strategies of classroom management and organization that appear to transcend subject matter” (Shulman, 1987, p. 8).

Grasp of Content

Recognition, comprehension, and can logically present to others the lesson content identified by FoT.

Integrative STEM Education

“the application of technological/engineering design based pedagogical approaches to *intentionally* teach content and practices of science and mathematics education concurrently with content and practices of technology/engineering education. Integrative STEM Education is equally applicable at the natural intersections of learning within the continuum of content areas, educational environments, and academic levels" (Wells & Ernst, 2013, para. 2).

Intellectual Rigor

Challenging content and practices for students at this grade level according to expectations identified by the FoT curriculum.

Lateral Transfer

"the use of some known knowledge in a new setting but at the same level of complexity as the old setting" (Gagné, Yekovich, & Yekovich, 1999, 243).

Learning

"a dual process in which, initially, the inside beliefs and understandings must come out, and only then can something outside get in" (Shulman & Hutchings, 2004, p. 36).

Learning Theory

A coherent explanation of a set of relationships that have been tested with lots of research in relation to the learning process (Darling-Hammond, Austin, Orcutt, & Rosso, 2001).

Learning Style

"an individual's preferred methods for perceiving and transforming his/her learning experiences" (Kulturel-Konak, D'Allegro, & Dickinson, 2011, p. 10).

Nature of Reality

That which possesses virtue of an actual or existent thing (formal reality), or that which possesses virtue for being a representation of something (objective reality) (Smith, 2014).

Pedagogical Content Knowledge (PCK)

"the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction" (Shulman, 1987, p. 8).

Real World Phenomena

Complex occurrences in authentic contexts.

Reflective

Thoughtfully thinking about practices as well as the content presented.

Scaffolding

"a design to provide support for students but only enough to allow the student to complete the task alone" (Benson, 1997, p. 126).

Technology and Engineering (T&E) education

"A study of technology, which provides an opportunity for students to learn about the processes and knowledge related to technology that are needed to solve problems and extend human capabilities" (ITEA/ITEEA, 2000/2002/2007, p. 242).

Technology and Engineering Abstraction

Nonconcrete concepts in T&E that are often difficult to see and explain.

Technological literacy

"The ability to use, manage, assess, and understand technology" (ITEA/ITEEA, 2000/2002/2007, p. 9).

Thought-Provoking Activity

Learning experience that keeps students intellectually stimulated and engaged.

Vertical Transfer

"the transfer of known knowledge to the acquisition of some more complex knowledge that incorporates the known knowledge" (Gagné, Yekovich, & Yekovich, 1999, p. 243).

Zone of Proximal Development

"The ZPD of a child is the distance between the level of his actual development, established with the help of problems independently solved, and the level of the child's possible development, established with the help of problems solved by the child under the guidance of adults or in cooperation with his more intelligent partners" (Vygotsky, 1933, p. 42).

Summary and Organization of the Study

This study represents a contribution to the limited research base examining the contribution of the preparation experiences to the PCK of T&E educators, in order to promote an integrative pedagogical approach. *The Next Generation Science Standards* (NGSS Lead States, 2014a) will help promote integration of STEM education concepts in science education just as *The Standards for Technological Literacy* (ITEA/ITEEA, 2000/2002/2007) did in T&E education. Despite the efforts of these standards, they will elicit more questions concerning which teachers are adequately prepared to teach STEM education from an integrative approach. Unfortunately most educators are not adequately prepared with enough science, technology, engineering, and mathematics CK or PCK to teach multiple subject areas in unison (Warner, 2003; Wells, 2008; Zubrowski, 2002). Wells (2008) believed T&E educators along with collaboration among STEM education teachers affords the most promise to teach STEM from an integrative approach. There is a need for research examining the PCK of T&E educators and the content outside of their subject area to enhance the integrative teaching preparation methods of STEM education.

This chapter described the educational movements and their impact on STEM education leading up to present day. These movements shed light on the rationale that led to the conception of Integrative STEM Education. Learning theories underlying the pedagogical methods proposed to teach in an integrative fashion during these educational movements varied. One common thread was that many of the learning theories used during these movements were rooted in the work of John Dewey, or those whose work was heavily influenced by Dewey. Despite the recommendations of Dewey, other researchers, and organizations, STEM education continues to be taught in isolation within public education (Wells, 2013). Hence research on the science PCK of T&E educators is limited, greatly impacting the ability to educate them to adequately implement STEM concepts from an integrative pedagogical method.

The purpose of this study was to investigate how select preparation experiences contributed to the science PCK of T&E educators. Underlying learning theories that impact pedagogical practices of T&E educators and the implementation of a DBL curriculum were also investigated. Chapter one described the problem, the rationale to conduct the research, presented research questions and sub-questions, and defined the limitations of the study to establish parameters for it. A list of operational definitions was provided to define some of the terminology used throughout this study.

Chapter two is a thorough review of literature related to the study. The research in this chapter focuses on the theories of learning that underpin STEM education pedagogy, characteristics of PCK, and PCK research design and data collection. The review also focuses on the relationships between these factors and student learning.

In chapter three the research methods and procedures are presented. Research questions and sub-questions are stated along with descriptions of the participants and instruments. This chapter closes with information about the data collection and analysis procedures for both the pilot study and major study.

The findings relative to each research question and sub-question are presented in chapter four. Also presented in this chapter is the confirmation of the instrument reliability and validity. Chapter four closes with a summary of the findings. Lastly, chapter five includes a discussion about the findings, implications for practice and research, and recommendations for future research.

CHAPTER TWO: REVIEW OF LITERATURE

Overview

In order to prepare for the research design, the author reviewed significant literature associated with the research problem. While reviewing the literature several areas of focus emerged, including underlying theories of learning, characteristics of PCK, relationships between PCK and student learning, and previous research methods regarding PCK. These areas of focus generated the sub-areas within this chapter. The relevant information presented within each area supports the rationale for the selected research design.

This review focuses on five areas that shaped and influenced PCK of educators in the STEM content areas. First, the foundational theories and standards impacting STEM education in the U.S., as well as the need for Integrative STEM Education are examined. Second, underlying theories of learning that have shaped PCK and assumptions associated with these theories are reviewed. Third, the characteristics of PCK, including increasing student learning and its shortcomings are reviewed relative to the demands PCK places on STEM education teachers. Fourth, some elements of quality instruction and their impact on student learning are analyzed in relation to PCK. Finally, research design and data collection of previous studies concerning the PCK of STEM educators is reviewed to better inform the methods of this study.

Foundations of Integrative STEM Education

STEM has had many acronyms over the past quarter century. The National Science Foundation (NSF) has historically been the largest facilitator of the STEM education reform, and it has used various acronyms to represent STEM (Wells, 2008). The acronym “STEM” originated as “SMET” in 1990’s by the NSF, however the NSF quickly changed the acronym because it did not sound appropriate (Bybee, 2010; Sanders, 2009). Householder (2007) compiled a small sample of approximately 13 acronyms that have been used to represent STEM since the 1990's. Despite deciding upon a universal acronym, it will take more than a four-letter word to bring together these disciplines that have defended their sovereign territories for years (Sanders, 2009).

As presented in chapter one, there were many curricular reform efforts that laid the foundation for Integrative STEM Education. Beginning with *A Nation at Risk* (1983), then *Science for All Americans* (AAAS, 1989), and *Benchmarks for Science Literacy* (1993), each provided the rationale and framework targeted toward improving student interest and proficiency in science, math, and technology (Wells, 2013). In 1996 the *National Science Education Standards* (NRC, 1996) promoted science, engineering, and technology concepts within science education. The *Standards for Technological Literacy* published in 2000, and revised again in 2002 and 2007, promoted the integration of various content areas using technological and engineering design as the vehicle to deliver multiple contents in an engaging and integrative manner. *A Framework for K-12 Science Education* (NRC, 2011) created a new directive among science educators when it announced the teaching of engineering concepts would be a part of the NGSS. The latest reform effort occurred in the science education community in which the NGSS called for engineering content and practices to be presented alongside the sciences (Moore, Tank, Glancy, Kersten, & Stohlmann, 2013). A more practical approach to teach engineering and science is not alongside each other, but interwoven within each other because of the crosscutting concepts they share. As engineering education content emerges in P-12 curricula, the ability to successfully integrate multiple STEM content areas via the engineering design process (EDP) will promote skills that extend beyond the classroom to prepare technologically literate students for the 21st century and beyond.

The Need for Integrative STEM Education

Over the past six decades the U.S. has gradually lost its global economic dominance to foreign countries. In response, the U.S. has continually turned to STEM education in hopes of preparing future generations to solve these problems. In 1957 the launch of Sputnik provoked President Kennedy to inspire NASA's scientists and engineers to ensure Americans were the first to walk on the moon. *A Nation at Risk* (NCEE, 1983) and *The World is Flat* (Friedman, 2005) caused America to reevaluate its STEM education system to address lost economic prominence to countries like China and India. Recently, President Obama has recognized the importance of a STEM literate society calling it, "essential to every goal we have as a nation" (Larson, 2012, para. 2). In his 2011 State of the Union speech he made it a priority to train 100,000 new STEM teachers in order to advance the U.S.'s global economic competitiveness, and educate a society that can "outcompete" and "outbuild" the rest of the world (Mervis, 2011). Integrative STEM Education is one step in the right direction to prepare students with the problem-solving skillset needed to address the problems of the future. It's ability to motivate students and maintain their interest in STEM would "add enormously to American education, culture, and global competitiveness" (Sanders, 2009, p. 25).

As presented in chapter one, many state and national organizations, as well as educational theorists, have advocated for the advantages of Integrative STEM Education. Maley (1959) responded to the Sputnik launch by presenting the "Research and Experimentation" course model for industrial arts. This model situated mathematics and science in the context of technological design, very similar to the model T&E education curricula use today. He believed industrial arts was perfectly suited for the application of mathematical and scientific knowledge with resources, materials, tools, and equipment that closely resemble society outside of school (Sanders, 2009).

Like Maley, Sanders (2009) also believed that STEM content needed to be taught in unison to give it an authentic context:

> Authentic inquiry is embedded in the design challenge. This is problem-based learning that purposefully situates scientific inquiry and the application of mathematics in the context of technological designing/problem solving. Inquiry of that sort rarely occurs in a technology education lab, and technological design rarely occurs in the science classroom. But in the world outside of schools, design and scientific inquiry are routinely employed concurrently in the engineering of solutions to real-world problems. (p. 21)

Keller and Pearson (2012) also advocated for the importance of students integrating multiple disciplines within their studies, because they found the barriers often seen between disciplines in P-12 education are less prevalent outside of the school walls.

Curricular reforms such as NGSS (NGSS Lead States, 2014a) recognized the importance of teaching STEM content congruently and the impact it can have on students beyond P-12 education, "participation in these practices also helps students form an understanding of the crosscutting concepts and disciplinary ideas of science and engineering; moreover it makes students' knowledge more meaningful and embeds it more deeply into their worldview" (pp. 1-2). The pedagogy used in scientific inquiry and engineering design are closely related, lending themselves to be easily integrated (Moore et al., 2013). The *Standards for Technological Literacy* (ITEA/ITEEA, 2000/2002/2007) were written to promote integration from the standpoint that technology "reinforces and complements the material that students learn in other classes" (p. 6). National mathematics standards are not as explicit about integrative approaches, however they do encourage teaching and learning mathematics in the context of "real-world and mathematical situations" (NCTM, 2000, p. 4) and real world and mathematical problems (CCSSI, 2010) throughout the standards.

Summary of the Foundations and the Need for Integrative STEM Education

Policy makers, national organizations, and researchers have recognized the importance of STEM education to better prepare students for solving 21st century problems. Efforts have been made to adjust standards and policies to promote integrative pedagogical methods that provide authentic learning experiences for students. Despite these efforts and support for Integrative STEM Education from policy makers, national organizations, and researchers; science and T&E education teacher preparation programs continue to inadequately prepare teachers with knowledge to properly implement integrative teaching and learning (Wells, 2010). Therefore, research examining the influence that select teacher preparation experiences have on the science PCK of T&E educators is warranted to better prepare teachers to use integrative teaching strategies. Finding benefits from certain preparation experiences could induce changes to preparation and pedagogical methods, leading to enhanced student learning. The following sections will provide an analysis of the literature in relation to underlying learning theories and pedagogies of Integrative STEM Education, an examination of the seven types of teacher knowledge, and a synthesis of previous PCK research efforts. To better understand PCK and teacher preparation, it is critical to first examine theories of learning that underlie the pedagogical methods and standards of Integrative STEM Education.

Underlying Theories of Learning and Instruction

Before studying PCK it is essential to examine the theoretical framework that underpinned Shulman's conceptualization of this form of teacher knowledge. Learning is "a dual process in which, initially, the inside beliefs and understandings must come out, and only then can something outside get in" (Shulman & Hutchings, 2004, p. 36). Darling-Hammond et al. (2001) described a learning theory as a coherent explanation of a set of relationships that have been tested with lots of research in relation to the learning process. A comprehensive review of all learning theories that influenced the creation of the concept PCK is beyond the scope of this study. Therefore, a brief overview of some notable learning theories that underpin the concept of PCK are presented. This overview presents issues raised in education over time and provides the foundation and rationale for the work of later psychologists such as John Dewey, Lev Vygotsky, and Robert M. Gagné who have greatly influenced Shulman's work and his theory of PCK. The learning theories presented by these three psychologists have been selected due to the level of influence they had on Shulman's work, as well as their influence on the creation of standards within STEM education content areas.

Learning Theories and Philosophy

Humans have been trying to understand learning for the past 2000 years (Darling-Hammond et al., 2001), however only since the 1800s have theoretical interpretations of the learning process concerned psychologists (Mowrer & Klein, 2000). Theories about learning have been debated since 469-322 B.C. between Greek philosophers Socrates, Plato, and Aristotle (Darling-Hammond et al., 2001). Plato and Socrates were rationalists (idealists) and believed self-reflection promoted learning. Aristotle on the other hand was an empiricist (realist) and believed learning occurred extrinsically through experiences with the world around him, or what is now referred to as inquiry. The Romans' view on education was drastically different than the Greeks. They were not concerned with philosophical views, but were more concerned with the vocational skills needed to build roads and aqueducts. From 1596-1650 Descartes revived the belief that knowledge existed in humans prior to experience. He proposed the idea that the mind was separate from the body, the environment and mind influence behavior, and the body produces unintended behaviors. Descartes' work influenced behavioral psychologists and cognitive scientists for over 300 years (Darling-Hammond et al., 2001).

In the 20th century learning was viewed as a scientific study, conducting objective tests to examine how people learn and the best method for teaching. Piaget (1896-1980) was the first to view learning as a developmental cognitive process, and Vygotsky (1896-1934) expanded on Piaget's work, emphasizing that learning occurs in a cultural context involving social interactions (Darling-Hammond et al., 2001). Following these theories Dewey (1859-1952) proposed that education should be child-centered and supplement the child's experiences in the world outside of school. He opined that "the teacher's goal is to understand both the demands of the discipline and the needs of the child and then provide learning experiences to enable the student to uncover the curriculum" (Darling-Hammond et al., 2001, p. 8). What Dewey described as "demands of the discipline" are similar to what Shulman called content knowledge, and Dewey's "needs of the child" are representative of Shulman's (1987) PCK. Shulman saw this distinction in Dewey's research and used it as the basis for his theory of teacher knowledge categories. Dewey also believed that the ability for a person to learn was dependent on many factors, including the educational environment.

Kolb (1939 -) developed the experiential learning theory to help explain the way one acquires knowledge (Draper, 2004). He envisioned learning as a holistic approach that combined experience, perception, cognition, and behavior, which he called stages. Kolb believed these series of stages provided a "process whereby knowledge is created through the transformation of experience" (Kolb, 1984, p. 38). A learner may begin learning at any stage, however they must follow the stages in order because each stage serves as a foundation for the subsequent one. The four stages were: (1) concrete experience, (2) reflective observation, (3) abstract conceptualization, and (4) active experimentation (see Figure 1). From these four stages of learning, Kolb found four learning style types in which an individual may experience a crossover between two stages. A learning style is, "An individual's preferred methods for perceiving and transforming his/her learning experiences" (Kulturel-Konak, D'Allegro, & Dickinson, 2011, p. 10). In addition to the four-stage holistic cycle, Kolb explained learning using two continuums. These continuums addressed how a task is approached, and the emotional response of how a person thinks or feels about the task (Di Muro & Terry, 2007). Kolb also found that different academic disciplines impose different kinds of learning demands on student and demonstrate sociocultural variation, difference in faculty and student demographics, personality, aptitudes, values, and group norms (Kulturel-Konak et al., 2011). The premise of Kolb's theory was that students' experiences impacted the way they learned best.

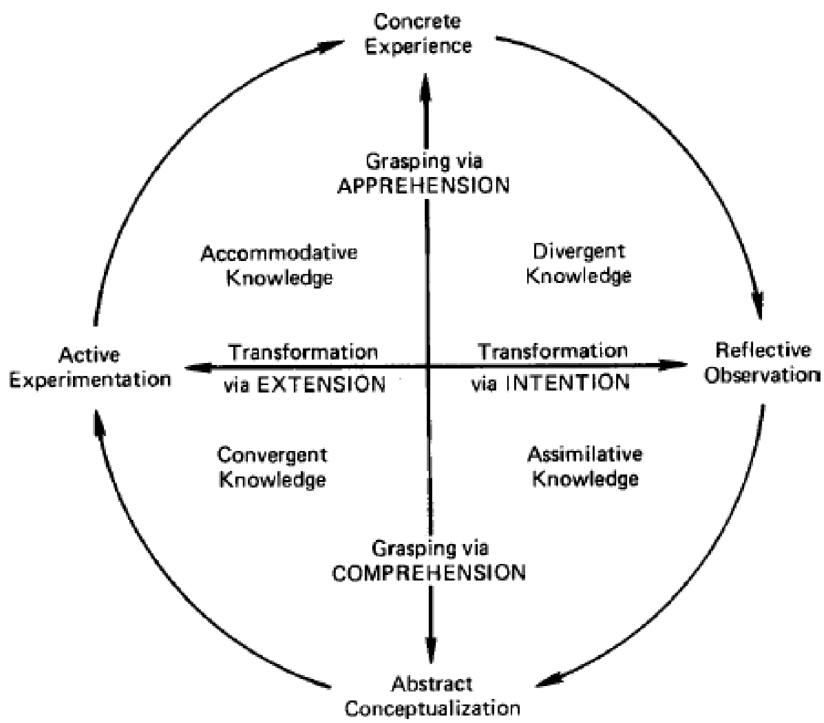

Figure 1. Kolb's experiential learning cycle with the four learning modes, the four learning styles, and the two continuums. Reproduced from "The Effects of Gender Grouping and Learning Style on Student Curiosity in Modular Technology Education Laboratories," by S. R. Draper, 2004, Blacksburg, VA: University Libraries, p. 30. Copyright 2004 by Virginia Polytechnic Institute and State University.

Many of the learning theories presented thus far were based on the premise that experience promotes learning. This is the same basis for PCK, which Williams and Lockley (2012) described as "a special blend of content knowledge and pedagogical knowledge built up over time and experience" (p. 468). Integrative STEM Education has pushed the envelope pedagogically, using a DBL approach to promote learning of multiple content areas as opposed to focusing on memorizing content in isolation of other content areas. A progression evident from this review is that learning theories have moved toward Dewey's child-centered focus, acknowledging that learning is contextual to each student based on numerous environmental factors.

John Dewey's Influence on PCK and T&E Education

Shulman stated, "I am following in the footsteps of many eminent scholars, including Dewey" (Shulman, 1987, p. 4). Shulman's notion of PCK was conceived from Dewey's (1902) *The Child and the Curriculum*, which focused on the differences between logical and psychological understanding necessary to teach (Shulman, 2008). The distinct and logical portion contributing to PCK is the content, while the psychological portion is the pedagogical skills needed to deliver the content in a manner that students can understand it. A critical component of the pedagogical skills is determining which teaching methods or strategies should be used to scaffold students to better understanding the content. When Shulman proposed the idea of PCK he was a professor of education and an affiliate professor of psychology at Stanford University, which could be one of the reasons why PCK is rooted in the work of educational psychologists such as Dewey, Vygotsky, and Gagné. Each of these educational psychologists proposed different learning theories that impacted pedagogical methods of teachers, consequently impacting student learning.

According to Dewey, education was a means for social progress and was essential for producing a well-balanced member of a democratic society. He attempted to integrate school with society and learning processes with real-world problems. Dewey viewed manual training, science, art, and similar subjects as more essential than reading writing and arithmetic. Students' constructive work would naturally lead to more abstract knowledge (Warde, 1960). He thought that, "education should be child-centered, guided by a well trained teacher who is grounded in pedagogical and subject knowledge" (Darling-Hammond et al., 2001, p. 8). This distinction between pedagogical and subject knowledge was the basis for distinction between what Shulman referred to as pedagogical and content knowledge.

It is evident that Dewey's work was influenced by the theories of philosophers and psychologists before him, and his work continues to influence psychologists and new learning theories. He proposed the requirement of a laboratory or field setting to educate teachers, which was also considered essential to teacher development by Shulman (2004). Dewey believed that learning should occur through experience or hands-on application and the teacher should act as a facilitator instead of an authoritarian (Bleakley, Bligh, & Browne, 2011). This belief helped shape the framework for Integrative STEM Education and was also seen in the work of many influential individuals in T&E education such as Calvin Woodward, Frederick Bonser, Lois Mossman, Lee Hornbake, Gordon Wilber, Donald Maley, Boyd Bode, William Warner, Paul DeVore, Donald Lux, Willis Ray, Stephen Petrina, and Karen Zuga (Warner, 2009). In addition to Dewey's influence on T&E education, Vygotsky's *Thought and Language* (1962) and Gagné's *Foundations in Learning Research* (Gagné & Glaser, 1987) and *Essentials of Learning for Instruction* (Gagné & Driscoll, 1988) were cited as sources that assisted in the creation of the *Standards for Technological Literacy* (ITEA/ITEEA, 2000/2002/2007, pp. 222-226). Their learning theories were seen by the International Technology and Engineering Educators Association (ITEEA) as beneficial for delivering the DBL pedagogy essential to T&E education. Dewey, Vygotsky, and Gagné all had a significant impact on the individuals, curricula, and standards that have shaped T&E education.

Social Development Theory

In 1924 Russian psychologist Lev Vygotsky criticized Pavlov and Kohler under his belief that humans had adaptive behaviors to alter the environment for their own purpose, unlike the animals used in Pavlov's and Kohler's studies. Vygotsky's most important contribution to psychology was his theory that socially meaningful activity had an important influence on human cognition (Schunk, 1996). He believed that cognition was greatly affected by the social environment (Culatta, 2013), consisting of cultural objects, language, and social institutions (e.g. schools, churches) (Schunk, 1996). Coleman et al. (1966) and Jencks (1972) also found that schools have little influence on a child's achievement that is independent of his or her background and general social context. As discussed earlier, both Vygotsky and Shulman's work had commonalities with Dewey's, which is evident from their emphasis on social influences. Vygotsky found that cognitive change resulted from the use of these items in social settings, internalizing them, and then transforming them into useful information for later use (Orlich et al., 2007). He contested that higher order thinking originates in the social environment (Vygotsky, 1962). Vygotsky (1978) summarized this process as:

> Every function in the child's cultural development appears twice: first, on the social level, and later, on the individual level; first, between people (interpsychological) and then inside the child (intrapsychological). This applies equally to voluntary attention, to logical memory, and to the formation of concepts. All the higher functions originate as actual relationships between individuals. (p. 57)

Within the context of engineering design, Brizuela and Gravel (2013) believe that design constructions, conversations, and drawings are all tools similar to ones Vygotsky proposed.

Perhaps the most notable contribution Vygosky (1933) is credited with is the concept of the Zone of Proximal Development (ZPD) which he defined as:

> The ZPD of a child is the distance between the level of his actual development, established with the help of problems independently solved, and the level of the child's

possible development, established with the help of problems solved by the child under the guidance of adults or in cooperation with his more intelligent partners. (p. 42)

Figure 2 displays these characteristics of the ZPD which he first proposed in 1933.

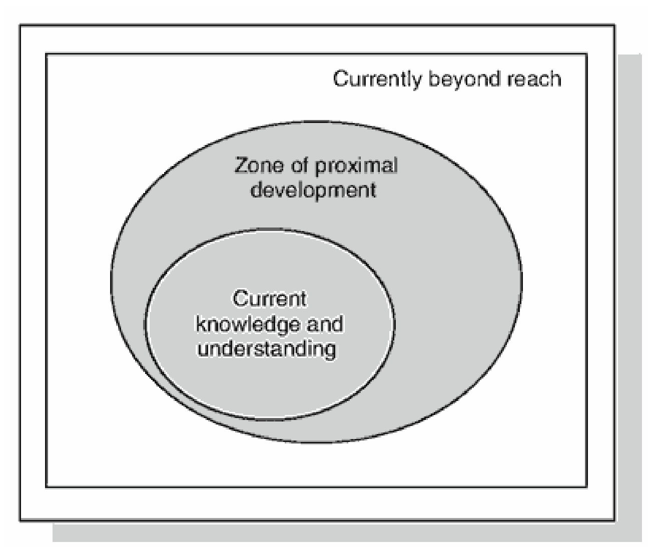

Figure 2. Zone of proximal development. Reproduced from "Psychology for the Classroom," by A. Pritchard and J. Woollard, 2013, p. 10. Copyright 2013 by Taylor and Francis.

Vygotsky argued that, "Instruction should offer tasks that are above the child's intellectual level, but not too far above. That way the child is sufficiently stimulated to try the new problems and to rise above his or her own intellectual level as it were" (Van der Veer, 2007, p. 79). ZPD has three aspects important to helping students shift into a new zone: (a) dimension of time and prognosis of mental development (b) dimension of social-individual transition and (c) instruction is the leading factor in mental development. All of these are equally important in assisting students, however instruction (pedagogy) is identified as the leading factor for mental development (Valsiner & Van der Veer, 1993). This fact reinforces the importance of good teaching methods and high levels of PCK to influence student learning.

The ZPD is ideal for teaching problem solving skills (Van der Veer, 2007) which is the crux of teaching students to be technologically literate. It is not surprising as to why this learning theory fits well within the pedagogical practices of Integrative STEM Education. As a student solves a problem and exits a ZPD, they shift into a new ZPD in which they will need assistance solving a more advanced problem. What once was a task within or beyond their ZPD, has now become an achievable task within the zone of actual development (Van der Veer, 2007). With the help of a teacher or other students, the pupil will be able to learn how to solve problems that they would not be able to solve individually. This process called "scaffolding," was introduced by Bruner in his spiral curriculum model and defined by Benson (1997) as "a design to provide support for students but only enough to allow the student to complete the task alone" (p. 126). It is used by the instructor or other students to help the pupil shift into a new ZPD. Scaffolding has five major functions: (a) provide support (b) function as a tool (c) extend the range of the learner (d) permit the attainment of tasks not otherwise possible, and (e) use selectively only as needed (Schunk, 1996).

Vygotsky's social development theory lends itself to numerous applications in T&E education such as self-regulation, reciprocal teaching, peer collaboration, and apprenticeships (Schunk, 1996). Brizuela and Gravel (2013) believed that using engineering design helps students pursue novel design ideas through manipulating tangible materials. They found that this helped students draw inferences between engineering design and scientific understanding of concepts. Vygotsky's social development theory has been influential in shaping the pedagogical methods needed to deliver the hands-on DBL content integral to Integrative STEM Education. Gagné's conditions of learning is another theory that was greatly influenced by Dewey and also a valuable resource for delivering Integrative STEM Education.

Conditions of Learning

American instructional psychologist Robert M. Gagné is best known for his work regarding *The Conditions of Learning* (1965) and his contributions to instructional design theory. The origin of his research stemmed from his experience with the U.S. military, and identified three principles of instruction (1) providing instruction on the set of component tasks that build up to the final task (2) ensuring mastery of each component task, and (3) confirming optimal transfer to the final task by sequencing the component tasks (Gagné, 1968a; Gagné, 1968b). Like Vygotsky, Gagné's theory focused on the individualized learning of each student and instruction was viewed as a transmission of information (Harasim, 2012). This transmission was also the basis for Shulman's PCK theory, transmitting CK from teacher to student via a blend of special attributes (Geddis, 1993; Veal & MaKinster, 1999).

In his research on transfer of information, Gagné discovered two types of transfer – lateral and vertical. He referred to lateral transfer as, "the use of some known knowledge in a new setting but at the same level of complexity as the old setting" (Gagné, Yekovich, & Yekovich, 1999, 243). Vertical transfer he described as, "the transfer of known knowledge to the acquisition of some more complex knowledge that incorporates the known knowledge" (Gagné, Yekovich, & Yekovich, 1999, p. 243). In relation to PCK, a teacher would be exhibiting lateral knowledge by recognizing an undiagnosed student's behavior as some form of learning disability and seeking the proper resources to accommodate that student. Vertical transfer would occur if based on their experiences, the teacher were able to identify what disability the student had and instantaneously change their instructional methods to help transfer knowledge of the content to the student. In this example lateral knowledge occurred by knowing the student had a disability, but being able to identify the type of disability and adjust pedagogical methods implemented higher level thinking skills to resolve more complex problem (vertical transfer).

Gagné's conditions of learning theory concentrated on studying the sequence in which learning activities were planned. His model suggested that learning could be organized into a hierarchy to identify prerequisites needed to facilitate learning at each level (Culatta, 2013). Descriptions of the nine instructional phases and cognitive functions can be found in Table 1. He cautioned that learning hierarchies are not intended to be descriptive of the entire process, they simply indicate the prerequisite skills that must be available to the learner to achieve tasks requiring higher level thinking (Gagné, 1973). Gagné studied the effects of hierarchical structure on learning, and utilized a task analysis model to subdivide the lesson into smaller, sequential steps from least to most complex concepts. The task analysis model had been previously successful in business and industry, lending itself to be successful in T&E education because of the career and technical epistemological roots of the field.

Table 1

Gagné's Nine Phases of Learning

Description	Phase	Function
Preparation for learning	1. Attending	Alerts the learner to the stimulus.
	2. Expectancy	Orients the learner to the learning goal.
	3. Retrieval (of relevant information and/or skills) to working memory	Provides recall of prerequisite capabilities.
Acquisition and performance	4. Selective perception of stimulus features	Permits temporary storage of important stimulus features in working memory.
	5. Semantic encoding	Transfers stimulus features and related information to long-term memory.
	6. Retrieval and responding	Returns stored information to the individual's response generator and activates response.

(continued)

Table 1 Continued

Description	Phase	Function
Acquisition and performance	7. Reinforcement	Confirms learner's expectancy about learning goal.
	8. Cueing retrieval	Provides additional cues for later recall of the capability.
Transfer of learning	9. Generalizability	Enhances transfer of learning to new situations.

Note. Adapted from "Learning and Instruction: Theory Into Practice," by M. E. Gredler, 2005, p. 169. Copyright 2005 by Pearson/Merrill Prentice Hall.

Grippin and Peters (1984) found that Gagné's work on cognitive strategies was rooted in problem solving. Gagné believed that problem solving encompassed both intellectual skill and cognitive strategies. The *Standards for Technological Literacy* (ITEA/ITEEA, 2000/2002/2007) are based on teaching problem solving skills to elicit higher level intellectual and cognitive skills applicable to real-world problems, "students in technology laboratory-classrooms are taught practical problem-solving skills and are asked to put them to work on different types of real-world problems" (p. 5).

Not all T&E educators agree with Gagné's theory. Reed (2007) criticizes Gagné's work as being "40 years of instructional materials that are not always coherent and do not factor in the key mental models involved in learning ever-increasing scientific content and skills" (p. 18). Despite the criticisms, Gagné's theory has provided the structure to create a sequence of steps for standards, curricula, and lessons that help transition students to higher level thinking tasks. The sequencing of these steps and tasks are critical to ensure a coherent product that factors in key mental models for learning STEM content and skills.

Gagné's conditions of learning incorporates learning outcomes and information processing by the learner, bridging the gap between operant conditioning and the cognitive theories discussed earlier (Gredler, 2005). Despite the research behind social development theory and conditions of learning, there are underlying assumptions about each regarding the nature of reality and knowledge, and how learning occurs. T&E researchers should consider these assumptions before implementing these theories into practice.

Theoretical Assumptions of Learning

Just as Plato and Aristotle debated if and how knowledge is transferred from teacher to student, social development theory and conditions of learning had to wrestle with how this transfer of knowledge occurs. Van der Veer (2007) believed that instruction was needed to shift the child to the next ZPD, "The only fruitful instruction is that which stimulates the child because it is just above the level of the child's individual performance" (p. 87). ZPD is tailored to help each individual student learn based on their current knowledge. It is assumed that the teacher has some form PCK to know when to scaffold each student and how much is the appropriate amount of scaffolding to help the student reach a level they could not achieve on their own. Just as in PCK, a teacher's experiences are critical and assumed to bolster their pedagogical arsenal. This could be seen with in a new teacher that has no formal teaching experience. Some would argue that the teacher has classroom and learning experience from shifting through the ZPD as a student. The teacher could read through the literature to learn how to scaffold students. Others would debate that with little or no teaching experience, teachers have limited awareness of which students need scaffolding, how much is appropriate, and how to adequately scaffold each student. Along this same strand, it is assumed that teachers can relate to their students and have knowledge of their students' social background. This may not always be the case and would affect the ability for a teacher to help shift students through the ZPD. Vygotsky also assumed that all students need some form of scaffolding, differing in levels, to shift through the ZPD. Some would agree with this, however critics would say that not all students need assistance.

Just as Vygotsky's social development theory has fallen under much scrutiny, Gagné's conditions of learning theory has also been widely criticized. Gagné's theory assumes that all lesson plan components and classroom events are controlled by the teacher. There is no room for student choice or planning within his theory (Ornstein & Lasley, 2000). Ornstein and Lasley (2000) believed that not one lesson plan format is ideal for every teacher, and suggested that teachers modify the suggestions of experts and learning theorists to better fit their teaching style and school requirements. Using the conditions of learning require the teacher to have very little pedagogical knowledge and follow the nine phases in the order presented. The theory follows a progression of phases that increase in cognitive ability needed to move to the next phase. Critics have contested that his theory does not allow room for social, motivational, and moral factors that impact student learning (Ornstein & Lasley, 2000).

Gagné's theory assumed that the student will transfer the knowledge learned from their short-term memory to their long-term memory. Some would agree that this is the logical flow to remember information, however others would argue that knowledge could be forgotten, in which case the learner would have to re-experience that phase. In Gagné's theory the phases are not cyclical, so a teacher would not be expected to revisit a previous phase. Gredler (2005) believed that this theory is useful for designing instruction from simple to complex concepts. It is assumed that the teacher or curriculum designer will start with the end in mind and use a backward design method from complex to simple. Also, it is assumed that each phase will increase in complexity. Sometimes students do not learn from simple to complex and will learn more complex tasks first because of their prior experiences outside of the classroom. In this case the teacher would have to come back to reteach the conceptual underpinning of that task, although the student may have already mastered the higher-level procedural task.

In order to design curricula or lessons using this theory, an individual would need knowledge about the learners' prior experiences and social backgrounds. The conditions of learning theory has been used as the framework to write national curricula, however Gagné did not intend for it to be used as a universal curricula design, which Reed (2007) found as a misuse of this theory. Curricula need to be flexible to provide a learning experience to fit topic and content specific lessons. It cannot be assumed that all students have the same prior knowledge and move through the phases at the same rate. This is where PCK plays a significant role to adapt the lesson to the learner.

Summary of Underlying Theories of Learning

The ideal methods for teaching and learning have been debated since 469 B.C. when Socrates, Plato, and Aristotle questioned each other's teaching and learning theories. Educational psychologists and philosophers continue to debate this topic today. These debates have evoked much thought and produced many valuable learning theories for teaching and learning. Shulman (2004) drew on the work of Aristotle when distinguishing between a mere scholar and an artist or expert. The concept of PCK is more than just experience, but a refined skill in addition to a wealth of knowledge. Over history, philosophers and psychologists have used the ideas of Socrates, Plato, Aristotle, Descarte, Piaget, Dewey, Kolb, Vygotsky, Gagné, and Shulman to form their theories and question others' theories. From the review of learning theories presented, it is clear that no single learning theory fits every situation. It is evident that teaching and learning are contextual to the teacher, students, and various other outside factors that impact educational contexts. Teachers should examine a variety of theories to select the ones that best fit their students and their teaching style (Lasley, 2000; Weitzel, 1999).

Many parallels can be seen between Shulman's theory of PCK, and Vygotsky and Gagné's theories of learning. Each believed that learning could not be standardized for every student, and it was contextual to each learner's background. Because of this Shulman (1987) stated that PCK was the most influential knowledge for teaching:

> The key to distinguishing the knowledge base of teaching lies at the intersection of content and pedagogy, in the capacity of a teacher to transform the content knowledge he or she possesses into forms that are pedagogically powerful and yet adaptive to the variations in ability and background presented by the students. (p. 15)

Like Vygotsky and Gagné, Shulman also believed variation in students' ability and background experiences played a major role in student learning, impacting the pedagogical knowledge teachers needed to help varying types of students learn the content.

Specifically, Vygotsky's theory supported the notion that learning was reciprocal for the teacher and the student. Teachers could shift to a new ZPD regarding their PCK while helping scaffold students into a new ZPD regarding content. There is a certain level of PCK needed for teachers to effectively use social development theory. They must know the needs of their students to provide the proper scaffolding and create an individualized learning experience for each student. Lastly, Vygotsky developed the ZPD in the context of education "as a means to ensure good instruction" (Van der Veer, 2007, p. 84). He recognized the prominence that instructor quality played in students' mental development. Shulman took Vygotsky's theory a step further by recognizing that a special blend of pedagogy in addition to CK are needed to improve the mental development of students and assist them in achieving tasks which would not be obtainable without quality instructors.

The specific characteristics of PCK can be better understood with increased knowledge of the philosophies and learning theories that influenced Shulman's conceptualization of PCK. Commonalities between Dewey's, Vygotsky's, Gagné's, and Shulman's theories are evident. The philosophies and learning theories presented in this review provided the foundational knowledge for researchers to better understand how Shulman theorized the concept of PCK. Shulman's view of individualized education during a time of standardized testing caused many to reexamine how teachers were prepared, and what pedagogical methods teachers implemented. His view also laid the groundwork for integrative curricula that use a special blend of content and pedagogy to teach STEM education simultaneously, and increase student achievement across those disciplines (Wells, 2010). PCK is a vital component of Integrative STEM Education due to the complexities of teaching multiple content areas simultaneously, and encouraging each student to produce a unique solution to a problem. The research of many educational psychologists, specifically Dewey, Vygotsky and Gagné, greatly influenced characteristics of PCK and the other six types of knowledge that teachers possess.

Characterizing PCK

Smith (2001) asserts that some teachers could be very effective in terms of promoting student learning, but unable to identify the learning theories that they used. Although they still provide adequate scaffolding to help students shift into a new ZPD when appropriate, and structure their lessons to assure students have the prior knowledge needed to move onto higher order tasks, they do not have to think about these methods because they just do it from experience. Effective teachers sometimes have difficulty reflecting on the techniques they use which make them successful educators. Their teaching experience provides them with a sense of "know how" without having to sit and analyze a situation to the same extent of which a novice teacher may. Schön (1983) and Smith (2001) would refer to this as "knowing-in-action." This innate sense is one that cannot be fully learned in pre-service teacher education programs, it simply comes from formal and informal teaching experiences and repetition.

The concept of being able to respond to the dynamics of a classroom environment and instantly adjust pedagogical methods to provide seamless instruction, was one of the teacher knowledge categories which Shulman (1987) referred to as PCK. Since Shulman proposed the concept of PCK in 1986, it has been used to research the effectiveness of teachers in various subject areas. In 1987 PCK evolved, with Shulman expanding his proposed three categories of knowledge, to seven categories. Researchers (Abell, 2008; Ball, Thames, & Phelps, 2008; Geddis, 1993; Gess-Newsome & Lederman, 2002; Hynes, 2012; Manizade & Mason, 2011; Mavhunga & Rollnick, 2013; NRC, 2009; Rohaan et al., 2011; Williams & Lockley, 2012) have expanded upon and adapted Shulman's definition of PCK to fit their own research agenda or highlight different characteristics and contexts (Park & Chen, 2012). There is still much to be learned about PCK, and future research will continue to help shape the way it is viewed and researched. In order to provide the framework for methods to assess the science PCK T&E educators, its characteristics must first be examined. The first set of characteristics to examine are the differences among Shulman's (1987) seven categories of knowledge in the context of Integrative STEM Education.

Types of Teaching Knowledge

Shulman (1987) identified seven categories of knowledge that grow in the mind of teachers, one of which was PCK. The other six categories of knowledge Shulman identified were: (a) CK (b) general pedagogical knowledge (GPK) (c) curriculum knowledge (d) knowledge of learners and their characteristics (e) knowledge of educational contexts, and (f) knowledge of educational ends, purposes, and values, and their philosophical and historical grounds. Each category of knowledge is distinct from the other six and integral to effective teaching.

Among the six categories Shulman has focused a large portion of his research on PCK because it was most likely to separate the understanding of content from pedagogy in a teacher (Veal & McKinster, 1999). He defined PCK as "the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction" (Shulman, 1987, p. 8). Shulman's (1987) theory of PCK added to research conducted by Fenstermacher (1978, 1986) who advocated that the goal of teacher education was to educate teachers to reason soundly about their teaching as well as to perform skillfully instead of train teachers in prescribed ways. Shulman and Grossman (1988) described PCK as the synthesis of three knowledge bases: (a) subject matter knowledge (b) pedagogical knowledge, and (c) knowledge of context (Veal & MaKinster, 1999).

Jones and Moreland (2004) adapted Shulman and Grossman's (1988) synthesis of three knowledge bases to make them specific to T&E education. They presented three dimensions of knowledge that technology educators need to be effective: (a) knowledge about technology (b) knowledge in technology, and (c) general technological pedagogical knowledge. Similarly, in 2008 De Miranda created a T&E education PCK model (Figure 3) to describe the complex synthesis of Shulman and Grossman's (1988) three knowledge bases in an instructional setting. De Miranda (2008), Jones and Moreland (2004), and Phillips et al. (2009) asserted that a teacher's CK in a subject (e.g., technology, industrial design, engineering) was distinctly different from a teacher's pedagogical knowledge, yet each is essential to classroom instruction. De Miranda (2008) and Phillips et al. (2009) declared that the synthesis of these three knowledge bases provoked a specialized form of PCK that is contextualized in an application authentic to teachers' subject area. Shulman (1987) also believed that PCK was topic, teacher, and context specific by describing it as "an understanding of how particular topics, problems, or issues are organized, presented, and adapted to diverse interests and abilities of learners and presented for instruction" (p. 8). This view mimics Dewey's and Vygotsky's beliefs of the impact that social influences have on students and the individualized learning experience for which teachers must accommodate.

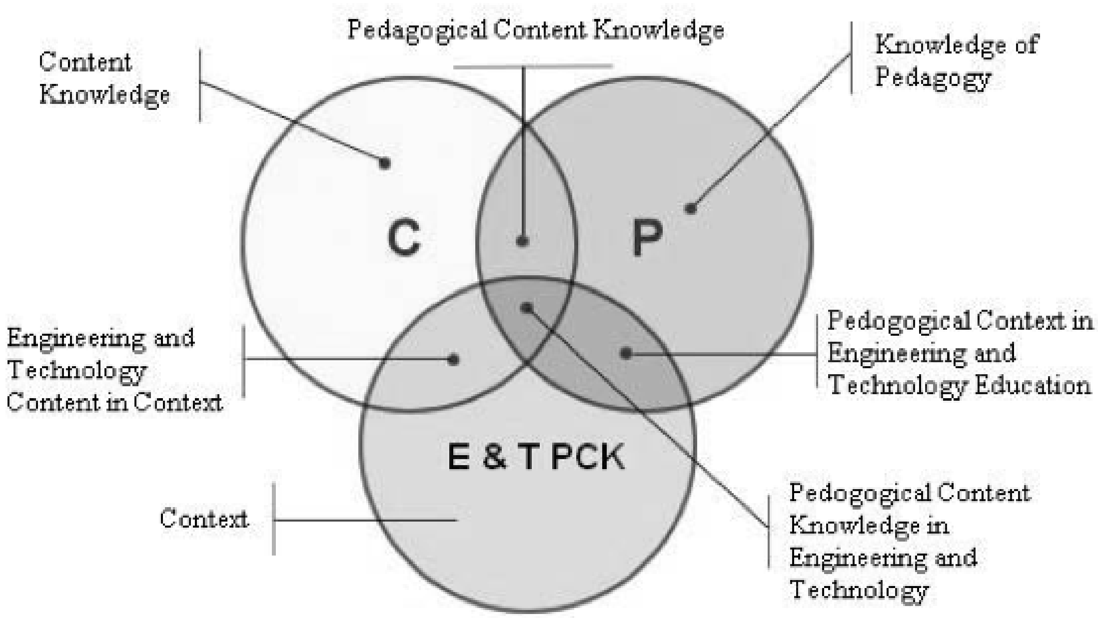

Figure 3. Infusion of engineering knowledge, pedagogy and context in technology education instruction. Reproduced from "Pedagogical Content Knowledge and Technology Teacher Education: Issues for thought," by M. A. De Miranda, *Journal of the Japanese Society of Technology Education, 50*(1), p. 19. Copyright 2008 by Virginia Polytechnic Institute and State University.

De Miranda (2008) created Figure 3 to show the special blend of CK, GPK, and PCK that attribute to PCK in the context of T&E education. In his model he attributes E&T PCK to the:

> Intersection of engineering science, i.e., knowledge of the scientific knowledge needed to engage in the analytical aspects of design, knowledge of engineering design, with teaching in the technology education classroom will wholly depend on the ability of teacher educators and pre-service teachers to transform this knowledge into adaptive instruction, with which students can engage. (p. 19)

While De Miranda (2008) acknowledges that science is embedded within T&E education, he does not distinguish between these unique knowledge bases that teachers need. Instead he viewed science CK and PCK as inherently occurring within engineering CK and PCK when T&E educators taught engineering concepts. However, like Lewis and Zuga (2005), he believed that T&E educators possess a competence level in mathematics and science to integrate these contents into the T&E education curriculum. T&E educators must have GPK, science CK, and science PCK, in addition to T&E CK and PCK to teach integrative concepts. Figure 4 shows the important role that science, technology, and engineering CK and PCK play in developing T&E educators' ability to teach science concepts within the context of technological/engineering design. Each discipline has its own unique CK and pedagogical practices to present the content, which cannot be assumed as instilled within T&E educators.

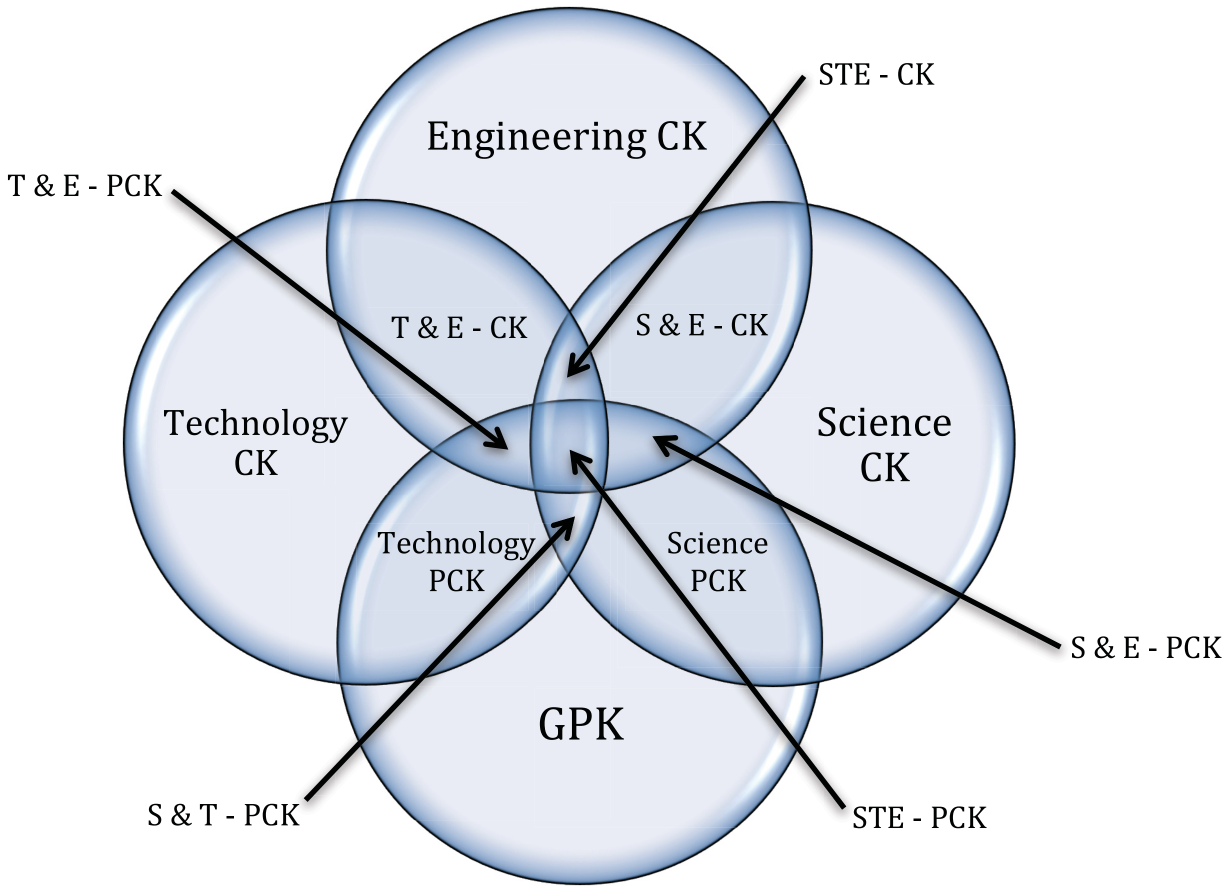

Figure 4. Model of content knowledge and pedagogical knowledge in science, technology, and engineering education.

Distinct differences between CK, GPK, and PCK have also been found by various researchers (Even, 1993; Geddis, 1993; Gess-Newsome & Lederman, 1999; Jones & Moreland, 2004; Loughran, Berry, & Mulhall, 2012; Parker & Heywood, 2000; Phillips et al., 2009; Rohaan et al., 2011; Van Driel, Verloop, & De Vos, 1998; Williams, 2012; Williams & Lockley, 2012; Williams, Eames, Hume, & Lockley, 2012) who believe that PCK is a unique form of teacher knowledge. Research in STEM education (Abell, 2008; Ball et al., 2008; Lankford, 2010; Loughran, et al., 2012; Manizade & Mason, 2011; Mavhunga & Rollnick, 2013; Monet, 2006; Mulhall, Berry, & Loughran, 2003; Phillips et al., 2009; Rohaan et al., 2011; Van Dijk & Kattmann, 2007; Veal & Kubasko, 2003; Veal & MaKinster, 1999; Williams & Lockley, 2012) has supported Shulman's (1987) belief that PCK is topic specific to particular subjects and contexts. Mulhall et al. (2003), Van Driel et al., (1998), and Veal and Kubasko (2003) indicated that a teacher who has high PCK in one area, may not have high PCK in another area. Each has unique CK and pedagogical methodologies to transform the CK into a form that promotes student learning. Although there may be some overlap between CK and pedagogical methods among specific topics, the content and pedagogical methods used to enhance student learning differs greatly (Williams, 2012). This creates challenges for Integrative STEM educators who are expected to teach multiple subject areas situated within a DBL context. Finding teachers who have the experience and expertise teaching all of these content areas is difficult and often unfeasible. That is why Wells (2008) suggested the collaboration of STEM educators as the most viable approach to teaching STEM in an integrative fashion.

The PCK needed to successfully teach a subject cannot be obtained through subject matter alone (Irby, 1996; Shulman, 1987). Darling-Hammond (1991) confirmed that PCK differs from CK, because she found PCK requires more knowledge from the teacher than that of just content. The challenge is discovering how to increase the PCK of a teacher. Fennema and Franke's (1992) findings highlighted three ways through which teachers could develop pedagogical knowledge and PCK: (a) knowledge through traditional education (b) knowledge through practice, and (c) knowledge as situated. Studying PCK is critical to improving teacher preparation programs and improving student learning because of the effect these programs can have on developing teachers' PCK.

These distinctions between teachers' GPK, CK, and PCK can also be seen between science and T&E education. By adapting Phillips et al.'s (2009) model to apply specifically to science and T&E educators, it can be used to better understand the synthesis of these three knowledge bases. Figure 4 shows the various complex knowledge bases that science and T&E (STE) educators must possess if they are to teach science, technology, and engineering concepts congruently.

GPK refers to "one's understanding of teaching and learning processes independent of subject matter" (De Miranda et al., 2009, p. 48) and includes "broad principles and strategies of classroom management and organization that appear to transcend subject matter" (Shulman & Hutchings, 2004, p. 92). It is needed to aid in the selection of methods to present material to students in a form that they will better understand. The dynamics of a classroom environment make GPK critical for keeping students focused on the content. Throughout a class period, teachers make quick decisions regarding pedagogical methods and classroom management because the classroom is often ill defined and variable (Nespor, 1987; Pajares, 1992).

Content knowledge, defined as "one's understanding of the subject matter" (De Miranda et al., 2009, p. 48), is also essential to student learning in the specific science, technology, engineering topics. If a T&E educator is teaching a biotechnology unit and knows little about the biological processes needed to make the system function properly, then the system either will not function or the students will not learn the full breadth of biological content knowledge embedded within that unit. The system may require going through the engineering design process (EDP) and problem solving, however the biological concepts will remain untaught because the teacher does not know what points to highlight or how to best teach those concepts. The inverse could occur with science educators tasked by the NGSS with incorporating engineering content into the science curriculum (NGSS Lead States, 2014b). This is where the lines start to blur and CK in various areas is critical. Technology educators have been expected to deliver engineering content in their curricula for a number of years, hence the easy marriage between T&E CK. Science and engineering CK, as well as STE CK has been more difficult to develop because of teachers' lack of preparation and experience within all of these areas.

When GPK and CK intersect, educators develop PCK which Shulman (1987) simply described as the "the blending of content and pedagogy" (p. 8). This knowledge is what STE educators use to transfer their content knowledge to the students. As Shulman (1987) stated in his definition of PCK, teachers must know how to adapt instruction to meet the diverse interests and abilities of learners, which happens to also be one of the seven knowledge categories he identified. Although social constructivists such as Vygotsky would agree that knowing the needs of learners is critical to scaffolding them into a new ZPD, Shulman further believed that teachers must also have knowledge of the content and pedagogical methods to help scaffold students.

Knowing the backgrounds and types of students being taught is a critical component in selecting which content and curriculum to promote student learning. The CK and PCK of teachers play a vital role in the way all curricula are enacted (Tal, Krajcik, & Blumenfeld, 2006). Shulman (2004) described curriculum knowledge as a "particular grasp of the materials and programs that serve as 'tools of the trade' for teachers" (p. 92). Expert and novice teachers often view curricular packages differently, some use them as a guide while others follow them step-by-step. In T&E education this can be seen with popular curriculum packages such as Project Lead the Way (PLTW), Engineering byDesign (EbD), and Engineering is Elementary (EiE). Teachers without technology education licensure that are tasked with teaching T&E courses may rely more heavily on these detailed curricula if they are not fully comfortable teaching the content. On the other hand, experienced T&E educators would be expected to use these curricula packages as a guide, and adapt the curricula to meet the needs of their students and teaching style.

In a similar vein as knowledge of learners and characteristics, Shulman (2004) identified knowledge of educational contexts as “ranging from the workings of the group or classroom, the governance and financing of school districts, to the character of communities and cultures” (p. 93). Although similar to knowledge of learners and characteristics, this type of knowledge addresses the larger community outside of the individual learner’s needs, such as selecting a curriculum for a school system. Making the most of these educational contexts can help teachers improve their methods used to present content to students. However, implementing these educational contexts still relies upon the CK of the teacher, and their ability to present content in a manner which students can relate.

Shulman’s (2004) final category of teacher knowledge is “knowledge of educational ends, purposes, and values and their philosophical and historical grounds” (p. 93). This ties back to the educational philosophies of psychologists, theorists, and philosophers. Knowledge of learning theories and the origins of those theories are beneficial for educators to understand the rationale behind pedagogical methods (e.g., scaffolding) and when to correctly apply each method. This intuitive skill is one that cannot fully be taught, and is the result of a special blend between content as well as the pedagogical knowledge. Because teachers often make these adaptations spontaneously in their teaching practice, it is difficult to research them. This intuitive skill is another reason PCK evolved as a unique trait that separates expert teachers from novice teachers, and the reason why Shulman focused heavily on studying PCK.

Figure 4 shows why PCK is the pinnacle of science and T&E educators’ knowledge. It is the overlapping of multiple content knowledge areas that contribute to the teacher knowledge of expert science and T&E educators, as well as enhanced student learning. STE PCK is the most difficult to achieve due to all of the knowledge factors that contribute toward it. All seven categories play a critical role in adding to the attributes of teachers' PCK, but on their own each of the categories could not enhance student learning of content and practices to the extent that PCK does.

PCK and Student Learning

In the literature it has been reported that high levels of teacher PCK are directly related to effective teaching and the enhancement of student learning in both content and practice. To fully understand what is meant by practice, the NGSS serve as a valuable resource. They explicitly addressed the importance of collaboration yet differences between three dimensions: (1) content (2) scientific and engineering practices, and (3) cross-cutting concepts. The science and engineering practices were used as performance expectations that depicted what students must do to show proficiency in science. The NGSS also noted that the use of the term practices was not in reference to teaching strategies, but of indicators of student achievement. They reiterated the need to couple practice with content to give the learning context, otherwise practices are just activities and content is just memorization. Specifically the NGSS listed eight science and engineering practices that students should know by the completion of grade 12.

Integrative STEM Education provides the context to make connections between content and practices through the use of a technological engineering DBL pedagogy. Jabot (2002) examined the PCK of physics teachers regarding direct electric circuits and the impact it had on changes in student learning gains about electrical circuits. Students' pre and post-test scores of electrical circuits were compared with teachers' PCK ratings determined from pre and post teacher interviews and surveys. The study indicated that PCK of teachers played a more significant role in student conceptual understanding of electrical circuits than the CK of teachers.

Additionally, Jabot (2002) discovered that PCK was the only predictor associated with these gains, once again displaying the importance of PCK versus pure CK.

More recently research by Sadler, Sonnert, Coyle, Cook-Smith, and Miller (2013) revealed significant gains in student knowledge based on the PCK of their teacher. They found that teachers who better understand their students' misconceptions of science topics had students with the greatest knowledge gains. This study showed that teacher misconceptions can be transferred to students. Sadler et al. (2013) concluded that the mastery of teaching has more impact on student learning than depth of knowledge on any particular topic. This study further exemplified why CK itself is not a predictor of student learning gains, but a blend of CK and GPK is important for student learning.

In T&E education, Jones and Moreland (2004) found that teachers with higher levels of PCK displayed evidence of greater conceptual and procedural understanding, as well as more effective knowledge transfer from other curriculum areas. The increase in procedural knowledge showed the shift from knowledge of content to practice. More significantly, the increased knowledge of transfer from other curriculum areas revealed the increase in thinking skills that could be elicited by higher levels of PCK as well as integrative pedagogical methods. In another T&E education study, Fox-Turnbull (2006) attributed teachers' technological knowledge and effective teaching methods to increased achievement in the quality of students' designs and procedural knowledge.

Research such as the examples presented, reinforce the need for further PCK research to see what other benefits it provides. Teachers' levels of PCK have demonstrated a direct correlation to effective teaching practices and advancement of learning gains in both content and practices. To better examine learning gains resulting from enhanced PCK it must be determined what constitutes effective teaching.

Elements of Effective Teaching

As discussed in previous portions of the literature review, highlighting the relationships between teacher quality and student achievement is essential for showing the importance of studying and enhancing the PCK of teachers. Specifically, examining teachers' classroom practices to determine teacher quality is important since this is the leading mechanism by which teachers affect students (Grossman et al., 2010). The impact of PCK on student achievement is one that Jabot (2002) and Settlage (2013) cited as the most critical shortcoming of PCK research to date. Showing connections between the PCK level of teachers and student achievement provide the rationale for further research such as this study, as well as pose implications to improve pre- and in-service STEM teacher preparation programs (Grossman et al. 2010).

What constitutes effective teaching has been studied for decades (Stronge, Ward, & Grant, 2011) yet still remains debated, "In the existing literature, teaching quality is neither a widely agreed upon nor uniformly accepted concept" (Wang, Lin, Spalding, Klecka, and Odell, 2011, p. 331). There is a need for better measures of teacher quality as well as more information about the validity of those measures (Hill, Umland, Litke, and Kapitula, 2012). Ball and Hill (2009) define high quality teaching as "those who consistently and effectively foster students' learning" (p. 95). It has traditionally been assessed by examining teacher qualifications, level of CK, and measuring the quality of instructional practice (Ball & Hill, 2009; Hill & Ball, 2009). However, teachers' performance on a multiple-choice licensure exam and possession of state certification are not strong indicators of teaching quality (Hill & Ball, 2009). Many studies have shown that teaching qualifications and CK alone have little to no effect on student achievement

(Hill & Ball, 2009; National Mathematics Advisory Panel, 2008; NCATE, 2012), therefore studying the skills and decisions teachers use to help students learn is critical to improving the PCK teachers and student learning. Hill, Rowan, and Ball (2005) echo the notion that teacher quality is more than CK, "Effectiveness in teaching resides not simply in the knowledge a teacher has accrued but how this knowledge is used in classrooms" (pp. 375-376). Examining what elements have been identified as characteristics of quality practice is essential for studying the PCK of teachers. Before conducting research to assess the PCK of teachers, researchers must recognize the elements that separate expert instructors from novice instructors.

Elements of Quality Practice

The education literature at large has indicated that teacher quality is the most effective predictor of student achievement (Darling-Hammond, 2000; Just for the Kids and The Southeast Center for Teaching Quality, 2002; McCray & Chen, 2012; National Commission on Teaching and America's Future, 1996; NRC, 1996; Rice, 2003; Wright, Horn, & Sanders, 1997). Willms (2000) and Rowe (2004) also found that "the single largest factor in student achievement is the teacher" (Lovat, 2011, p. 3), and Wells (2010) cited Shluman's teacher knowledge as having significant impacts on student learning:

> The significance of teacher knowledge (e.g. Shulman, 1986) in the teaching/learning process has been consistently and repeatedly supported through empirical research, and continues to substantiate the teacher as the single most important factor in facilitating student learning (Darling-Hammond, 2000, 2002; Darling-Hammond & Youngs, 2002; Committee on Science and Mathematics Teacher Preparation, 2001). (p. 205)

Significant correlations have been found linking teacher quality and student achievement, even after controlling for student poverty and student language background factors (Darling-

Hammond, 2000). Rivkin, Hanushek, and Kain (2001) attributed 7% of variance in student test score gains to differences in teachers. However, limited research has been conducted on the relationship between the PCK of T&E educators and student learning. More research regarding teaching and learning along with teacher education has been conducted in science education, which Wells (2010) recommended as a viable resource for addressing the similar gaps identified in T&E education.

Labuta and Smith (1997) identified three major components of quality instruction: planning, implementing instruction, and assessing student learning. PCK has been assessed through examining a teacher's planning and implementation of lessons, but rarely through their assessment of students. Smith (2001) defined teaching quality through the lens of characteristics that expert teachers possess. He cited learning from experience, being an expert in a topic specific teaching areas, and knowing how to move inquiry forward during class sessions as indicators of expert teachers. These characteristics are in line with Shulman (1987) who believed that PCK is topic specific, and William and Lockley (2012) who believed PCK was built up over time and experience. Examining how to adequately assess teachers and students is critical to examining quality of practice and PCK.

Hill and Ball (2009) described teaching knowledge as a "horizon knowledge" (p. 70) which is comprised of a blend of common CK, specialized CK, knowledge of students, GPK, and knowledge of curriculum. Specifically, they found that posing questions, interpreting students' answers, providing explanations, using representations, using the appropriate language in regards to content, the ability to see content from another's perspective, and the ability to understand what another person is doing were all elements of quality practice that impacted student learning. They suggested that one task teachers engage in and could be linked to teacher quality is the ability to analyze and understand student work (Ball & Hill, 2009).

The National Council for Accrediting Teacher Education (NCATE, 2012), which identified the benchmarks for higher education institutions to become accredited in teacher preparation, identified several elements of effective teachers based on research. They stated that teachers must have CK and GPK to be effective, and clarify that although CK is important it alone cannot determine how well a teacher is able to teach students. NCATE (2012) found that high quality teacher preparation programs make a difference in student achievement. Their report also discovered that effective teachers have knowledge of teaching and learning, but more importantly are able to apply this knowledge to raise student achievement. This further supports why it is important to observe teachers and their actions in a natural classroom setting when assessing quality of practice.

Challenges with Measuring Effective Teaching and Quality Practice

This section highlights the various elements that researchers have identified as measures of quality practice in teaching. Amidst the different elements that each study suggested, it is clear that effective teachers possess an assortment of characteristics which set them apart from their colleagues. The elements presented in the research show a distinct relation to Shulman's seven categories of knowledge that grow in the mind of teachers. Experience was seen as a common factor attributed to quality of practice. Knowledge of content, and knowledge of pedagogical methods were also common across the research. Researchers (Hill & Ball, 2009; Wang et al., 2011) stated that knowledge of students was important, which Shulman (1987) referred to as knowledge of learners and their characteristics. Hill and Ball (2009) found curriculum knowledge to be essential for quality practice, and one final characteristic which related to Shulman's (1987) knowledge of education contexts was Stronge et al.'s (2011) finding that managing the learning environment is essential for determining quality practice.

In addition to the breadth of elements of quality practice that emerged from the literature, various research methodologies were used to assess quality practice and its impact on student learning. Mathematical Knowledge for Teaching (MKT) (Hill et al., 2005) was seen as a widely used instrument in mathematics education to help assess the mathematics CK and GPK of teachers. Unfortunately the MKT could not assess the differences between teachers' CK and PCK, like Jabot (2002) was able to do in science education. Even with the weaknesses that these instruments and studies possessed, they still contributed to the knowledge of PCK. Using the knowledge gained from previous research presented in this review is vital for developing a methodology that accurately examines the various characteristics of the PCK of T&E educators. Despite the vast amount of research showing a positive correlation between these factors, there are many shortcomings of conducting research on PCK, which researchers have identified throughout the literature.

Shortcomings of PCK Research

Since its inception PCK has been highly scrutinized by many educational scholars. Labaree (1992) described PCK as nothing more than an invented construct to enhance teacher educators' professional status, Daehler and Shinohara (2001) called PCK "a complicated and inherently ambiguous notion that is open to a myriad of interpretations" (p. 268), and Settlage (2013) referred to PCK as a "mirage in a desert or a mythical siren along the shore" (p. 1). The borders between Shulman's (1987) seven knowledge domains have been criticized as fuzzy, making it difficult to conceptualize PCK as a separate construct (Karaman, 2012; Marks, 1990; Gess-Newsome & Lederman, 1999; Magnuson, Krajcik, and Borko, 1999). Gess-Newsome and

Lederman (1999) asserted that the movement between knowledge bases are seamless in expert teachers, therefore PCK is difficult to identify as a separate knowledge base. While Carlsen (1991) and Lederman and Gess-Newsome (1992) believed PCK to be more of a theoretical concept without enough evidence to support it as a separate construct, Magnuson et al. (1999) argued that PCK is a separate construct depending on how one chose to organize knowledge domains.

Despite the criticisms of PCK and how to best research it, there are also many scholars who believe it exists and have collected data in its support. It is critical to understand what effective teachers need to know (Magnuson et al., 1999), and PCK has been recognized as a critical component of teacher knowledge. It has been asserted that teachers need PCK to organize their lessons, develop representations of the content, and understand student difficulties with a topic (Van Driel, Veal, & Janssen, 2001). Additionally, it has been found to serve as a conceptual framework to establish more effective teacher education programs (Carlsen, 1999; Van Driel et al., 2001).

One of the leading criticisms is the continual questioning of how (if at all possible) to adequately assess the PCK of a teacher since it is an internal construct (Baxter & Lederman, 1999; Kagan, 1990). It has also been questioned to what extent researchers can capture and disseminate (Settlage, 2013) the cognitive process teachers go through when making teaching decisions (Rohaan et al., 2009). PCK advocates have countered this argument with findings from numerous data collection methods such as multiple-choice tests, Likert scale instruments, open-ended questionnaires, interviews, field notes, curriculum content, ethnographic data, journals, lesson plans, video recordings, student portfolios, case studies, and the speak-aloud approach (Love, 2013c). Despite these attempts to document teachers' cognitive teaching processes, determining specific elements of PCK in practice and how to accurately assess those elements has been difficult (Gess-Newsome & Lederman, 1999; Karaman, 2012).

Settlage (2013) raised many concerns with conducting research on PCK. First he described the complexity of it and how difficult it is to unpack. Multiple models of PCK have been constructed since 1986 to better understand its characteristics in the context of the subject areas being taught. Settlage (2013) and Van Driel, Verloop, and De Vos (1998) criticized PCK due to researchers inability to achieve consensus of a universally accepted conceptualization of it. In the literature at large, most researchers appear to use a form of Shulman's definition to define PCK (Love, 2013c; Rohaan et al., 2009). Rohaan et al. (2011) used a panel of T&E education experts to formulate a working definition of PCK. Additionally they agreed upon three aspects of PCK in T&E education: (1) knowledge of pupils' prior knowledge and misconceptions of technology (2) knowledge of the nature and goals of T&E education, and (3) knowledge of pedagogical approaches and teaching strategies for T&E education.

Secondly, Settlage (2013) criticized the focus of most PCK research being too teacher centered instead of student learning centered. He argued that the pinnacle of PCK research should be equating the value of a teacher to their students' learning of content. However, Settlage (2013) believed it was much easier to measure teachers' content knowledge than their pedagogical knowledge. Another shortcoming Settlage (2013) exposed is the misconception that increased CK results in more effective teaching and greater student achievement. He found there to be a lack of research addressing the minimum amount of CK science teachers need, and if too much CK interferes with the their capacity to transmit knowledge to students. Some studies investigating CK and its relation to PCK have shown that CK had an insignificant influence on student achievement (Hattie, 2012; Mapolelo, 1999; Olitsky, 2007), while others have shown that strong CK is necessary for the development of PCK (Carlson, Gess-Newsome, Gardner, Wilson, & Stuhlsatz, 2010; Cochran, DeRuiter, & King, 1993; Halim & Meerah, 2002; Kaya, 2008; Van Driel, De Jong, & Verloop, 2002; Veal & MaKinster, 1999). CK knowledge is a critical component of PCK and although research about its influence on PCK varied, it was still found to be an essential element of PCK. Finally, Özden (2008) reminded educators and researchers that CK is important because inaccurate and inadequate CK can cause the transfer of misconceptions to students and impact their achievement.

Settlage (2013) believed that PCK is the result of knowledge as an activity, not the accumulation of information. A similar belief was shared by Cochran et al. (1993) who called PCK "pedagogical content knowing (PCKg)" because they believed the term knowledge to be too static. Their constructivist view of PCK helped define PCKg as "a teacher's integrated understanding of four components of pedagogy, subject matter content, student characteristics, and the environmental context of learning" (p. 266). Cochran et al. (1993) preferred using the term "knowing" because they believed it connoted teaching, which is an autonomous conceptual understanding, as opposed to training which is a replication of behavior. They placed emphasis on two areas in which they believed Shulman did not address when defining PCK: (1) teachers' understanding of students, and (2) the environmental context of learning. Cochran et al.'s (1993) definition of PCKg also placed emphasis on the importance of the teacher recognizing students' misconceptions as well as the social, political, cultural, and physical context of the environment that shapes the teaching and learning process.

When discussing knowledge of context as one of the three knowledge bases of PCK (Shulman & Grossman, 1988), Settlage (2013) also believed that research in this area did not address the sociocultural dynamics that impact teaching and learning. Instead, context is often viewed through the lens of different contents, not as sociocultural factors of students. Fernández-Balboa and Stiehl (1995) identified knowledge of students and their backgrounds as central to PCK. However, Darling-Hammond (2000) and Ferguson (1991) found that teachers' expertise, including experience, accounted for more gains in student achievement within the classroom than socioeconomic status. Furthermore, Hill et al. (2005), Nye, Konstantopoulos, and Hedges (2004), and Clement's (2009) found that socioeconomic status did not affect student gains in learning, suggesting that "knowledgeable teachers can substantially affect students' learning" (Hill et al., 2005, p. 396). Teachers' preparation experiences play a critical role in developing their PCK and must be taken into consideration when examining student learning. While it has been shown that teacher preparation programs help in developing increased PCK (Darling-Hammond, 1991; Fennema & Franke, 1992; Guyton & Farokhi, 1987; Monk, 1994), Shulman (1987) and others (Cochran et al., 1993; De Miranda, 2008; Jabot, 2002; Kind, 2009; Phillips et al., 2009; Rohaan, Taconis, & Jochems, 2010; Williams & Lockley, 2012) have found that PCK is a special blend of content and pedagogical knowledge that develops over time and is heavily reliant on teaching experience. Determining different methods to fully examine one's experiences can be difficult.

Lastly, Loughran et al. (2012) cited generalizability as a limitation of PCK research because PCK varies among content areas and specific topics. Within the U.S. and territories of other countries, there are variations of what content is taught and how it is taught. This elicits a unique form of PCK for each topic. Loughran et al. (2012) and Van Driel et al. (1998) have contested that despite these differences, research on the PCK of a teacher should enable useful generalizations to be made since CK and PCK for each subject area is unique in and of itself. Methodologically, qualitative data collection has been shown as helpful for gaining more in-depth knowledge about the unique background experiences and PCK of a teacher. These shortcomings are not the only factors to consider when researching PCK. In conjunction with these criticisms, researchers must also consider the new demands placed on teachers' PCK resulting from standards and assessments at the state and national levels.

Creating New Demands on Integrative STEM Education Teachers

National and state standards have received mixed reviews from critics. Carmichael, Martino, Porter-Magee, and Wilson (2010) called standards "the blueprint or roadmap of K-12 education" (p. 1). They believed that standards should guide state assessments and accountability systems, inform teacher preparation, licensure, and professional development as well as shape curricula. They quickly noted that standards which are vague, watered-down, or misguided can result in negative or no outcomes. The success of standards hinges on how robust and relevant they are written along with how well they are implemented. As Carmichael et al. (2010) stated, "Standards do matter – but only when implemented aggressively" (p. 2). Standards impact how teachers teach, how they are prepared, and how they are professionally developed (Carmichael et al., 2010). Examining standards of the most recent educational reform efforts is critical to studying the knowledge of teachers and how they are prepared due to the demands placed on them.

In 2000 the *Standards for Technological Literacy* (ITEA/ITEEA, 2000/2002/2007) strengthened the rationale for technology educators to integrate content from areas outside of technology education, specifically engineering, math, and science. The standards stated that technology education was situated in a unique position within the school setting to allow for the inclusion of integrative practices to promote learning in the context of real world problem solving (ITEA/ITEEA, 2000/2002/2007). This call for integration helped change the structure of

T&E teacher education programs, curricula, and professional development to prepare T&E educators to teach using a more integrative approach (Reeve, Nielson, & Meade, 2003; Russell, 2003). The *Standards for Technological Literacy* required increased teacher CK about technological literacy, and a unique form of PCK to integrate multiple contents within T&E education. The changes brought about by the *Standards for Technological Literacy* created a demand to reeducate pre- and in-service teachers so they could adequately address the new standards in their practice. PCK in each new topic specific area (e.g., medical technologies, agricultural and related biotechnologies) was needed for teachers to present the content to students in an integrative manner that they could understand it. Conversely, the NGSS recently incorporated engineering content and practices that will require science educators to develop engineering CK and PCK to successfully integrate those concepts into the science curricula.

The NGSS (NGSS Lead States, 2014a) identified practices that all P-12 science students should know and were based upon three dimensions: to provide a context for the content of science, how science knowledge is acquired and understood, and how the sciences are connected through concepts that have universal meaning across disciplines. The three dimensions in the NGSS lend themselves to be taught collaboratively and promote integrative pedagogical approaches. The NGSS were written on the premise that "real world science and engineering is always a combination of content and practice" (NGSS Lead States, 2014a, p. 2), mirroring Shulman's (1987) theory of PCK resulting from a special blend of CK and GPK. Due to the requirements the NGSS placed on science educators to teach engineering and science in an integrative fashion, these teachers will be expected to have a broader CK and PCK base. Science teachers are now expected to have ample CK not only in science, but also in engineering and other crosscutting concepts taught (see Figure 4), which contributes to the PCK demands placed on these teachers. Prior to the release of the NGSS, science teacher preparation programs or in-service professional development were not expected to address the development of science teachers' engineering CK and PCK. Preparing science teachers with an adequate amount of this knowledge, and introducing them to the proper use of the EDP to integrate various content, is essential for preparing science educators to effectively teach content and practices called for in the NGSS.

Another demand placed on science teachers stemming from the NGSS's recommended integration of engineering practices is laboratory safety. Student safety is of utmost concern when working in a laboratory setting (Love & Strimel, 2013). T&E education teachers complete laboratory safety training courses to use large-scale tools and machines as part of their teacher preparation program. Science educators are trained from the lens of science laboratory safety, which does not cover the majority of tools and machines traditionally found in T&E education laboratories. Although parallels can be drawn between science and T&E education laboratory safety, liability, and tort law; science educators' lack of experience and knowledge using the tools and machines required to fully implement the EDP requires additional safety training (Love, 2013a, 2013b, 2014; Roy, 2012). This creates new pre- and in-service preparation demands on science education, which is another reason collaboration among science and T&E education is critical (Love, 2014; Roy, 2014). T&E education provides a unique approach to teaching engineering practices because of its ability to use tools and equipment in the design and fabrication of EDP solutions, which T&E teachers have been expected to perform since the release of the *Standards for Technological Literacy* (ITEA/ITEEA, 2000/2002/2007) in 2000.

The Common Core State Standards (CCSS) were introduced in June of 2010. According to the Common Core State Initiative's (2012) website, they were designed to "be robust and relevant to the real world, reflecting the knowledge and skills that our young people need for success in college and careers" (para. 1). Adopting the CCSS were 45 states, the District of Columbia, four territories, and the Department of Defense Education Activity. The CCSS aimed to prepare students to be both college and career ready, and provide a framework to promote more rigorous curricula to elicit students' higher level thinking skills. Also, the CCSS aimed to prepare students for the competitive global economy that was discussed as a critical need for STEM education in Chapter 1.

The National Assessment of Educational Progress (NAEP) is another standardized test that provides results on subject-matter achievement, instructional experiences, and school environment for populations of students in grades 4, 8, and 12. It does not provide data for individual students or schools, and is the largest national assessment of American students (U.S. Department of Education, 2012b). The NAEP assesses contents such as mathematics and science, and as of 2014 assesses Technology and Engineering Literacy (TEL). Podgursky (2002) found from the NAEP data that student's socioeconomic background has the most significant effect on student achievement. Consistent with the findings of Darling-Hammond (2000) and Ferguson (1991), he also found that teachers with proper credentials, professional development, and classroom practice could offset the effect that socioeconomic disadvantage has on student achievement. Unfortunately high stakes tests have been shown to cause school curricula to narrow and cause teachers to teach to the test (Madaus, 1985). The demand for student gains placed on teachers by high stakes tests have inadvertently caused some educators to teach in a less integrative fashion and solely for their students to perform well on the test.

The NAEP was the first nationwide assessment of student achievement in T&E Literacy, and provided the framework to develop more tests to discover how well students are learning to understand and use various forms of technology (Dugger, 2010). This assessment showed what knowledge and skills students use in the development of design solutions (Bybee, 2010) as well as finally provided the assessment structure to research connections between pedagogical practices and student achievement (Wells, 2010). T&E education should benefit greatly from the findings of the NAEP, using them to determine in which areas teachers need to provide more assistance to students. It will serve as a good measure for the profession to see what students are learning from T&E educators. With NAEP now assessing T&E Literacy, it has created a need for increased teacher PCK of T&E educators. T&E education can use NAEP to show that the field does in fact promote student learning in addition to integrating and teaching other content areas within the context of technological design. The NAEP will help inform pre- and in-service teacher preparation programs to prepare T&E education teachers to address areas where students did not perform well. These preparation methods will contribute to the PCK of teachers, and in turn should result in increased student T&E literacy.

Some data have caused researchers (Loveless, 2012, Mathews, 2012; Holliday & Smith, 2012) to be skeptical of the ability of educational reform standards such as the CCSS to increase student achievement. Mathews (2012) interviewed hundreds of teachers who significantly raised student achievement, and not one credited it to the CCSS. Mathews asserted that, "Good curriculums help, but high-minded, numbingly detailed standards don't produce them. How teachers are trained and supported in the classroom is what matters, even in states as enlightened as Virginia" (Mathews, 2012, para. 10). This viewpoint sheds light on the reason that PCK is critical for student achievement. As Mathews (2012) proclaimed, standards do not produce better teachers with increased PCK, the training and support teachers receive over time help boost their PCK, resulting in higher student achievement.

Despite the touted benefits of standards, Whitehurst (2009) found that there is no link between the quality of state standards and actual student performance. Carmichael et al. (2010) contributed this to weak standards and the inability to implement them. An example of successful standards creating the framework for increased student achievement can be found in Massachusetts. The state of Massachusetts has led the nation in student achievement gains over the past decade due to its excellent standards and ability to implement them, which shows the importance of creating quality standards and implementation (Carmichael et al., 2010). Massachusetts also topped the charts for the NAEP in reading and math and had significant gains for high-need students. Most impressively, Massachusetts students who took the international Trends in International Mathematics and Science Study (TIMMS) exam in 2007 scored among the best in the world, tied with Japan. This shows that if implemented correctly, initiatives like the ones discussed in this section can contribute to the resurrection of the United States' slipping economic dominance that has been attributed to poor pedagogical practices of the American school system (Friedman, 2005; NCEE, 1983).

Standards used as the frameworks to present STEM education in an integrative fashion have drawbacks, but also possess great potential in demanding more rigor from STEM education. If implemented correctly, standards such as the *Standards for Technological Literacy*, the CCSS, and the NAEP all have the ability to help prepare students to be better prepared for a competitive global economy. Research must be conducted to examine the science CK and PCK that T&E educators possess to determine if pre- and in-service programs are adequately preparing them to teach science, technology, and engineering in an integrative manner. The purpose of this study was to investigate the PCK of T&E educators to better inform

T&E education teacher preparation programs about the teacher knowledge that T&E educators possess.

Summary of Characterizing PCK

Regardless of the differing definitions of PCK and the contexts it has been applied to, it still remains an important topic requiring further exploration within T&E education. Over a quarter century after Shulman proposed the concept, his definition is still widely accepted as the basis for defining PCK (Love, 2013a; Rohaan et al., 2009) despite attempts to define it in various topic specific contexts. PCK is an "amalgam of content and pedagogy" (Shluman, 1987, p. 8) that requires a special blend of technological, scientific, engineering, and pedagogical knowledge (Figure 4) for T&E educators to be most effective. New demands on the PCK of teachers have resulted from recent educational reform efforts and national initiatives, which have evoked the need to investigate how to better prepare teachers in Integrative STEM Education. The connections found between teachers' effectiveness, level of PCK, and student learning of content and practices provide a promising outlook for PCK and the impact it can have on future STEM education teachers and students.

Characteristics that define and make up PCK were presented in this section. Examining what PCK is, the similarities and differences between its characteristics, and challenges associated with conducting research on PCK can give researchers a better basis to understand and critique previous PCK research methodologies. To formulate a method for examining select preparation experiences contributing to the science PCK of T&E educators, the next section will review PCK research methods and the impact that educators' actions in contextualized educational settings have had on PCK research.

Research on PCK

As presented in the previous sections, various attempts have been made to accurately assess teachers' PCK in and across the STEM education disciplines. Due to PCK being an internal construct (Baxter & Lederman, 1999; Kagan, 1990) and the complexity of the seven characteristics that comprise PCK, finding the best methods to assess it has been an ongoing challenge facing educational researchers. In addition, difficulty to conceptualize PCK as a separate construct (Karaman, 2012; Marks, 1990; Gess-Newsome & Lederman, 1999; Magnuson, Krajcik, and Borko, 1999) and difficulty distinguishing teachers' movement between knowledge bases (Gess-Newsome & Lederman, 1999) has added to the challenges of assessing PCK. Unpacking the characteristics of it is difficult (Gess-Newsome & Lederman, 1999; Karaman, 2012), but there are studies that have accurately identified specific elements of PCK in relation to the cognitive processes teachers use in contextualized educational settings (Gess-Newsome & Lederman, 1999).

Some PCK research has been very broad, while some has been extremely detailed, examining the PCK teachers in one specific course at a particular grade level. Regardless of content area and grade level, much can be learned from methods used in constructing instruments to measure the PCK of a teacher in the various STEM education contexts. This section focuses strictly on previous research methodologies used in relation to PCK. It will review how research on PCK used by teachers in an authentic classroom setting has impacted research designs and data collection methods. Additionally, previous data collection methods as well as the validity of instruments used to measure the CK, GPK, and PCK of teachers will be examined.

Research Design and Data Collection Methods

Settlage's (2013) most prominent criticism of PCK research was that it has exerted too much effort examining teachers' knowledge as opposed to examining how teachers apply their knowledge while working with students, "The actions of science teachers should take precedence over any measure about what they seem to know" (p. 9). Settlage (2013) also identified the relationship between teaching practices and student achievement as a gap in PCK research. PCK research has not been developed in a manner that would encourage teachers to enact it as a central aspect of their practice (Berry & Milroy, 2002; Loughran et al., 2012; Van Driel et al., 1998). Using input from research examining the PCK of teachers and their actions in the classroom is essential to creating a framework for the practical application of PCK. Although not all PCK research has been easily applicable to the classroom, teachers' practices have greatly influenced the design and data collection mechanisms of most PCK research.

Researchers and teacher educators have utilized an array of methodologies and techniques such as multiple-choice tests, concept maps, pictorial representations, interviews, and multi-method evaluations to study PCK (Baxter & Lederman, 1999). Table 3 highlights some relevant PCK research conducted within STEM education that contributed to the development of instruments and data collection in further PCK research.

Table 2

Synthesis of Previous PCK Instruments and Their Validity Measurements

Author(s)	Instrument	Content Area	Methods	Validity Measures
Dwyer, 1998	Praxis III	General Domain	Class/Instruction profile, Observations, interviews	Evidence based on test content, relations to other variables, internal structure

(continued)

Table 2 Continued

Author(s)	Instrument	Content Area	Methods	Validity Measures
Hill et al. (2004)	Mathematical Knowledge for Teaching (MKT)	Mathematics	Multiple-choice, open ended questions	Evidence based on test content, relations to other variables, internal structure
Loughran et al., 2004	CoRe and PaP-eRs	Science	Interviews, observations, discussions	Evidence based on test content
Heller et al., 2004	Science Case for Teacher Learning Project	Science	Interview rubric	Evidence based on test content and relations to other variables
Abdullah and Halim (2007)	Environmental Science Instrument	Science	Multiple-choice, 5-point Likert scale	Evidence based on expert review of instrument
Rohaan et al., (2009)	Teaching of Technology Test	T&E education	Multiple-choice	Checked for correlation to content and self efficacy tests
Krauss et al. (2008)	COACTIV	Mathematics	Open ended questions	Administering test to contrast populations, comparing to other similar tests
Hynes	Qualitative instruments	Engineering	Observations, interviews, think-aloud tasks, assessment of student work	Compared qualitative findings to previous studies

In recognition of the gap between PCK research and practice, Loughran, Berry, and Mulhall (2004) aimed to create an instrument to share knowledge of PCK in ways that were applicable for teachers, teacher educators, and researchers. They found that teachers were unable to articulate their well-developed PCK regardless of the various data collection methods used.

Based on this experience, they decided to work with small groups of teachers allowing them to think aloud and share their science teaching knowledge among other teachers. From this Loughran et al. (2004) developed the content representation (CoRe) and pedagogical and professional-experience repertoire (PaP-eRs) instruments based on their findings that PCK was not something that resided solely in a teacher as an individual. Loughran et al. (2004) believed that PCK must be captured at both the individual and collective levels, because it is the result of membership to the teaching profession in addition to individual teaching and learning practices.

The CoRe instrument reveals the CK of teachers by examining specific aspects of PCK (e.g., overview of main ideas, knowledge of alternative conceptions, insightful ways of testing for understanding, known points of confusion, effective sequencing, and important approaches to the framing of ideas) (Loughran et al., 2004). It is administered to groups of three or four teachers via interview to elicit their understandings of important aspects of the course content. The instrument helps organize teachers' knowledge in common ways and identify important features of the content that they recognize and respond to in their teaching.

The PaP-eRs instrument offers a view into a teaching and learning situation in which the content shapes the pedagogy. It illustrates aspects of PCK in action through the lens of a specific content area. Because of this, the PaP-eRs and CoRe are linked to expose connections between understanding of content and pedagogical practices, highlighting the decisions that underpin teachers' actions and help students better understand the content. Validity of the CoRe was established through individual and small groups of teachers by examining the applicability and usefulness in how ideas were organized and expressed. PaP-eRs was validated through the consensus process of drafting and verification between researchers and teachers (Loughran et al., 2004).

In a 2007 study Loughran, Berry, and Mulhall further validated the CoRe and PaP-eRs instruments (Bertram & Loughran, 2012). They tested the instruments with two groups of science teachers to see how they were interpreted and how they influenced the teachers' reflection on their own practice. Loughran et al. (2007) found that teachers believed the CoRe was useful for planning, organizing and thinking about CK, and the PaP-eRs contributed to developing their professional knowledge by inducing new ways of viewing science teaching and learning.

According to Bertram & Loughran (2012), many researchers worldwide (Bertram & Loughran, 2012; Hume & Berry, 2011; Mayhunga & Rollnick, in press; Williams & Lockley, 2012) have utilized the CoRe and PaP-eRs instruments to assess PCK in topic specific content areas, especially within STEM education. Williams and Lockley (2012) used the CoRe and PaP-eRs instruments to examine the differences between the PCK of science and T&E educators. They found that these instruments have relevant implications for use in T&E education and would be able to reach a broader audience if conducted via an online format. The CoRe instrument was found to be helpful in integrating both conceptual and procedural knowledge to bridge the gap between theory and practice (Bertram & Loughran, 2012; Williams & Lockley, 2012), which is essential to teach integrative concepts through a DBL pedagogical approach.

Bertram and Loughran (2012) used the CoRe and PaP-eRs instruments to examine the individual views of practicing teachers and how they believed these instruments influenced their practice. They found that teachers in this study identified these instruments as "worthwhile and valid tools which improved their understanding of their own practice" (Betram & Loughran, 2012, p. 1043) and it helped teachers highlight and recognize significant aspects of their own

PCK. Teachers from this study valued PCK more because of these instruments and the concrete portrayals of PCK they provided.

Hume and Berry (2011) used the CoRe to assess the PCK of student teachers. The student teachers were tasked with constructing their own CoRe for new topics, which they found challenging due to lack of classroom experience and experimentation. This CoRe instrument was used the following year to scaffold new student teachers. It was determined from this study that it is possible to increase the PCK of novice teachers through appropriate and timely scaffolding using instruments such as the CoRe. This study provides implications for teacher preparation programs to assess the CK and PCK of their students, or lack of, and provide the proper guidance to enhance the PCK of novice teachers prior to graduation.

Ratcliffe (2008) and Garritz, Porro, Rembado, and Trinidad (2005) confirmed the value of the CoRe and PaP-eRs instruments to represent the individuality and nature of each teachers' PCK. Although the CoRe and PaP-eRs instruments have been used primarily to assess the PCK of science educators, they have shown implications for improving practice in other disciplines. Given the established validity and benefits found from various researchers using the CoRe and PaP-eRs instruments across various STEM disciplines, these instruments serve as a viable option to assess the science PCK of T&E educators.

The use of CoRe and Pa-PeRs are just one choice of instrumentation to address the gap in research between PCK and teaching practices, the main shortcoming of PCK research according to Settlage (2013). Many other attempts have been made to fully understand this concept. There are strengths and weaknesses of each instrument, but they have both contributed to the knowledge about PCK research design and data collection. Examining other methods are worthwhile when developing a methodology to assess the science PCK of T&E teachers.

In most states, the evaluation of teachers emphasizes assessing the capacity to teach (Shulman, 1986). The Educational Testing Service's (ETS) Praxis series is often used by state licensing agencies to determine if an individual has enough CK and GPK to teach. The ETS's Praxis III is used to measure PCK in conjunction with the Praxis II measure of subject matter knowledge (Dwyer, 1998). Praxis III emphasizes the application of CK and GPK of teachers that have been teaching for a number of years. It examines class and instructional profiles, interviews, and classroom observations. Dwyer (1998) validated the Praxis III through the use of trained observer ratings, stating that classroom context is essential to interpreting teacher actions, and observers' judgments are essential to teaching ratings. The Praxis II (ETS, 2011) content and pedagogy tests have recognized the need to distinguish between the assessment of CK and GPK. They cite Shulman's seven knowledge bases for teaching as the definition of teaching knowledge, and also mention Hill et al.'s (2008) classroom applicable multiple-choice questions as significant in assessing the CK and GPK of teachers. ETS has validated these tests through expert panels formulating the questions and pilot testing them over a three-year span. This conscious effort to separate and assess the CK and GPK of teachers (which make up their PCK) reinforces the importance of PCK as recognized by educators and policy makers. It is also a positive step toward bridging the gap between PCK research and teaching practices. Future research on PCK has the potential to inform teaching licensure requirements such as the Praxis series.

Professional development is a critical component of in-service teacher development once teachers are licensed. Heller, Daehler, Shinohara, and Kaskowitz (2004) found that teachers' ability to explain the reasoning for correct answers increased when both CK and GPK were integrated in professional development sessions. In addition to in-service professional development, pre-service teacher preparation is critical for developing the PCK of teachers. Kleickmann et al. (2013) used the Cognitively Activation in the Classroom (COACTIV) instrument to examine CK or PCK variables of pre- and in-service mathematics teachers. Content validity was established through expert ratings during pilot testing, and discriminant construct validity was established by finding no significant correlation between CK or PCK and classroom factors (e.g., classroom management). Their study revealed that CK was significantly high from beginning to ending pre-service teachers. They also found that in-service teachers had higher PCK than ending pre-service teachers, however pre-service teachers showed the largest PCK gains while in-service teachers showed smaller gains in PCK over time. Kleickmann et al.'s (2013) research showed the importance that teacher preparation programs have on developing the PCK of teachers.

PCK is often very topic specific, which requires a unique knowledge for teaching specific topics. Abdullah and Halim (2007) studied the PCK of environmental education teachers. The first two constructs of their instrument (curriculum knowledge, and subject matter knowledge) were developed using multiple-choice questions with five answer choices. The last three constructs, (knowledge of students, teaching strategies knowledge, and knowledge of teaching and learning evaluation) were developed using a 5-point Likert scale. Experts in science PCK and environmental education established face and construct validity by reviewing the instrument. The researchers recommended using a factorial analysis test to determine the constructs of validity in any similar instruments developed.

Hynes (2009) conducted one of the few studies examining the PCK of P-12 engineering educators. He utilized a qualitative approach involving interviews, think-aloud tasks, classroom observations, and evaluation of student projects. Hynes (2009) found that educators with more years of teaching experience made more connections to mathematics and science concepts during an engineering unit as opposed to teachers with less years of teaching experience. Teachers with increased experience employed a more student-centered approach and spent a larger amount of time engaging students through discussion. Although this study did not examine the ability of T&E educators to teach mathematics and science concepts, it does provide a rationale for further research on P-12 engineering education.

Rohaan et al. (2009, 2010, 2011) investigated how the science and technology PCK of technology educators impacts their ability to convert subject matter into meaningful effective activities. Their research found that PCK was commonly measured using multi-method evaluations, which utilized a variety of techniques including interviews, observations, and concept mapping. The results from these evaluations were validated through triangulation and used to produce a general profile of a teachers' PCK. Rohaan et al. (2009, 2010, 2011) had a team of seven experts construct a multiple-choice PCK test (the Teaching of Technology Test [TTT]). One of the aims of their study was to address Abell's (2008) recommendation to shift from small-scale to large-scale PCK studies. They chose a multiple-choice format because qualitative studies often measure small sample sizes that are content, context, and teacher specific, not lending themselves to generalization. Rohaan believed a multiple-choice format can measure the cognitive aspect of PCK since teachers only use a small portion of their behavioral PCK in interviews and teaching observations. Before constructing the test, the experts had to reach consensus on what technology education curriculum model to base the test questions and come to consensus on a working definition of PCK for technology education. Each expert wrote, judged, and revised the multiple-choice questions to establish content validity. The instrument was then field tested twice to refine the test items and generate a test/re-test reliability. The instrument was finally used to assess the technology education PCK of primary school teachers. To establish construct validity of the instrument, teachers took the Cito technology test which measures CK, as well as the Science Teaching Efficacy Belief Instrument (STEBI) to measure their self-efficacy beliefs. The scores from these two tests were correlated to the TTT to ensure that the TTT was measuring PCK and not solely CK or self-efficacy beliefs. There was a small significance between the Cito and TTT as well as the STEBI and TTT, which was attributed to low internal consistency of the TTT and later adjusted by Rohaan et al. (2011). Due to the small significance, discriminant construct validity could not be affirmed, however content validity was found to be sufficient. Rohaan et al. (2011) suggested using a speak-aloud approach while solving the questions to verify construct validity in future studies. From this research it was found that the TTT could correctly predict teaching behavior and PCK reasoning. The format of the TTT also was less time and labor intensive for researchers than many qualitative approaches. It was concluded that larger samples of teachers could be studied with implications for generalizability using this method.

Hill, Schilling, and Ball (2004) also tried to quantify PCK with their instrument which they titled the Mathematics Knowledge for Teaching (MKT). The MKT used a mixed methods approach through multiple-choice questions regarding mathematical teaching scenarios and interviews to examine participants' thought process regarding their answer selection. The content of the multiple-choice questions were based off of the national mathematics education standards. After the test was piloted, teacher interviews were used to help revise it until the test was readministered to a larger population. Content validity was established by using the national mathematics standards and feedback from the participating teachers. They recommended future studies employ a speak-aloud approach providing participants the opportunity to describe their thought process while selecting an answer. In a follow up study, Hill, Ball, and Schilling (2008) established convergent and discriminant validity of the MKT. They used a series of Likert scale questions that asked teachers to rate how much they learned about certain items that were explicitly taught at the professional development and other outside factors that could have influenced their teaching. A scale of reliability and mean was formed from the answers, establishing construct validity and showing the instrument measured what it was intended to.

Unfortunately the MKT developed by Hill et al. (2004) did not distinguish between CK and PCK, and the effect they had on student achievement. The MKT grouped CK and PCK into one knowledge base required for teaching. Jabot (2002) was able to separate CK and PCK of teachers' and view the effects of each on student learning. He investigated high school physics teachers' PCK about circuits and its connection to their students' achievement using pre and post-test scores. Teachers were given a survey that was the same as the content test administered to the students, except it was modified from a multiple-choice format to open ended questions which correlated with Shulman's (1986) teacher knowledge categories. This format required teachers to explain challenges their students would encounter with the question and also what methods they would employ to help the student understand the concept better. Jabot (2005) found significant student gains at the 0.05 level as a result of high teacher CK, and at the 0.01 level as a result of high teacher PCK. This study showed the significance that PCK had on student learning, more so than CK.

Krauss, Baumert, and Blum (2008) conducted research building on Hill et al.'s (2004) MKT, and like Jabot (2005) aimed to distinguish between CK and PCK. For this purpose, Krauss et al. (2008) created their own instrument (the COACTIV) to better distinguish between CK and PCK questions. During their research they found a correlation between CK and PCK, however each was separable and had a unique dimension. They established construct validity by testing the instrument on contrast populations to see if it accurately measured what it was intended to (e.g., science teachers should score lower on the test than mathematics teachers, and mathematics students should score high on CK but low on PCK knowledge). They validated their construct validity findings by comparing and contrasting them to other researchers (e.g., Hill et al., 2004) findings when administering instruments to contrast populations. Krauss et al. (2008) found it difficult to develop discriminant validity between CK and PCK to purely assess PCK, however they did successfully separate them despite the deep connections between the two. They used the teacher PCK data from the COACTIV instrument to correlate it with students' Program for International Assessment (PISA) scores. For the first time, this allowed for representative large-scale data about the teacher, their lessons, and their students to be analyzed within a common framework (Krauss, 2008). They established convergent construct validity between PCK and PISA scores by accrediting lesson attributes (e.g., classroom management, learning support) as part of the pedagogical skills that help teachers transfer knowledge to students.

In a subsequent longitudinal study, Baumert et al. (2010) used the COACTIV instrument to directly link mathematical teachers' CK and PCK to assessments of instruction and student outcomes. Specifically they investigated the influence that different types of teacher preparation programs have on teachers' CK and PCK, and how it influences student outcomes. Teachers' CK was measured using a paper and pencil test covering a variety of mathematics topics. Their PCK was also measured via paper and pencil items based on their ability to identify multiple solutions, recognize student misconceptions, and provide different representations and explanations of standard mathematics problems. Homework assignments and tests administered by the teachers throughout the year were analyzed for instructional strategies and correspondence with the curriculum. A rating scale was utilized to quantify six measures of instructional quality and classroom management effectiveness. At the end of the school year students mathematics achievement was assessed based on federal states' curriculum test scores, and PISA mathematics literacy scores.

The findings from Baumert et al. (2010) revealed that teachers' CK and PCK scores were highly dependent on the type of teacher preparation program attended. Teachers prepared in a five-year academic track program exhibited increased CK and PCK scores as opposed to their counterparts prepared in a four-year training program. To determine whether CK and PCK leveled out over a teaching career, they examined interactions between certification type and years of service to find that differences continued over an entire teaching career. Baumert et al.'s (2010) study revealed a linear relationship between PCK and mathematics achievement, with 39% of the variance in achievement between classes resulting solely from the variable of PCK. Further exemplifying the distinction between CK and PCK, their research found that PCK influences cognitive levels, curricular levels and learning support of instructional quality, whereas CK was not found to affect cognitive levels. Teachers with higher levels of CK were more able to align material to the curriculum, but higher CK levels had no direct impact on potential for cognitive activation or providing learning support; however, PCK was decisive in both of these cases. In relation to teacher preparation programs they found that compromising on subject matter training (CK) had detrimental effects on PCK, instructional quality, and student progress. They did acknowledge that teaching ability is not solely dependent on CK and PCK, which is consistent with Shulman's (1987) proposal of other teacher knowledge categories.

Baumert et al.'s (2010) research contradicted Hill et al.'s (2004) study by concluding that mathematical knowledge for teaching is not an amalgam of everyday knowledge, but is a specific form of PCK that is highly influenced by the type of teacher preparation program attended. Also, Baumert et al.'s (2010) study reaffirmed Kleickmann et al.'s (2013) findings that PCK and CK vary independently of classroom management, and teacher preparation programs have a significant influence on teachers' PCK. This research revealing separation of CK and PCK from classroom management impacts data collection efforts of future PCK studies by allowing researchers the means to isolate and examine PCK and CK. By exposing the influence teacher preparation programs have on PCK levels, this research provided the rationale to further examine specific preparation experiences of T&E teacher preparation programs and their correlation with science PCK levels.

Methods Outside of STEM Education

Due to the lack of research that exists regarding the PCK of P-12 T&E educators, areas outside of STEM education serve as valuable resources for examining research methodologies and instrumentation. Solomon, Bezdek, and Rosenberg (1963) conducted a mixed methods study investigating the relationship between teaching behavior and adult learning (andragogy). Although this research focused on andragogy, it has many implications for designing and conducting research examining connections between teachers' PCK and student achievement in P-12 Integrative STEM Education. Their study did not specifically mention PCK because it was not introduced yet, however they did assess teacher qualities (e.g. control, clarity, encouraging participation) that could be viewed as pedagogical attributes contributing to a teacher's PCK, just as Krauss et al. (2008) classified lesson attributes (e.g., classroom management) as PCK. Solomon et al. (1963) found it important to study teachers and students in a natural setting to avoid influencing teacher or student behavior. They also recommended viewing multiple teachers that teach the same course or as similar as possible. Currently in T&E education at the secondary level there are two national curriculums, Project Lead the Way (PLTW) and Engineering byDesign (EbD), that would serve as consistent platforms to study the PCK of T&E educators teaching the same content and lessons. Studying teachers using these curriculums would be of benefit to upholding consistency among the study, especially if examining the separate CK and GPK that make up the PCK of a teacher.

This section has revealed that researchers have used various methods (especially qualitative) to capture the PCK of teachers and the effects of quality teaching on student learning. Some of these methods included survey research, case studies, ethnography, classroom observation, and laboratory experimentation (Murray, 2007). These methods are often time consuming to design, implement, and analyze (Baxter & Lederman, 1999). When assessing PCK quantitatively, it is difficult to create robust test items, but quantitative instruments had the capability to assess more participants than qualitative instruments (Rohaan et al., 2009). Hill, Schilling, and Ball's (2004) research found that quantitative approaches of studying PCK helped assess CK in relation to PCK. Qualitative PCK studies have had difficulty accessing teachers within a real classroom environment, although it is possible for researchers to assume a role that is non-intrusive to the teacher and students. Small sample sizes are another delimitation of qualitative studies, although more participants could be researched if there were an adequate number of researchers and time to examine larger samples. Despite its limitations and delimitations presented, qualitative research has provided in-depth analyses of teachers' pedagogical performance and created the framework for future quantitative and qualitative PCK studies (Love, 2013).

Summary of Research on PCK

The research presented on PCK across STEM education and other disciplines shows the breadth of research conducted on the topic. Methodologies and validation of the instruments used in the studies varied, however they all contributed to the knowledge of assessing the PCK of teachers. These studies presented ways to apply PCK research in the classroom, and in many of them, feedback from classroom observations aided in the refinement of studying PCK. Heller et al. (2004) showed the impact that professional development can have on enhancing the PCK of teachers. Hume and Berry (2011) demonstrated the usefulness of instruments such as the CoRe and PaP-eRs to increase the PCK of novice teachers, and Bertram and Loughran (2012) reaffirmed the value of the CoRe and PaP-eRs instruments for practicing teachers. Even methods to study correlations between teacher behavior and student achievement in andragogy (Solomon et al. 1963) were insightful for designing PCK research. Future research, such as this study, is needed to continue promoting the importance and applicability of PCK in contextualized educational settings.

Science education has lead the way in PCK research, but T&E educators can learn much from PCK research in other areas such as mathematics, instructional technology, and andragogy. Developing valid PCK research is critical for T&E education to improve teaching and student learning. With the NAEP TEL assessment released in 2014, T&E education is in a position to show the impact that it has on STEM education student achievement. Looking to increase student NAEP scores will depend on the preparation of T&E teachers and their ability to deliver these content areas in an integrative and relevant manner. PCK's impact on student achievement is an area lacking attention in the literature (Settlage, 2013). Examining how T&E teachers' preparation experiences influence their ability to teach science concepts and impact students'

STEM achievement provides the rationale and foundation for this study. Using some of the methodologies and instruments presented in this section are essential for developing an approach to study the relationship between select preparation experiences of T&E teachers, and their science PCK.

Summary of the Literature Review

Current educational reform calling for the integration of engineering practices in science education (NGSS Lead States, 2014a) and the integration of STEM content taught from a DBL pedagogical approach (ITEA/ITEEA, 2000/2002/2007) warrant the need for research examining how well prepared T&E educators are to teach these content and practices. In addition, the future of the United States' global economic competitiveness relies on STEM education (Larson, 2012) and STEM educators (Mervis, 2011) to prepare STEM literate students. The unveiling of the NAEP TEL assessment in 2014 is a critical component promoting the benefits that T&E education provides to P-12 education in preparing a more STEM literate citizenry.

Integrative STEM Education is not intended to be a new stand-alone subject area with licensure requirements. Due to the amount of CK needed to be an effective teacher in each of the STEM content areas, it is difficult to imagine a teacher preparation program that would prepare pre- and in-service teachers with sufficient STEM content expertise and PCK to effectively teach all STEM subject areas (Sanders, 2009). A solution proposed by Wells (2008) and De Miranda (2008) as the most viable option to teach in an integrative fashion is for T&E educators to collaborate with science and mathematics education teachers. Encouraging T&E educators to branch out and collaborate with other STEM education partners for improved teacher preparation is one of the implications for researching the science PCK of T&E educators (De Miranda, 2008). Due to the extensive amount of CK and PCK needed by teachers to teach all STEM content areas in an integrative fashion, focusing solely on the science PCK of T&E educators seems to be a more feasible approach given the convergent path on which science and T&E education continue to travel.

Shulman's (1987) seven knowledge categories that teachers possess are grounded in the educational theories of Dewey, Vygotsky, and Gagné. Building on Dewey's and Vygotsky's beliefs that teaching and learning are unique to each individual and impacted by society, Shulman's notion of PCK was conceived to call attention to the special blend of content and pedagogical skills teachers possess. Much like a potter has a unique set of skills for molding clay into a work of art, T&E teachers possess a unique set of skills for molding students into technologically literate citizens. Shulman's (1987) notion of teachers possessing a special set of skills is reflected in the literature which shows that teachers are the single largest factor on student achievement in the classroom (Darling-Hammond, 2000; Just for the Kids and The Southeast Center for Teaching Quality, 2002; McCray & Chen, 2012; National Commission on Teaching and America's Future, 1996; Rice, 2003; Rowe, 2004; Willms, 2000; Wright, Horn, & Sanders, 1997). Assessing these skills and the knowledge teachers apply in their daily practice is no easy task: "if a study can be found denying a position on teaching, another can usually be found which confirms it; if no position can be said to be clearly demonstrated, none can be said to be clearly wrong" (Solomon, Bezdek, & Rosenberg, 1963, p. 1). The criticisms of whether PCK exists and how it can be adequately examined demonstrates why there is still much to be learned about it. Specifically, assessing the PCK of teachers, their preparation experiences, and their students' achievement, are no easy task; hence the number of diverse studies that have been conducted on these topics and continue to need further investigation.

Quality teaching and the attributes of quality practice are dynamic notions that vary from each researcher's observations (Clement, 2009). Trying to generalize effective teaching practices for instruction across all subject areas can be problematic since teaching requires topic specific skills. It is evident from the review of literature that there are elements which separate quality teachers and quality practice from novice teachers. These elements span over all of Shulman's (1987) seven categories of knowledge that grow in the mind of teachers. All of the various elements presented are needed for quality instruction and show the complexity of PCK. These elements also highlight the amount of knowledge and skills that teachers must possess in their repertoire to be effective. This review exposed the various factors that must be accounted for when studying PCK, which is what researchers have struggled with for decades.

Based on the literature presented it can also be concluded that there is not one correct pedagogical method or theory for teaching. It has also been determined that not all pedagogical strategies and knowledge of content are observable during a lesson, requiring the use of other methods (e.g. testing, interviews) to investigate these skills. Some teachers may have great pedagogical skills but are unable to identify those skills or their rationale for using them in a particular situation. Furthermore, PCK is based on the premise that good teaching is built up over time and experience (Shulman 2004; Williams & Lockley, 2012). This presents a challenge for researching PCK because the teacher has been practicing at refining their pedagogical skills for so long, that they just act on instinct without having to analyze their actions. This review of literature lays out our current progress and difficulties in attempting to document good pedagogy.

As seen in this review, PCK is very difficult to study because of the dynamics of a classroom, and trying to record pedagogical strategies is even more challenging. The literature revealed a wide array of methods that have been implemented to research PCK. Although there were some methods and instruments that yielded more detailed results than others, no single method or instrument has been identified as the best approach to research PCK. Some would say that it is sufficient to use multiple-choice questions, classroom observations, student portfolios, student test scores, and lesson plans to assess a teacher's level of PCK; while others would argue that open-ended questions and interviews examining underlying strategies not explicitly observable during a lesson are necessary to assess a teacher's level of PCK. Each theory has its strengths and limitations and can only complement each other when implemented together.

From the critiques presented about studying teaching and learning, it has been determined that a mixed methods approach would be best to study the PCK of teachers. This methodology would allow for the analyses of tangible teaching artifacts, as well as unobservable or unmentioned pedagogical strategies through various methods. Student learning would also be difficult to critique, and formal testing may not be the best way to analyze this. Again various methods would have to be employed to tease out information not assessed through formal testing.

In addition to the lack of knowledge regarding PCK and its impact on student learning (Jabot, 2002; Settlage, 2013), teacher preparation factors must be also be studied to examine methods for improving quality of practice. Analyzing teaching is more than assessing student learning outcomes, it also includes analyzing the acts of teaching (Smith, 2002), which is why studying the relationship between the PCK of teachers and their preparation experiences is critical. Few studies have attempted to show the relationship between these factors, none in relation to the ability of T&E educators to teach science. Research in this area is critical at a time when current educational reform and national standards have called for the integration of STEM concepts. This gap in the research provides the rationale and need for this study –

examining the preparation of T&E educators and its impact on their PCK used to enhance student science learning and T&E teacher preparation.

In the next chapter, the research methodology and procedures are described along with the presentation of the research questions and sub-questions. Also presented is information on the participants, instrument, phases of the study, and data collection procedures. Finally, chapter three concludes with a description of the statistical analysis, as well as the validity and reliability of this study.

CHAPTER THREE: RESEARCH METHOD

This chapter describes the method used to conduct the research for this study in the following sections: research design, participants, instruments, data collection procedures, data analysis (quantitative, qualitative, and mixed), and summary. Multiple phases were used to triangulate quantitative and qualitative data from this study (Figure 5).

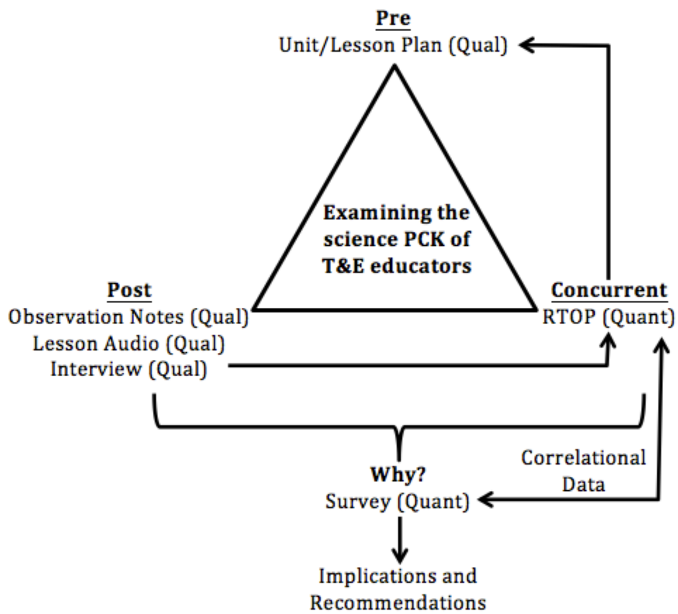

Figure 5. Triangulated mixed methods design for this study.

A fully integrated mixed design (Teddlie & Tashakkori, 2006) was used to answer the two main research questions with their two sub-questions. It featured characteristics of a fully integrated mixed design because quantitative and qualitative strands influenced the conceptualization and inferential stages of the study. Quantitative and qualitative data were collected and analyzed separately for the survey and interviews, however the RTOP converted qualitative observations into quantitative values. This methodology aimed to answer the following research questions and sub-questions guiding this study:

RQ1 – To what extent do select teacher preparation factors inform in-service secondary level technology and engineering (T&E) educators how to teach *science* ***content*** in T&E education classrooms?

In the context of teaching the Foundations of Technology (FoT) unit of the Engineering byDesign (EbD) curriculum:

RQ1, SQ1- To what extent do select *science-related* preparation experiences inform in-service secondary level T&E educators how to *teach science content* embedded within the FoT unit?

RQ1, SQ2- To what extent do select *T&E-related* preparation experiences inform in-service secondary level T&E educators how to *teach science content* embedded within the FoT unit?

RQ2 – To what extent do select teacher preparation factors inform in-service secondary level T&E educators how to teach *science* ***practices*** in T&E education classrooms?

In the context of teaching the Foundations of Technology (FoT) unit of the Engineering byDesign (EbD) curriculum:

RQ1, SQ1- To what extent do select *science-related* preparation experiences inform in-service secondary level T&E educators how to *teach science practices* embedded within the FoT unit?

RQ2, SQ2- To what extent do select *T&E-related* preparation experiences inform in-service secondary level T&E educators how to *teach science practices* embedded within the FoT unit?

Research Design

This study examined select T&E and science preparation experiences of T&E educators, and the relationship between those experiences and how they informed the teaching of content and practices. The fully integrated mixed design used for this study involved the administration of the T&E Educators' Science PCK (TEES-PCK) instrument. The TEES-PCK is an adapted survey from a amalgam of PCK instruments to collect participant self-efficacy data using the Science Teaching Efficacy Belief Instrument (STEBI) by Riggs and Enochs (1990), and preparation experiences and demographic data (Ball & Hill, 2008; Cwik, 2012; Perez, 2013). For classroom observations the Reformed Teaching Observation Protocol (RTOP) instrument by

Sawada et al. (2000) was adapted for this study to measure pedagogical practices and teaching of content in both T&E and science. Additionally, the PCK interview questions from Park, Jang, Chen, and Jung (2011) were adapted to help corroborate the observed teaching strategies recorded using the RTOP.

The dependent variable of this study was the science PCK of T&E educators needed to teach the FoT curriculum. To measure the dependent variable, this study used the TEES-PCK instrument, RTOP, observation notes, FoT lesson plans, audio recordings of the lessons, and interview questions to investigate preparation experiences with the potential to influence how T&E educators teach science content and practices embedded within the FoT curriculum.

The independent variables (predictors) in this study were: the select science and T&E education preparation experiences of T&E educators that inform the strategies they use to teach science content and practices. Table 3 presents the alignment between the research questions and sub-questions, data sources, and the methodologies used in analyzing those data.

Table 3

Alignment Between Research Questions, Data Sources, and Analysis Procedures

Question	Data Collection Method	Data Analysis
Research Question 1		
To what extent do select teacher preparation factors inform in-service secondary level technology and engineering (T&E) educators how to teach *science content* in T&E education classrooms?		

(continued)

Table 3 Continued

Question	Data Collection Method	Data Analysis

SQ1.1- To what extent do select *science-related* preparation experiences inform in-service secondary level T&E educators how to *teach science content* embedded within the FoT unit?	<u>Quantitative</u>
	• Survey (TEES-PCK)
	  • STEBI (Section 2)
	  • Preparation Experiences (Sections 3-7)
	  • Demographic Information (Section 8)
	  • RTOP (Section IV)
		• Spearman's rho
		  • Survey (TEES-PCK) (Sections 2-8)
		  • RTOP (Section IV)

	<u>Qualitative</u> • Interview • Questions 8b and 8c • Observation notes • Observation audio recordings • FoT lesson plans	• Corroborative Analyses

SQ1.2- To what extent do select *T&E-related* preparation experiences inform in-service secondary level T&E educators how to *teach science content* embedded within the FoT unit?	<u>Quantitative</u>
	• Survey (TEES-PCK)
	  • STEBI (Section 2)
	  • Preparation Experiences (Sections 3-7)
	  • Demographic Information (Section 8)
	  • RTOP
		• Spearman's rho
		  • Survey (TEES-PCK) (Sections 2-8)
		  • RTOP (Section IV)

	<u>Qualitative</u> • Interview • Questions 8a and 8c • Observation notes • Observation audio recordings • FoT lesson plans	• Corroborative Analyses

(continued)

Table 3 Continued

Question	Data Collection Method	Data Analysis
Research Question 2 To what extent do select teacher preparation factors inform in-service secondary level T&E educators how to teach *science practices* in T&E education classrooms?		

SQ2.1- To what extent do select *science-related* preparation experiences inform in-service secondary level T&E educators how to *teach science practices* embedded within the FoT unit?	Quantitative
	• Survey (TEES-PCK)
	  • STEBI (Section 2)
	  • Preparation Experiences (Sections 3-7)
	  • Demographic Information (Section 8)
	  • RTOP
		• Spearman's rho
		  • Survey (TEES-PCK) Sections 2-8.
		  • RTOP (Section IV)

	Qualitative • Interview • Questions 8b, 8c, and 10 • Observation notes • Observation audio recordings • FoT lesson plans	• Corroborative Analyses

SQ2.2- To what extent do select *T&E-related* preparation experiences inform in-service secondary level T&E educators how to *teach science practices* embedded within the FoT unit?	Quantitative
	• Survey (TEES-PCK)
	  • STEBI (Section 2)
	  • Preparation Experiences (Sections 3-7)
	  • Demographic Information (Section 8)
	  • RTOP
		• Spearman's rho
		  • Survey (TEES-PCK) Sections 2-8.
		  • RTOP (Section IV)

	Qualitative • Interview • Questions 8a and 9 • Observation notes • Observation audio recordings • FoT lesson plans	• Corroborative Analyses

Participants

The participants in this study consisted of practicing high school educators currently teaching the FoT curriculum in an EbD consortium state. Methods to recruit and select participants were informed by a pilot study conducted with 25 teachers across six school systems during the spring of 2014. All educators teaching FoT at agreement schools in the state during the fall of 2014, and whose school system granted approval to conduct research were invited to participate in the survey portion of this study. The consortium state was purposefully selected due to its large population of FoT schools with signed agreements to implement the curriculum with fidelity. This state also has the largest sample of FoT teachers and agreement schools in the United States (Rhine, 2013), making it a logical choice to acquire the largest possible sample size and address Abel's (2008) criticism regarding small sample sizes in PCK studies. At the time of the survey there were approximately 662 FoT teachers within the state (Rhine, 2013), 233 teachers were sent email invitations to participate in the survey following approval from the county boards of education (Appendix D). Fifty-five teachers from 12 school systems provided complete responses to the online survey, resulting in a 24% (55/233) response rate.

Following the analysis of survey results, eight teachers were selected for classroom observations and interviews based upon their reported teacher preparation experiences. The eight participants were purposefully selected to cover a spectrum of experience levels (from novice to veteran) since research has shown teaching experience to be a key factor contributing to PCK levels (Shulman & Hutchings, 2004; Williams & Lockley, 2012). One method to ensure participants with varying levels of PCK are selected is to separate them into three categories (novice, intermediate, and veteran) as dictated by the median and quartiles of their reported years of teaching experience. Next the mode response for each question was identified according to the three teaching experience categories. Based on these mode values, participants' responses to each question were rated low, average, or high among teachers in their category. From this teachers with unique characteristics for each category were identified and selected to participate in the observation and interview portion of the study (Appendix H).

This selection of participants provided a sufficient sample size for the observations and interviews based on qualitative methodology research, which found that three to five participants are adequate for qualitative studies (Collins, Onwuegbuzie, & Jiao, 2007; Creswell, 2002; Onwuegbuzie & Leech, 2005). Additionally, numerous qualitative PCK studies (Aydin & Boz, 2013; Brown, Friedrichsen & Abell, 2013; Hynes, 2009, 2012; Hynes, Crismond, & Brizuela, 2010; Jones & Moreland, 2004; Williams, 2012; Williams et al., 2012; Williams & Lockley, 2012) have found sample sizes of five or less ample for data analysis. Specifically in T&E education, Hynes (2009, 2012) conducted qualitative studies examining the PCK of six teachers using the Project Lead the Way curriculum, and Williams et al. (2012) investigated the science and technology PCK of four teachers through interview, observation, and document analyses.

Instruments

Three main instruments were used to gather data investigating the research questions posed by this study. Quantitative and qualitative instruments were mixed during their development and data analyses to strengthen the validity of the findings. The quantitative TEES-PCK survey provided a broad picture of the self-efficacy and preparation experiences of FoT teachers across the state, while the quantitative RTOP instrument and qualitative interview questions provided in-depth analyses of teaching practices and preparation experiences. The next section describes the pilot study that was used to validate the instruments.

Pilot Study

To establish the reliability and validity of the TEES-PCK instrument, two methods were applied: (1) a review by a panel of experts, and (2) a pilot study involving a small sample of T&E educators. The final TEES-PCK administered in the pilot study was reviewed by the panel of higher education faculty members with expertise in T&E education, teacher preparation, and teacher evaluation, to substantiate the construct validity of the survey. Once the content and format of the TEES-PCK survey instrument was established, it was converted into a digital version and formatted for the Qualtrics survey software. It was then sent out for a small sample of Integrative STEM Education graduate students and practicing teachers to evaluate the online format and wording of the questions.

In April 2014 the online link to the TEES-PCK survey was emailed to the 23 FoT teachers at agreement schools in the consortium state as identified by the state supervisor for T&E education. A reminder email was sent out the following week and closed the week after that, resulting in 13 total teachers who completed the survey. This yielded a 57% response rate (13/23). Results were analyzed to assess the instrument reliability to assure that the items measured what they intended to measure. A few minor formatting changes were made to make the survey more reader friendly and to provide more categories to accommodate participant responses. In May 2014 the researcher conducted classroom observations and interviews with six of the pilot study survey participants at their schools and the data was analyzed.

An accumulation of this feedback, along with the results from the pilot study, were taken into account when analyzing the data. The researcher and panel of experts used these analyses to inform the following revisions to the instruments and data collection procedures: (a)Remove unnecessary survey questions, (b) Operationally define and specify rating criteria used in the

RTOP, (c) Modify the RTOP to have separate sections to assess content and practices of both T&E and science, and (d) Adapt interview questions to focus on specific parts of the lesson and teaching strategies. All of these data sources helped to increase the validity and reliability of the study and allowed the researcher to confidently move forward with data collection using a larger sample from the rest of the state. Each instrument is described in greater detail in the subsequent sections.

Survey

The TEES-PCK survey is an amalgam of four different instruments (Ball & Hill, 2008; Cwik, 2012; Perez, 2013; Riggs & Enochs, 1990) blended together specifically to collect participant self-efficacy, preparation, and demographic data. These data were used to distinguish key independent variables informing the teaching strategies used by T&E educators to teach science content and practices. The TEES-PCK survey instrument (Appendix G) consisted of eight sections. Section 1 was used strictly to collect identifying information to allow the researcher to contact teachers for selection of the classroom observation and interview. This information was removed from the data set and replaced with a numbering system for confidentiality reasons. In Section 2 self-efficacy questions about the teachers' beliefs regarding their preparation to teach T&E education were asked which were adapted from the STEBI. Section 3 sought to gather information about the teachers' background which led them into teaching. Sections 4 and 5 were designed to collect data regarding participant undergraduate and graduate education experiences that could impact their teaching. In Sections 6 and 7 data regarding informal preparation experiences that could contribute to their teaching of science within T&E were collected, and Section 8 collected participant demographic data. The following sections present a more detailed description of all eight sections of the TEES-PCK instrument.

Self-efficacy data. The second section of the TEES-PCK instrument was used to collect data regarding the self-efficacy of FoT teachers toward teaching T&E. For the purpose of this study the STEBI instrument by Riggs and Enochs (1990) was adapted to measure their self-efficacy in the context of T&E education. It measured the dependent variable (the science PCK of T&E educators needed to teach the FoT curriculum) regarding how confident teachers were in teaching T&E education with its embedded science concepts, and to what extent it impacted the level of their PCK. Riggs and Enochs (1990) found that beliefs regarding certain information a person considers to be true can impact their teaching. Specifically they found that a teacher "judges his/her ability to be lacking in science (belief) and consequently develops a dislike for science teaching (attitude). The result is a teacher who avoids teaching science if at all possible (behavior)" (pp. 625-626). This rationale aligned with one of the goals of this study, examining to what extent T&E educators' informal and formal preparation experiences supported their teaching of science content and practices. The STEBI was developed based on two of Bandura's beliefs: (1) Personal Science Teaching Efficacy Beliefs (PSTE), and (2) Science Teaching Outcome Expectancy (STOE). This 25 item instrument (13 PSTE items and 12 STOE items) utilized a nominal five point Likert scale (5="strongly agree" to 1="strongly disagree"), with negatively worded items reversed scored to produce high scores for those high and low scores for those low in efficacy and outcome beliefs (Riggs & Enochs, 1990). The answers from the STEBI produced a possible sum of 13-65 for the PSTE items and 12-60 for the STOE items, with greater sums representing higher efficacy or expectancy. Riggs and Enochs (1990) found the PSTE scale (α=0.91) and the STOE scale (α=0.73) of the STEBI to have a high reliability in correlation with their own scales. Bleicher (2004) later reexamined the validity and reliability of the STEBI, also finding that the PSTE (α=0.87) and STOE (α=0.72) had high reliability coefficients, upholding the integrity of the STEBI scales.

The STEBI was originally designed to determine the science teaching self-efficacy of elementary teachers, but has been adapted and validated for use at various grade levels and in various disciplines, such as the Mathematics Teaching Efficacy Beliefs Instrument (Enochs, Smith, & Huinker, 2000). Rohaan et al. (2009, 2011) adapted the PSTE questions from the STEBI and found them to be reliable (α=0.91) for measuring self-efficacy of teaching technology (as defined by ITEA/ITEEA [2000/2002/2007]), and also for use in their multiple-choice PCK instrument. Rohaan et al. (2011) found a small correlation between teachers' scores on the STEBI and their scores on their multiple-choice PCK test. For the reasons mentioned above, it was determined that the STEBI was suitable to help measure associations between select preparation factors and the PCK of FoT teachers. The reliability of the adapted STEBI questions used in the TEES-PCK was found by using the SPSS software to conduct measures of internal consistency tests for Cronbach's alpha on the major study sample (n=55). These analyses helped to determine if all questions in the two sections were a reliable measure the targeted variable (teacher efficacy for the PSTE questions, and outcome expectancy for the STOE questions). They revealed a high reliability value for the PSTE (α=.883) items and an acceptable reliability for the STOE (α=.652) questions.

Teacher preparation experiences data. Sections 3 through 5 were designed to gather data pertaining to the teachers' formal and informal preparation experiences. In Section 3 there were four sets of questions examining their high school T&E and science courses taken, their path into teaching and any previous careers, and the level and area of any degrees they held.

Section 4 targeted the teachers' undergraduate preparation experiences (types and number of courses taken in science, T&E, mathematics, and teaching methods), while Section 5 researched their graduate preparation experiences (types and number of courses beyond undergraduate coursework in science, T&E, mathematics, teaching methods, and Interdisciplinary STEM education) to better understand their formal preparation. These sections collect data to allow for examination of the dependent variable (the science PCK of the T&E educators needed to teach the FoT curriculum) by measuring the relationship between select formal preparation factors and their science PCK. Some of these questions were self-generated, while others were adapted from PCK survey instrument questions by Ball and Hill (2008), Cwik (2012), and Perez (2013) (Appendix G). They were vetted by a panel of higher education faculty members with expertise in T&E education, teacher preparation, and teacher evaluation prior to testing them through the pilot study.

Informal preparation experiences data. The sixth and seventh sections were used to collect data regarding teachers' non-collaborative and collaborative preparation experiences. Section 6 included questions about clubs and activities, readings, and professional development activities related to science and T&E education. In Section 7 the questions collected data regarding teachers participation in school activities, committees, collaborative professional development and school activities, and conferences related to science and T&E education. These sections also collect data to investigate the dependent variable, but investigated the relationship between select informal preparation factors and the science PCK of T&E educators. As with Sections 3 through 5, some of these questions were self-generated and some were adapted from PCK survey instruments by Ball and Hill (2008), Cwik (2012), and Perez (2013) (Appendix G).

The questions in this section were also vetted by the panel, and evaluated through implementation of a pilot study.

Demographic data. Section 8 of the TEES-PCK instrument was designed to collect demographic data regarding six areas: (a) general data (gender, ethnicity, and age), (b) background data (childhood settings), (c) school system employment setting data, (d) teaching experience data (years of teaching, and content areas taught in), (e) certification data (areas teaching certifications are held), and (d) FoT experience (years of teaching FoT, and length of FoT training attended). In total, 13 demographic items (Table 4) collected data regarding these topic areas. Most of these demographic questions were self-generated with a few adapted from the Perez (2013) PCK survey (Appendix G).

Table 4

Sections and Data Types Collected from Participants in the TEES-PCK

Section	Data Type(s)
1. Contact Info	1.1-1.2 Name and school email address
2. Self-Efficacy	2.1 STEBI - Beliefs about ability to teach T&E concepts
3. Teacher Preparation Experiences	3.1 High school courses completed 3.2 Path into teaching 3.3-3.4 Degrees held
4. Undergraduate Preparation	4.1 Types and number of science courses completed 4.2 Types and number of T&E courses completed 4.3 Types and number of math courses completed 4.4 Types and number of education courses completed

(continued)

Table 4 Continued

Section	Data Type(s)
5. Graduate Preparation	5.1 Types and number of science courses completed 5.2 Types and number of T&E courses completed 5.3 Types and number of math courses completed 5.4 Types and number of education courses completed 5.5 Interdisciplinary STEM higher education courses taken
6. Informal Non-Collaborative preparation	6.1 Clubs and activities involved with 6.2 Engagement in independent Readings 6.3 Interdisciplinary STEM Professional Development (PD) 6.4 Technology education PD
7. Informal Collaborative preparation	7.1-7.2 Types and amounts of activities or committees 7.3 Interdisciplinary STEM PD 7.4 Technology education PD 7.5-7.6 Types of conferences and sessions attended 7.7 Amount of collaboration with other subject areas
8. Demographics	8.1-8.3 Gender, ethnicity, and age 8.4 Childhood Background (Setting[s] grew up in) 8.5-8.7 Years taught in different settings 8.8-8.10 Years and areas of teaching experience 8.11 Certification areas 8.12 Years of teaching FoT 8.13 Length of FoT training attended

RTOP

The RTOP from Sawada et al. (2000) was selected to provide a valid and reliable instrument that could help document the science PCK teachers exhibited during a lesson. The RTOP was designed, piloted, and validated by the Evaluation Facilitation Group of the Arizona Collaborative for Excellence in the Preparation of Teachers (ACEPT). It was designed as an observational instrument to measure reformed teaching of mathematics and science. However various studies (Lomas & Nicholas, 2009; Ogletree, 2007; Park et al., 2011) have used it in conjunction with other instruments to measure the PCK levels of teachers. It is theoretically grounded in constructivism, which is reflected in the characteristics of PCK as discussed in Chapter 2. The RTOP is divided into five sub-scales: 1) Background Information 2) Contextual Background and Activities 3) Lesson Design and Implementation 4) Content (divided into Propositional Knowledge and Procedural Knowledge), and 5) Classroom Culture (divided into Communicative Interactions and Student/Teacher Relationships). The first two sections collect observational notes, demographic data, and information about the classroom environment. The other three sections are comprised of 25 items using a five-point nominal Likert scale ranging from 0 (not observed) to 4 (very descriptive). Lomas and Nicholas (2009) found the fourth section about content able to assess the PCK of a teacher:

> They assess the teacher's understanding of the key concept(s) that they are endeavoring to help the students learn, the possible misconceptions that the students might possess, and ways to help them overcome them. It also takes into consideration the teacher's ability to contextualize the lesson by, where appropriate, making connections with other disciplines and real-life situations. (p. 191)

To better examine each research question in this study, sub scale 4 was modified with help from experts in teacher evaluation, science education, and T&E education to accurately reflect the propositional (content) knowledge of T&E and science, and the procedural (practices) knowledge of T&E and science. This also allowed the data to remain consistent with the language and teaching strategies proposed by the NGSS. These modifications entailed duplicating sub scale 4, creating two similar yet separate sub scales to score teaching of both T&E and science content and practices, and replacing the words "subject matter" and "concepts" with “content” (Appendix I). This also allowed the researcher to better distinguish between teacher’s content knowledge and general pedagogical knowledge during observations (Shulman, 1987). Additionally, terms from the RTOP were operationally defined for clarity of what was being observed, and a rubric for each of the sub scale 4 criteria was created to help provide more consistent scoring (Appendix J).

The fifth section assesses the classroom culture or climate, and the effectiveness of communication that is evident within the classroom. Sawada et al. (2000) tested the reliability of the entire RTOP through interrater reliability of physics and mathematics classroom observations (r^2=.954, p<.01) and also by internal consistency (Cronbach’s α=.97). Face validity was based on the following national mathematics and science standards documents:

- National Council of Teachers of Mathematics. *Curriculum and Evaluation Standards* (NCTM, 1989), *Professional Teaching Standards* (NCTM, 1991), and *Assessment Standards* (NCTM, 1995).
- National Academy of Science, National Research Council. *National Science Education Standards* (1996).
- AAAS, Project 2061. *Science for All Americans* (1989), *Benchmarks for Scientific Literacy*, (1993).

The RTOP was deemed adequate for this study based on its use by Taylor et al. (2013) to measure teacher practice and its alignment with recommendations for research-based instructional reform as described in national science standards documents such as the NGSS. They determined construct validity by examining the reliability of the five sub-scales as a predictor of the overall reliability score. Four of the subscales were determined to be very good predictors (r^2=.941 and above) and one was found to be a good predictor (r^2=.769), supporting the validity of the questions that make up the RTOP. Predictive validity was established by comparing content pre and posttests of instructors who attended ACEPT workshops with those who did not attend any workshops.

Lomas and Nicholas (2009) found it adequate to use the RTOP for a single classroom observation (about an hour) for each teacher. They trained one observer to use the RTOP, and due to similar time and funding limitations of the Lomas and Nicholas study, the researcher of this study would be the sole observer to rate teachers during the classroom observations. He and two science and T&E education experts learned how to use the RTOP from an online training module (Buffalo State University of New York, 2007). This module required the raters to view videos of science lessons and rate the teachers using the RTOP. At the completion of each video the researchers' ratings would be compared with the ratings from the module. Following this training of how to use the RTOP, the researcher and two experts practiced using it to rate two filmed T&E education lessons. Ratings were compared and arbitrated until consensus was met, which helped to establish an acceptable level of interrater reliability. A more detailed explanation of the procedures used to develop interrater reliability are described in Chapter 4. From the RTOP, teacher PCK levels were reported as quantitative measures and are described in the data analysis section of this chapter.

Interview Questions

Interview questions developed by Park et al. (2011) were adapted for the specific purpose of teaching science content and practices within T&E education. Park et al. generated the original PCK interview instrument to examine the correlation between the PCK level of a teacher and the degree to which their classroom is reform oriented. This provides the rationale for why they also selected the RTOP instrument to examine the PCK of teachers. The interview instrument included questions that sought further detail from the RTOP regarding preparation and pedagogical experiences. To address the research questions of this study, the interview questions were adapted to ask about science experiences and T&E experiences that may inform T&E educators how to teach science content and practices. In addition to asking about their preparation experiences, the interview questions further examined the rationale for what was taught during the observed lesson in comparison to what was called for by the FoT lesson plan. Since the interview questions already aligned well with the RTOP, the researcher and panel of experts revised the questions to also provide more detail about the items in the TEES-PCK survey. This triangulation between the TEES-PCK survey, the RTOP, and the interview questions provided a mixing of quantitative and qualitative instruments during the design (Teddlie & Tashakkori, 2006) of the survey items and interview questions. Interview questions were carefully crafted to address RTOP and survey items which required more detailed data to examine associations between participants' preparation factors and their PCK levels. After testing the interview questions in the pilot study and analyzing the data, they were revised one final time to ensure that they collected the detailed information required to answer the research questions and sub-questions of this study (Appendix L).

Data Collection Procedures

The data collection procedures used in this study are as follows: IRB approval obtained, emails sent to the school systems requesting permission to conduct research and contact teachers, emails sent inviting teachers to participate in the survey, participant data collected from completed surveys, emails sent asking selected teachers to voluntarily participate in a classroom observation and a post lesson interview, and participant data collected from observations and interviews.

Upon receiving approval from the Board of Human Subjects at Virginia Tech in March 2014 to conduct this study (Appendix A), a request email asking for the names and email addresses of FoT teachers at agreement schools was sent to the state supervisor of T&E education. They agreed to assist by forwarding the survey invitation letter to the 24 school system supervisors in the state, and the T&E school system supervisors forwarded the invitation letter to the teachers in their respective areas. The survey invitation letter provided a brief introduction about the researcher, the study, directions to complete the survey, a link to the online survey, and contact information for questions (Appendix D). A follow up email was sent seven days following the initial email to encourage participation. On October 1, 2014 data collection from the survey was closed and the data was imported into the SPSS software to analyze for median and quartile ranges to separate participants into experience categories as described in the participant section. Prior to the observation the power and energy and troubleshooting units from the FoT curriculum were selected for the lessons that would be observed due to the amount of science content identified in the lessons. The data from the FoT lesson plans, observation field notes, observation audio transcriptions, and interview questions were entered into separate Microsoft Word tables for qualitative analysis.

Quantitative data (self-efficacy, preparation, and demographic data) were collected by administering the TEES-PCK instrument online via Qualtrics, and PCK levels were generated from the RTOP. Qualitative data were collected from teachers prior to the observation (FoT lesson plan, and interview questions 1 and 2), during the observation (observation notes, observation audio tape), and following the observation (interview questions 3-10, observation transcriptions). Quantitative data were analyzed using descriptive statistics to identify differences among participants according to the median and quartile ranges of each experience category, and the mode of every survey item for each category. The FoT lesson plans were qualitatively analyzed using content analysis to identify key science and T&E content (Vaismoradi, Turunen, & Bondas, 2013). Content analysis is a qualitative method used to describe characteristics that emerge from the content of a document (Bloor & Wood, 2006). The observation notes, audio recordings, and interview responses were analyzed using corroborative analyses to validate what was observed during the lesson according to what was expected from the lesson content analysis. Following the quantitative and qualitative data analyses, Spearman's rho analyses were performed to examine the level of association between two variables: teacher preparation factors reported in the survey and levels of PCK as recorded using the RTOP. The following sections of this chapter describe the instruments, procedures followed during data collection and analysis, and limitations and delimitations.

Data Analyses

Quantitative Analyses

The TEES-PCK survey utilized a variety of survey question formats. The adapted STEBI in Section 2 used a 5 point Likert scale where 25 items collected data regarding teachers' T&E teaching self-efficacy. Sections 3 through 7 used questions with one choice, multiple choices, and self entered data to collect information about teachers' background and preparation experiences. Lastly, Section 8 utilized 13 items to collect demographic data about the participants, their childhood experiences, and their teaching background. All of the above data was used as the independent variable, aiding with answering the research sub-questions. Descriptive statistics were used to analyze the mode for each survey question among the teacher preparation experience categories. Following these analyses, the data were tested with the mixed observation data. Spearman's rho tests were used to determine if an identifiable relationship existed between teachers' unique preparation experiences and their level of PCK.

Qualitative Analyses

For the interview data collection, the adapted interview questions by Park et al. (2011) were used. Participants' responses were audio recorded to aid with later qualitative analysis of the interviews. The interview occurred directly after the lesson in the teachers' classroom or office if their schedule allowed, and lasted approximately 30 minutes. Participants were not limited to responding to only the criteria asked in the questions, but were allowed to elaborate on the topic as they saw fit. This contributed to the corroborative analyses of the teachers' preparation and PCK experiences that emerged from the interview data. Interview responses provided more in-depth data regarding personal preparation experiences, which may not have been fully drawn out from the survey. Obtaining more detailed information from the interview questions allowed the researcher to verify what he observed in the lesson.

In addition to the interviews, the lesson plans for the FoT energy and power unit were provided by ITEEA prior to the observations. The lesson plans were analyzed using a content analysis method (Vaismoradi, Turunen, & Bondas, 2013) to identify the key science and T&E concepts that should be emphasized when teaching this unit as specified by ITEEA (Appendix E). Additionally, field notes were taken on the pedagogical methods along with interactions that occurred between students, and the teacher and students during the observed lesson. These field notes were separately analyzed using corroborative analysis. These qualitative analyses were then corroborated with all other data sources (TEES-PCK and RTOP) resulting in a mixed analysis of quantitative and qualitative data. These various forms of data were mixed at the design and analyses stages to elicit more detail about the PCK of T&E teachers, and factors that inform how they teach science.

Mixed Analyses

Data collection for the eight observations was conducted during a lesson at the selected teachers' classrooms or laboratories. After obtaining verbal and written consent to conduct the observation and interview, the researcher sat in the back of the classroom as a non-participating observer. The lesson was also audio recorded for later analysis. During this time the researcher took field notes about different pedagogical approaches, student interactions, and notable quotations by the teacher and students. The modified RTOP (Sawada et al., 2000) was used to quantify five aspects related to the teaching of T&E and science content and practices (background information, contextual background and activities, lesson design and implementation, content [propositional and procedural], and classroom culture [communicative interactions and student/teacher relationships]). Teaching strategies from the observations were recorded for 35 items using the modified RTOP five-point nominal Likert scale, ranging from 0 (not observed) to 4 (very descriptive) with total scores ranging from 0-140. These scores were then triangulated with TEES-PCK items and significant content identified in the FoT lesson plans, field notes, observation audio files, and interviews to determine the extent of the relationship between certain preparation factors and the PCK level of T&E educators (Figure 5). Triangulation occurred through constant comparison (Glaser, 1965) among each teacher's TEES-PCK preparation data, sectional RTOP ratings, field notes, and interview responses. This triangulation of data provided a snapshot of the science PCK of each teacher observed, and findings were compared across cases (teachers). Additionally, select items from the TEES-PCK were analyzed with the RTOP ratings using Spearman's rho tests to examine the level of association between certain preparation factors and the science PCK of T&E educators.

Summary of the Research Method

To answer the research questions and sub-questions, the data collected from the TEES-PCK, FoT lesson plans, observation transcriptions, field notes, and interviews were examined separately using descriptive statistics, content analysis, corroborative analyses, and also mixed using Spearman's rho tests. These data collection methods helped examine one dependent variable and multiple independent variables that could contribute to the preparation factors that inform T&E educators how to teach science content and practices. Findings from these data analyses are described in further detail in Chapter 4.

CHAPTER FOUR: FINDINGS

This chapter presents the results of data analyses from the online TEES-PCK survey, classroom observations, and interview questions. Quantitative data addressing Sections 2 through 8 of the TEES-PCK survey (Appendix G) were mixed with the qualitative data collected from the classroom observations and interviews. Mixing of these data occurred at the analysis phase using statistical and corroborative data analyses to gain a richer understanding of teachers' preparation experiences.

This chapter opens with a description of the pilot study used to establish instrument reliability, followed by a presentation of findings from the main study regarding participant demographics, characteristics, and teaching strategies. Additionally, findings from statistical and corroborative analyses of each research sub-question are provided.

Instrumentation

Pilot Study

A pilot study using teachers from a Mid-Atlantic state was deemed necessary to develop reliability of the instruments and allow the researcher to gain experience using them prior to the main study. The results from the TEES-PCK survey in the pilot study were later included with results of the main study. The pilot study helped to modify the interview questions so they were more focused on the research questions. From the pilot study it was determined that the PSTE survey items had high reliability (α=.885) while the STOE items had acceptable reliability (α=.650), and all sections of the modified RTOP revealed adequate interrater reliability, giving the researcher the confidence to continue using them for analysis. Most importantly, the data analyzed from the pilot study determined the instruments were sufficient for collecting reliable data to answer the research questions and sub-questions. At this point the researcher felt confident that data collected from the TEES-PCK survey, classroom observations, and interviews would be reliable for the analyses explained in Chapter 3.

The TEES-PCK instrument was comprised of an amalgam of questions from four survey instruments by Riggs and Enochs (1990), Ball and Hill (2008), Cwik (2012), and Perez (2013) that were modified to fit the need of this study. It was administered online via Qualtrics survey software to collect teacher data in the following areas: self-efficacy, formal and informal preparation experiences, and general demographics.

RTOP interrater reliability. As mentioned in Chapter 3, the RTOP was modified to rate the teaching of science and T&E content and practices (Appendix I, Modified Section 4 of the RTOP Instrument), and was utilized in a pilot study to help the researcher gain more experience using the instrument while also increasing its reliability. Other experts demonstrated their ability to independently rate the same as the researcher, therefore establishing instrument reliability to ensure the researcher was prepared to independently use the modified RTOP for similar FoT lessons. For this study interrater reliability was established by video taping two FoT lessons from the same units as those used during the data collection. The researcher conducted a training session with two other individuals having expertise in Integrative STEM Education teaching practices to discuss how to use the modified RTOP. All of the raters had completed the online RTOP tutorials (Buffalo State University of New York, 2007), and one rater who had experience as both a science educator and T&E educator, had previously used the original RTOP in science and T&E classrooms.

The three raters separately analyzed one of the FoT lesson videos and submitted their scores to the researcher. The researcher then calculated the interrater reliability agreement among each rater using a percent agreement (the ratio of the number of items raters agree on divided by the total number of items, and then multiplied by 100) for the first items (1, 6, 11, 16, 21, 26, 31) of each modified RTOP sections, which was 10% of the instrument items. Calculations determined the interrater agreement to be 60% for the first round (Table 5). The researcher facilitated an arbitration of the items differing in score by allowing each rater to state the rationale for their score. After each rater presented their rationale the researcher drew conclusions based on commonalities voiced among the raters and presented these conclusions to the group. Any final discrepancies the raters had were allowed to be shared before the group agreed on scores and how to use the rating criteria for each item. This process was repeated to score the second items (2, 7, 12, 17, 22, 27, 32) of each of the modified RTOP sections (an additional 10%), resulting in a 56% agreement. Again an arbitration of the differing scores was facilitated by the researcher until a consensus was met. Since the interrater percentage decreased the second round, the researcher decided to facilitate discussions about the rest of the RTOP items among the raters. The remaining items were discussed according to section until a consensus on the interpretation of items within the rubric was reached.

After gaining experience using the modified RTOP to rate a FoT lesson, the raters analyzed a second FoT lesson and submitted their scores to the researcher. Following the same protocol used to rate the first lesson, the research facilitated an arbitration of the first 10% of the RTOP items which resulted in an agreement of 71%. The second items of each modified RTOP section (an additional 10% of the instrument) resulted in an interrater agreement of 90% and again an arbitration of these items was led by the researcher. Since the raters had reached an overall agreement level above the 80% threshold for reliability preferred by Howell (2007), they separately coded the remaining 80% of the RTOP criterion and submitted to the researcher for comparison. He then facilitated the arbitration of these items (Appendix L), resulting in an interrater agreement of 83% for round 3 (Table 5).

Table 5

RTOP Interrater Reliability Percentage Established Among Raters

	Observation 1				Observation 2			
Round	Rater 1 (%)	Rater 2 (%)	Rater 3 (%)	Total (%)	Rater 1 (%)	Rater 2 (%)	Rater 3 (%)	Total (%)
1	80	60	40	60	100	57	57	71
2	67	50	50	56	100	86	86	90
3	-	-	-	-	86	90	71	83

Note: Rounds 1 and 2 each analyzed 10% of the RTOP items; Round 3 analyzed the remaining 80% of the RTOP items; Total was the percent agreement among all raters by round.

Since the interrater agreement for round 3 was above 80% the RTOP instrument was deemed reliable for scoring a FoT lesson according to Howell (2007). The arbitration process described above influenced the way to score each item on the previously modified RTOP, but did not result in any changes to the instrument items. The researcher used the modified RTOP at the completion of each school visit to rate observed teaching strategies. To ensure the ratings were as accurate as possible the research completed the RTOP immediately after the lesson and interview while still knowledgeable about what was observed. Within 48 hours the researcher reviewed the lesson audio and the interview responses to confirm or adjust the ratings for accuracy. Once all observations were completed, they were again reanalyzed via the audio recordings and notes to ensure consistency across all observation ratings.

Main Study

Research Questions

The two main research questions with their two sub-questions that guided this study were:

RQ1 – To what extent do select teacher preparation factors inform in-service secondary level technology and engineering (T&E) educators how to teach *science **content*** in T&E education classrooms?

In the context of teaching the Foundations of Technology (FoT) unit of the Engineering byDesign (EbD) curriculum:

RQ1, SQ1- To what extent do select *science-related* preparation experiences inform in-service secondary level T&E educators how to *teach science content* embedded within the FoT unit?

RQ1, SQ2- To what extent do select *T&E-related* preparation experiences inform in-service secondary level T&E educators how to *teach science content* embedded within the FoT unit?

RQ2 – To what extent do select teacher preparation factors inform in-service secondary level T&E educators how to teach *science **practices*** in T&E education classrooms?

In the context of teaching the Foundations of Technology (FoT) unit of the Engineering byDesign (EbD) curriculum:

RQ2, SQ1- To what extent do select *science-related* preparation experiences inform in-service secondary level T&E educators how to *teach science practices* embedded within the FoT unit?

RQ2, SQ2- To what extent do select *T&E-related* preparation experiences inform in-service secondary level T&E educators how to *teach science practices* embedded within the FoT unit?

Data Sources

The demographic data and TEES-PCK survey data from the FoT teachers who participated in the main study was analyzed using statistical software (SPSS, v 22.0) and Microsoft Excel. Classroom observation notes and interview responses from the main study were analyzed and compared to the EbD lesson plans using corroborative analysis. Mixing of these qualitative and quantitative data analyses (Teddlie & Tashakkori, 2006) occurred by conducting Spearman's rho tests using the SPSS software to provide a more in-depth understanding of the select preparation experiences associated with T&E educators' science PCK levels as stated in the research questions and sub-questions. These data were used to address the two main research questions and their sub-questions. The following Summary of Data section specifically presents the findings regarding participant demographics, self-efficacy and expected outcomes, observations, and interview responses collected during the main study. The demographic data for the participants in the study are presented in the following order: general demographic data (ethnicity, gender, age, years of teaching, years of teaching FoT, degree level, certification area, and length of FoT training), participant preparation (informal and formal, collaborative and non-collaborative), and STEBI scores for teaching science and T&E education. In total there were 71 practicing FoT teachers within the targeted EbD consortium state who responded to the TEES-PCK survey, 16 of which were incomplete and therefore removed, resulting in 55 participants. This resulted in a 24% (55/233) response rate, which is within the acceptable range based on Nulty's (2008) analysis of online survey response rates.

Summary of Data

Survey. Sections 2-8 of the TEES-PCK collected data regarding participants' demographics, formal and informal preparation experiences, and self-efficacy. Due to the extensive amount of data collected from the survey, only data of interest is presented in the following sections. The full range of data is presented in Appendix O.

Demographic data.

Select demographics. Respondents for this study consisted of 55 high school FoT teachers within a Mid-Atlantic state. The population for this study consisted of mostly Caucasian (93%) male (73%) teachers between the ages of 31-50 (51%) years old (Table 6). Most participants (44%) held master's degrees, and were certified to teach Technology Education (84%) (Table 7).

Table 6

Summary of Participant Demographics

Gender n(%)	Ethnicity n(%)	Age n(%)	Age (μ)
Male 40(73)	Caucasian 51(93)	21-30 yrs. 12(22)	43
Female 15(27)	African American 1(2)	31-50 yrs. 28(51)	
	Asian 1(2)	51+ yrs. 15(27)	
	Ugandan-American 1(2)		
	African American/Caucasian 1(2)		

Note. yrs. = years old

Table 7

Summary of Participant Degrees and Certifications

Degree n(%)	Certification n(%)
BA 12(24)	Technology Education 46(84)
MA 24(44)	Business Education 10(18)
Doc 2(4)	Mathematics Education 4(7)
	Other 29(53)

Furthermore, among the specific degrees areas, the majority of participants held a bachelor's (40%) or master's (28%) degree in Technology Education. There were also a significant amount of participants who held a master's degree in administration/leadership (13%) or a bachelor's degree in industrial arts (11%) (Table 8).

Table 8

Summary of Participant Degree Data

	Degree			
Subject	Certificate n(%)	BA n(%)	MA n(%)	Doc n(%)
Technology Education	0(0)	22(40)	15(28)	0(0)
Administration/Leadership	3(6)	0(0)	7(13)	1(2)
Industrial Arts	6(11)	6(11)	3(6)	0(0)
Business Education	1(2)	5(9)	0(0)	0(0)
Physical Education/Health	0(0)	4(8)	0(0)	0(0)
Curriculum & Instruction	0(0)	2(4)	5(9)	0(0)

Note. BA = bachelor's degree; MA = master's degree; Doc = doctorate.

The mean number of years that participants taught was 13, and more than half (55%) taught in suburban settings. Participants had taught FoT for an average of five years and 51% had attended some form of FoT training. Specifically, one week was reported as the most common (33%) length of FoT training attended, while 18% received training through other means such as higher education coursework or county professional development (Table 9).

Table 9

Summary of Participant Teaching Experience and Training Data

Years Teaching (μ)	Years Teaching FoT (μ)	School Setting n(%)	FoT Training n(%)
13	5	Urban 13(24)	None 14(26)
		Suburban 30(55)	1 week 18(33)
		Rural 12(22)	Other 10(18)

Teacher preparation data.

In terms of the participants' preparation experiences, this information was organized and presented in five sections: formal preparation, undergraduate coursework, graduate coursework, informal collaborative, and informal non-collaborative experiences. Among the 55 respondents, the majority (73%) of teachers had completed a traditional teacher preparation program, while less (17%) held a previous career before transitioning into teaching (Table 10).

Table 10

Summary of Teacher Preparation Experiences

Type of Preparation n(%)		
No Formal Training	Previous Career	Teacher Prep Program
3(6)	9(17)	40(73)

Formal experiences. Undergraduate coursework (Table 11), graduate coursework (Table 12), and Interdisciplinary STEM Education coursework (Table 13) were the next areas of collected data reported. Many participants reported completing two or more undergraduate courses in physics (27%), biology (27%), or algebra (24%). In regards to T&E education, about half of the participants reported taking one or more courses in electronics (53%), Power, Electronics, and Transportation (PET) (49%), or methods for teaching technology education (53%). Only 15% of the participants reported taking two more courses in chemistry, and only 18% completed one or more biotechnology course (Table 11). The amount of courses completed in these areas proved to be important later in the study when examining what preparation experiences had significant influences on teaching of content and practices.

Table 11

Summary of Undergraduate Coursework Completed

Subject	Comp			Courses n(%)		
Science		Physics	Biology	Chemistry	Earth Science	
	≤ 2	15(27)	15(27)	8(15)	4(7)	
T&E		Electronics	PET	Robotics	Materials/ Manufacturing	Biotechnology
	≤ 1	29(53)	27(49)	17(31)	14(25)	10(18)
Math		Algebra	Statistics	Geometry	Pre-Calculus	Calculus
	≤ 2	13(24)	8(15)	5(9)	3(5)	7(13)
Methods		Tech Ed	IA	Science	Mathematics	
	≤ 1	29(53)	15(27)	8(15)	8(15)	

Note. Comp = Courses completed; Tech Ed = Technology Education; IA = Industrial Arts.

Similar to the most frequent undergraduate courses completed (Table 11), participants reported biology (7%) as the most frequent graduate course taken. Related to T&E education, electronics (15%), PET (15%), and methods for teaching technology education (45%) were also frequently reported graduate courses completed as in participants' undergraduate studies. However, the percentage of participants completing these graduate level courses was much less than those in who completed them for their undergraduate coursework. The most frequent T&E course taken was biotechnology (18%), and statistics (29%) was the most common math course. A small amount of participants completed a graduate level course in physics (5%), chemistry

(5%), or science education methods (5%) (Table 12). Data collected regarding graduate level coursework reflected the completion of one or more courses, while some undergraduate coursework data reported completing two or more courses. This indicates that participants are taking less science courses in their graduate studies as compared to their undergraduate coursework. The influence that the amount of undergraduate and graduate courses in these areas had on teaching of content and practices was examined later in this study.

Table 12

Summary of Graduate Coursework Completed

Subject	Comp	Courses n(%)			
Science		Physics	Biology	Chemistry	Space Science
	≤ 1	3(5)	4(7)	3(5)	3(5)
T&E		Electronics	PET	Biotechnology	
	≤ 1	8(15)	8(15)	10(18)	
Math		Algebra	Statistics	Geometry	Pre-Calculus
	≤ 1	3(6)	16(29)	3(6)	3(6)
Methods		Tech Ed	IA	Science	Mathematics
	≤ 1	25(45)	12(22)	3(5)	4(7)

Note. Comp = Courses completed; Tech Ed = Technology Education; IA = Industrial Arts.

Of the 55 participants, approximately three quarters (73%) reported taking some form of higher education course about integrating science within T&E education (Table 13).

Table 13

Higher Education Coursework on Integrating Science in T&E

	Yes	No
n(%)	40(73)	15(27)

Informal experiences. High school coursework and informal collaborative preparation experiences were the next area of data reported. Data regarding high school coursework was recorded to examine teaching methods since teachers' often teach how they were taught (Nespor, 1987; Shulman, 2004). This question revealed that all but one (98%) participant completed a biology course in high school, while 47% completed a chemistry course and only 64% took a physics course. Most teachers reported completing an industrial arts (65%) or technology education (44%) course in high school (Table 14).

Table 14

Summary of High School Coursework Completed

	Course n(%)					
Courses	Industrial Arts	Technology Education	Biology	Chemistry	Physics	Earth Science
≤ 1	36(65)	24(44)	54(98)	47(85)	35(64)	40(73)

In summarizing all reported coursework data, the typical participant in this study would have completed the following courses:

- High school: ≤ 1 industrial arts or technology education, and ≤ 1 biology, chemistry, and earth science courses.
- Undergraduate: ≤ 2 physics or biology, ≤ 1 electronics or PET, ≤ 2 algebra, and ≤ 1 technology education or industrial arts teaching methods courses.
- Graduate: ≤ 1 biology, ≤ 1 biotechnology, ≤ 1 statistics, ≤ 1 technology education or industrial arts teaching methods, and ≤ 1 Interdisciplinary STEM Education courses.

Data pertaining to the informal non-collaborative experiences exposed that many teachers (58%) did not help with after school clubs. Robotics (25%) was the most commonly reported club that participants reported helping with after school. Despite low participation helping with after school clubs, 40% of the teachers claimed they spent 35 or more hours within the past three years reading T&E education literature, while only 22% spent six hours or less reading science education literature. A greater number of teachers also participated in workshops or in-service trainings about teaching T&E education (75%) as opposed to teaching science within T&E

education (65%). These findings indicated that participants partook in fewer science related informal non-collaborative experiences than those related to T&E education (Table 15).

Table 15

Summary of Informal Non-Collaborative Experiences

Club/Activity n(%)	Readings n(%)	Workshops/In-Service n(%)
None 32(58)	≤ 35 hours in T&E 22(40)	Science in T&E 36(65)
Robotics 14(25)	≥6 hours in Science 12(22)	T&E 41(75)
TSA 7(13)		

Note. TSA = Technology Student Association

Informal collaborative preparation experiences comprised the final portion of data collected from the TEES-PCK survey. Specific to professional development many reported observing T&E classes (69%), consulting a T&E curriculum specialist (67%), and coaching/mentoring a T&E teacher (53%), while only 33% consulted with a science curriculum specialist and 16% observed a science class. Forty-five percent of participants served on T&E education committees while only 18% served on science education committees (Table 16).

Table 16

Summary of Informal Collaborative Experiences

			Collaborative Experience n(%)		
Area	District/School Committee	Coach/ Mentor	Deliver In-Service/Workshop	Observed Class	Consulted Curriculum Specialist
T&E	26(47)	29(53)	23(42)	38(69)	37(67)
Science	2(4)	1(2)	2(4)	9(16)	18(33)

Additionally, 73% of participants engaged in T&E educator collaborative online networks while only 38% participated in similar networks related to science education (Table 17).

Table 17

Summary of Committee and Network Participation

Committees/Task Forces n(%)	Teacher Collaborative Networks n(%)
Science 10(18)	Science in T&E 21(38)
T&E 25(45)	T&E 40(73)

Slightly less than a third (27%) of the participants reported going to a state or national T&E conference within the past three years, at which 35% attended mostly T&E education sessions (Table 18).

Table 18

Summary of Participant Conference Attendance

Conference n(%)	Sessions Attended n(%)
State or Ntl. Science 5(9)	Science 0(0)
State or Ntl. T&E 15(27)	T&E 19(35)
	Science and T&E 10(18)
	Unsure 25(46)

Note. Ntl. = National

Thirty-six percent of participants reported collaborating with other T&E education teachers on a daily basis, while many claimed they never collaborated with physics (51%), biology (66%), or mathematics (51%) educators during the school year (Table 19).

Table 19

Summary of Teacher Collaboration

	Subject Area n(%)			
Frequency	T&E	Physics	Biology	Mathematics
Never	2(4)	28(51)	36(66)	28(51)
Daily	20(36)	1(2)	1(2)	1(2)

These findings clearly demonstrate that FoT teachers in this study chose to participate in more informal collaborative experiences related to T&E education than science education. Also, their collaborations in T&E education contexts occurred more frequently than those in science education as evidenced by their collaborative efforts between other T&E educators in comparison to science educators.

In summarizing all informal preparation data, the typical participant in this study would have participated in the following experiences within the past three years:

- Non-Collaborative: did not help with any after school clubs, spent ≤ 35 hours reading technology education literature, and participated in T&E workshops or in-service.
- Collaborative: served on a district/school T&E committee or task force, served as a T&E coach/mentor, delivered a T&E in-service/workshop, observed a T&E class, consulted a T&E or science curriculum specialist, participated in a T&E teacher collaborative network, attended mostly T&E conference sessions at T&E conferences, collaborated with T&E teachers regularly, and never collaborated with physics, biology, or mathematics teachers.

The full range of formal and informal preparation data (Appendix O) contributed to the analyses of the research questions and sub-questions regarding preparation factors that influence the teaching of science content and practices.

Self-efficacy and expected outcomes. Table 20 summarizes the self-efficacy and expected outcome data for the 55 participants as recorded by the STEBI questions included in Section 2 of the TEES-PCK survey. High, intermediate, and low levels were determined by dividing each scale into thirds based on the maximum possible rating.

Table 20

Summary of STEBI Results

		Category n(%)			
SE	EO	Low SE, Inter EO	Low SE, High EO	Inter SE, Inter EO	Inter SE, High EO
Low 24(44)	Low 0(0)	23(42)	2(4)	29(53)	1(2)
Inter 31(56)	Inter 52(95)				
High 0(0)	High 3(6)				

Note. SE = Self-Efficacy; EO = Expected Outcome; Inter = Intermediate.

Of the overall responses most reported having intermediate (56%) to low (44%) self-efficacy, and intermediate (95%) expected outcomes for T&E educators. Further analysis revealed that many participants had low self-efficacy and intermediate expected outcomes (42%), or intermediate levels for both self-efficacy and expected outcomes (53%). These results indicate that although most teachers had low (44%) to intermediate (56%) self-efficacy levels about their own ability to teach T&E content and practices, and they had higher expected outcomes (95% intermediate, and 6% high) for other T&E educators to teach these content and practices. Moreover, this would suggest that participating teachers believed FoT educators make a difference in student T&E learning. However, findings also indicate they were less confident in their teaching ability.

Observations. Participants with unique survey characteristics according to the mode experiences among participants in their experience category were identified to ensure the selection of a broad spectrum of teachers with various preparation experiences as described in Chapter 3.

Observed participant characteristics. The identified subset of participants were contacted via email and a follow up phone call to participate in the observation and interview portion of the study. Of the 20 individuals contacted, four did not respond, one withdrew due to an early retirement, two did not teach the specified FoT units needed for this study, three did not teach the specified units until the following semester, and two did not wish to be observed. Of the two that declined to be observed, one was certified to teach art while the other was certified to teach business education, and neither was certified to teach technology education. This resulted in eight participants (Table 21) with unique characteristics that agreed to voluntarily participate in a classroom observation and interview.

Table 21

Demographic Data for Observed Participants

Participant	Gender	Ethnicity	Age	Years of Teaching	Years Teaching FOT	Years Teaching Science	Tech Ed Certif -ied	FoT Training	Interdis-ciplinary STEM Course	STEBI Self-Efficacy	STEBI Expected Outcome
Teacher 1	Male	Caucasian	62	30	2	0	Yes	Half Day	No	22	38
Teacher 2	Male	Caucasian	47	10	8	1	Yes	1 week	Yes	26	35
Teacher 3	Female	Caucasian	24	2	2	0	Yes	1 week	No	17	27
Teacher 4	Male	Caucasian	47	13	5	2	Yes	Half Day	Yes	13	31
Teacher 5	Male	Caucasian	56	33	4	0	Yes	Half Day	Yes	13	28
Teacher 6	Male	Caucasian	61	28	10	0	Yes	1 week	No	19	30
Teacher 7	Male	Caucasian	59	21	6	0	Yes	1 week	Yes	25	32
Teacher 8	Male	African American/ Caucasian	25	3	3	0	No	1 week	No	18	30

In order to better describe the participants, the researcher briefly contextualized (Gumbo & Williams, 2014) the unique science and T&E education experiences of each teacher he observed and interviewed. These descriptions include demographic and preparation information from the TEES-PCK instrument, notable observations from the lesson, and significant information shared during the interview. Only data that reflect the most significant characteristics from the descriptions are presented in Table 22, and the full set of descriptions are provided in Appendix I.

Table 22

Summary of Unique Characteristics among Observed Participants

Participant	Unique Characteristics				
	Background	Coursework	Additional Experiences within the Past Three Years	School and Learners	Lesson and Activity
Teacher 1	• Tinkerer as child • Served in armed forces • B.S. Industrial Ed • Master's Tech Ed	• 2 earth science courses in HS • 2 bio and tech ed methods courses in undergrad	• Helped with TSA, Odyssey of the Mind, and Science Olympiad • 35+ hours reading science literature • Facilitated 6 or more tech ed professional development sessions • Attended national tech ed conference • Collaborated with math and physics teachers once a month	• Rectangular tables facing smart board • Adjacent fabrication lab with equipment • Diverse (ethnicity) class population	• Unit 3, Lesson 1: Conversion of Energy • Focused on energy from a power plant to a house
Teacher 2	• Father was a civil engineer • Tinkerer as child • B.S. Business Ed • Grad Cert. Tech Ed	• 1 physics and 4 space science courses in undergrad • 2 grad courses in physics, bio, and chem	• Helped with Vex robotics, state engineering competitions • 6 or more higher education courses, workshops or in-service trainings, summer institutes, and conferences • Served on 2 science and 6 or more tech ed committees • Attended state T&E and national science conferences • Collaborated with physics teachers once a week, math and chem teachers once a semester, and FACS teachers once a month	• Alternative school • Small classroom with tables facing white board • Adjacent fabrication lab with equipment • 64% of students received FARMS	• Unit 4, Lesson 2: Trouble-shooting Electronic Circuit Components • Focused on building career skills
Teacher 3	• MS tech ed teacher influenced her	• No bio, chem, physics, or earth science courses in	• Helped with TSA • Attended state T&E conference • Spent 6 hours in an online T&E	• Large CADD lab with computers for each student	• Unit 3, Lesson 1: Conversion

(continued)

Table 22 Continued

Participant	Background	Coursework	Additional Experiences within the Past Three Years	School and Learners	Lesson and Activity
	Unique Characteristics				
Teacher 3	to become a tech ed teacher • B.S. Tech Ed	HS • 2 bio, space science, and biotech courses in undergrad • Teacher preparation program focused on manufacturing skills • No graduate coursework	collaborative network • Collaborated with bio, physics, chem, earth science, space science, math, business, and FACS teachers on a daily basis	• Rectangular tables facing white board • No fabrication equipment in classroom • Homogenous (ethnicity) student population	of Energy • Focused on content of slides as provided by EbD
Teacher 4	• Former engineer • B.S. Industrial Engineering • Provisional Licensure	• Graduate coursework in CTE • 2 bio and chem courses in HS • 4 physics, 2 biology, and 1 space science courses in undergrad	• Participated in EbD assessment writing summer workshops • 6 hours of reading literature, 4 in-service workshops, and 3 summer institutes about teaching science in T&E • Served on 2 school committees and delivered 2 or more workshops in both science and T&E education • Spent 6-35 hours mentoring and observing, participating in collaborative networks, and consulting with curriculum specialists in science and T&E	• Small room with tables facing chalk board • Science lab tables in middle of room with pulleys, planes, and scales • Science vocab terms on board • Adjacent fabrication lab with equipment • Homogenous (ethnicity) student population	• Unit 3, Lesson 1: Conversion of Energy • Focused on making students critical consumers of energy

(continued)

Table 22 Continued

Participant	Unique Characteristics				
	Background	Coursework	Additional Experiences within the Past Three Years	School and Learners	Lesson and Activity
Teacher 4			• Collaborated with physics teacher once a semester		
Teacher 5	• Taught career education and tech ed • HS industrial arts teacher influenced him to become a tech ed teacher • B.S. Tech Ed • Master's Tech Ed • Arts and Sciences I & II Licensure • Certified to teach Tech Ed and Elementary Ed	• 1 physics course in HS and 2 in undergrad • 3 electronics and 2 robotics undergraduate courses • 1 space science and 1 robotics graduate course	• Teacher in Space program • Delivered CATTS PD • Held T&E education supervisory roles at county and state levels • Past president of a national T&E education organization • Helped write and pilot the STLs • Delivered workshops in science and T&E education • 6-15 hours serving on science and T&E committees, mentoring T&E teachers, and consulting with a science curriculum specialist about teaching T&E education • 6 hours reading science education literature • Attended and presented at state T&E, and national science education conferences • Collaborated with physics and bio teachers once a year, and earth and space science teachers once a month.	• Large room with tables facing chalk board • Drill press, band saw, and hand tools in back of classroom • Diverse (ethnicity) class population	• Unit 4, Lesson 2: Trouble-shooting Electronic Circuit Components • Focused on electric components, and inventory and organization skills for future careers

(continued)

Table 22 Continued

Participant	Unique Characteristics Background	Coursework	Additional Experiences within the Past Three Years	School and Learners	Lesson and Activity
Teacher 6	• Owned home remodeling business • Master's Theology • Ed.S. Tech Ed • Worked for engineering firm in the summers • Taught European and U.S. history • National Board Certified in CTE	• No tech ed, physics, or earth science courses in HS No electronics, PET, or science courses in undergrad • 1 bio, 1 industrial arts methods, and 2 tech ed methods courses grad courses	• Helped with FIRST robotics • 35+ hours reading science literature Observed at another school's science facility, participated in in-service trainings, and a completed a summer institute for teaching science in T&E education • Participated in T&E in-service • Annually attended state T&E conference • 6+ hours in science discussion groups, teacher collaborative networks, and consulted with a science curriculum specialist • 6-15 hours mentoring a T&E education class, participating in T&E educator collaborative networks, and consulted with a science curriculum specialist about teaching T&E • 16-35 hours in T&E teacher collaborative network • 6-15 hours mentoring a T&E teacher • Collaborated with physics, business, and FACS teachers once a month.	• Large Modular classroom converted for FoT • Tables facing white board • Small fabrication equipment where modules used to be housed • Homogenous (ethnicity) student population	• Unit 3, Lesson 1: Conversion of Energy Focused on content of slides as provided by EbD

(continued)

Table 22 Continued

Participant	Unique Characteristics				
	Background	Coursework	Additional Experiences within the Past Three Years	School and Learners	Lesson and Activity
Teacher 7	• HS industrial arts teacher influenced him to become a tech ed teacher • B.A. Psychology • B.S. Tech Ed • Worked in HVAC	• 1 space science and no physics course in undergrad • No courses on integrating science within T&E Ed • No graduate coursework	• 35+ hours reading T&E literature • Delivered 6+ workshops about T&E and how to integrate science in T&E • 6-15 hours in science discussion groups • Annually delivered weeklong FoT training sessions • Annually attended state science and T&E education conferences • Collaborated with T&E teachers 2-3 times a week	• Large CADD lab with computers for each student • Tables facing white board • No fabrication equipment in classroom Homogenous (ethnicity) student population	• Unit 3, Lesson 1: Conversion of Energy Focused on integrating the math and science concepts that are part of energy conversion
Teacher 8	• B.S. Physical and Health Education • Grad Cert. Tech Ed • Hands on tech ed courses in HS got him interested in teaching tech ed	• 2 HS tech ed courses • 1 bio, chem, physics, and earth science courses in HS • 1 bio, chem, and electronics course in undergrad • No teaching methods courses in undergrad • No graduate coursework	• Spent less than 15 hours reading T&E and science literature • 6-15 hours in a workshop about teaching science in T&E • Served on 3 T&E education task force committees • 35+ hours peer coaching, completing in-service training, and participating in collaborative networks regarding T&E education	• Former science classroom with computers • Tables facing white board • No fabrication equipment in classroom • Diverse (ethnicity) class population	• Unit 3, Lesson 1: Conversion of Energy • Focused on developing technical skills for home repairs

(continued)

Table 22 Continued

Participant	Background	Coursework	Additional Experiences within the Past Three Years	School and Learners	Lesson and Activity
			Unique Characteristics		
Teacher 8			• Less than 6 hours observing a class, in a discussion group, in a teacher collaborative network, and consulting with a science curriculum specialist regarding the teaching of science • Attended a state T&E conference • Collaborated with physics, chem, bio, earth science, T&E, business, and FACS teachers once a year		

Note: Tech ed = technology education; Grad Cert. = Graduate Certificate; bio = biology; chem = chemistry; FACS = Family and Consumer Science; FARMS = Free and Reduced Meals; MS = Middle School; HS = High School; CADD = Computer Aided Drafting and Design; CTE = Career and Technical Education; HVAC = Heating, Ventilation, and Air Conditioning; PET = Power, Energy, and Transportation; CATTS = Center to Advance the Teaching of Technology and Science; and PD = Professional Development.

Summary of unique participant characteristics. As emphasized in Table 22 the observed participants had a variety of preparation experiences that informed their teaching. There were some commonalities in their backgrounds, such as three participants who identified themselves as tinkerers (those who experiment with tools and materials) growing up. Additionally two had family members that were engineers and one himself was a former engineer, as well as three of the participants working in technical fields prior to teaching. Industrial arts/technology education teachers influenced three participants to pursue a career in T&E education.

From data reported in Table 22, it was concluded that the typical participant had the following characteristics:

- Background: a bachelor's or master's degree in technology education.
- Coursework: ≤ 1 high school biology and technology education courses, ≤ 1 undergraduate biology or space science courses, ≤ 1 undergraduate algebra or statistics courses, ≤ 1 undergraduate T&E teaching methods courses, ≤ 1 graduate T&E teaching methods courses, and ≤ 1 higher education Interdisciplinary STEM Education course.
- Additional Experiences: spent ≤ 6 hours engaged in T&E readings, participated in ≤ 2 workshops or in-services about teaching science within T&E, ≤ 6 workshops or in-services about teaching T&E, participated in ≤ 1 professional development activities related to science, served on ≤ 2 T&E committees, spent ≤ 6 hours in a science discussion group, spent ≤ 6 hours in a science educator online collaborative network, spent ≤ 15 hours in a T&E online collaborative network, spent ≤ 15 hours observing a T&E class, spent ≤ 6 hours consulting a science

education curriculum specialist, attended ≤ 1 T&E conference, and collaborated with physics, mathematics, and Family and Consumer Science (FACS) teachers at least once a month.

- School and Learners: All classrooms had rectangular tables with students facing a whiteboard, and half had diverse student populations.
- Lesson: Two-thirds taught Unit 3 regarding the conversion of energy.

In further examining the coursework completed, two teachers claimed they did not take any physics courses in high school. Three teachers reported completing two biology courses, and three said they took at least one physics course during their undergraduate studies. For graduate coursework, one teacher completed a physics course and one completed a biology course. One participant took two undergraduate robotics courses and one graduate level robotics course. At the time of the study, three of the participants had not completed any graduate coursework.

In addition, select preparation experiences varied greatly among the eight observed participants. Four of them helped with after school clubs related to robotics or TSA. Within the past three years seven of the participants had attended a state T&E and science conference, and two attended a national T&E conference. Four teachers reported reading science literature for 6 or more hours, four claimed to spend 6 or more hours engaging in an online collaborative science education network, and three delivered workshops about teaching T&E education. One participant served as the president of a national T&E association as well as a writer and pilot site for the STLs. Also, one participant was a writer for the FoT assessment, and another participant was a teacher trainer for the FoT curriculum.

Two facilities also served as CADD classrooms, one was converted for FoT from a modular classroom, and three looked like they were previously science classrooms. Fabrication equipment (e.g., drill press, band saw) was non-existent in three of the classrooms, two had this equipment either in the back or on the sides, and the remaining three classrooms had traditional fabrication labs adjacent to them.

Six teachers taught the first lesson from Unit 3 regarding the conversion of energy, while two taught the second lesson from Unit 4 regarding troubleshooting electronic circuit components. Despite the consistency in FoT lessons taught, the focus of the lessons varied among teachers. Three emphasized building career skills while three participants focused on the content of the slides as provided by EbD. These vast range of characteristics helped to examine the relationships that existed between select preparation experiences and the teaching of content and practices.

Classroom observation results. Participant ratings for all 35 RTOP items are reported in Appendix P, however for the data analyses needed to examine the research questions and sub-questions of this study, the RTOP ratings were examined by section among teachers (Table 23). These ratings varied for numerous reasons which are discussed in further detail in Chapter 5.

Table 23

Participants' Observation Ratings

Scores According to RTOP Categories								
Participant	Category and Score							
	LD&I	SC	T&E C	SP	T&E P	CI	S/TR	Total
Teacher 1	2	6	7	1	1	3	3	23
Teacher 2	12	9	17	6	12	12	10	78
Teacher 3	2	3	7	1	1	3	3	20

(continued)

Table 23 Continued

Scores According to RTOP Categories								
Participant	Category and Score							
	LD&I	SC	T&E C	SP	T&E P	CI	S/TR	Total
Teacher 4	12	17	20	10	16	13	14	102
Teacher 5	15	19	20	15	16	15	18	118
Teacher 6	0	3	9	1	2	1	2	18
Teacher 7	6	14	19	7	6	7	10	69
Teacher 8	4	6	10	5	7	9	6	47
Mean	6.6	9.6	13.6	5.8	7.6	7.9	8.3	59.4

Note: LD&I=Lesson Design and Implementation; SC=Science Content; T&E C=Technology and Engineering Content; SP=Science Practices; T&E P=Technology and Engineering Practices; CI=Communicative Interactions; S/TR=Student/Teacher Relationships. Scores for each category range from 0-20, with higher scores indicating a greater rating.

To describe what was observed and provide the rationale for RTOP ratings specific to the science content and science practices portions of Section IV, the researcher prepared detailed student/teacher vignettes drawn from the lesson and quotes from the interviews. These data were examined concurrently with the observation notes to make sense of the teaching strategies observed. The following section provides a summary of the RTOP scores, followed by a summary of the findings from the observations and interviews. The full description of the classroom observations are presented according to each participant in Appendix O.

Summaries of classroom observation results. The following sections provide detailed summaries of the quantitative RTOP ratings and qualitative classroom observations.

Summary of RTOP ratings. The total RTOP ratings for each participant ranged from 18 to 118 out of a possible 140 with a mean of 59.4 (42%). Specifically in terms of science content and practices, the mean rating for teaching of science content was 9.6 (48%) and for science practices was 5.8 (29%). Four teachers scored six (30%) or lower on teaching of science content, and three received a score of one (5%) on the teaching of science practices. Conversely, T&E educators scored higher in observed teaching of T&E content and practices as demonstrated with their mean ratings of 13.6 (68%) for T&E content and 7.6 (38%) for T&E practices. When examining these scores in more detail there were only three teachers who scored nine (45%) or lower for teaching T&E content, but for T&E practices three teachers scored a two (10%) or lower (Table 23).

When analyzing the scores according to the type of teacher preparation experiences participants had (T&E education teacher preparation program, teacher preparation program outside of science and T&E education, and engineering program), all three groups received their highest mean ratings in T&E content and their lowest in science practices. The teacher that earned a degree in engineering had the highest mean RTOP rating (102), while teachers who completed teacher preparation programs in disciplines outside of science and T&E education received the lowest mean score (48) (Table 24).

Table 24

Summary of RTOP Ratings according to Preparation

Teacher Preparation	Total n(μ)	SC(μ)	T&E C(μ)	SP(μ)	T&E P(μ)
T&E teacher prep	4(58)	10.5	13	6	6
Non-T&E teacher prep	3(48)	6	9	2	3
Engineering prep	1(102)	17	20	10	16

Similar findings emerged when analyzing the data according to experience categories (novice, intermediate, and veteran teachers). Novice teachers recorded the lowest mean RTOP rating (33.5) with veteran teachers next (57), and intermediate teachers scored the highest (90). Again, all groups recorded their highest mean ratings in T&E content, and their lowest in science practices (Table 25).

Table 25

Summary of RTOP Ratings according to Experience

Experience Level	Total n(μ)	SC(μ)	T&E C(μ)	SP(μ)	T&E P(μ)
Novice	2(33.5)	4.5	8.5	3	4
Intermediate	2(90)	13	18.5	8	14
Veteran	4(57)	10.5	14	6	6

Consistent across both categories were the low scores in teaching of science practices and high scores in teaching T&E content (Tables 24 & 25). Differences in scores within the categories called for the need to further investigate what specific preparation experiences had a significant influence in the teaching of science content and practices.

Among all eight participants, only two (Teachers 4 and 5) demonstrated a perfect score on any item, which occurred in teaching of T&E content. Teacher 5 also posted the highest ratings in both science content and practices. Teachers 3 and 6 earned the lowest scores in science content, while Teachers 1, 3, and 6 received the lowest ratings in science practices (Table 23). The participants identified above represented a variety of experience levels that received high and low ratings, suggesting that teaching of science content and practices was not solely dependent upon years of teaching experience. These data suggest that a bachelor's or masters degree in technology education, high school biology and technology education courses, undergraduate science courses, undergraduate and graduate T&E methods courses, higher education Interdisciplinary STEM Education courses, T&E workshops, science professional development, serving on T&E committees, participating in online collaborative networks, consulting with science curriculum specialists, attending T&E conferences, and collaborating with physics teachers could have a significant influence on the teaching of science content and practices. This prompted the need for further analyses to identify which specific preparation factors were significantly correlated with the teaching of science content and practices.

Veteran Teachers 1 and 6 earned two of the lower total ratings (18 and 23 respectively) among all observation participants, while intermediate teachers posted some of the higher ratings (102, 78, 69). However, the highest rating (118) was achieved by veteran Teacher 5 who had a wealth of experiences over his 35-year career. As emerged from his interview responses and the Spearman's rho results examining his informal preparation experiences, his continual commitment to stay involved in professional development efforts and network with other professionals helped him adapt to changes in the field as it transitioned from industrial arts, to industrial technology, to technology education, and to its current focus of T&E education. Although one novice teacher recorded the second lowest rating, the other novice instructor had the fourth highest rating. Furthermore, two of the lowest ratings were from veteran instructors with over 28 years of teaching experience. If consistent with the review of literature on PCK presented in Chapter 2, one would expect to find experience as the greatest predictor of teacher performance (Shulman & Hutchings, 2004; Williams & Lockley, 2012). This discrepancy between the data and the literature led the researcher to further investigate the types of preparation experiences and their level of association among observed teaching of science content and practices. The research questions and sub-questions provided the framework for this investigation.

Summary of classroom observations. As mentioned in Chapter 3, qualitative findings from classroom observations were recorded via audio and notes to corroborate findings from the RTOP ratings. This study purposefully selected to observe a lesson from FoT Units 3 or 4 to ensure consistency in targeted content and specifically analyze differences in pedagogical strategies used to teach science content and practices. Although all teachers received the same curricular resources from FoT, there were many variations in the observed lessons. Of the three teachers who used the home appliance energy consumption worksheet from FoT, none demonstrated how to do the calculations step-by-step and explain what the units (e.g., kilowatts) meant. They simply explained the example provided on the worksheet despite a sense of confusion expressed by some students. The survey data would suggest that participants had the necessary coursework to prepare them for teaching students this concept. Four of the observed participants completed at least one undergraduate course in PET, and six took at least one undergraduate course in algebra, statistics, and electronics. Despite having these preparation experiences, participants missed this opportunity to elaborate on science content using this authentic example. This prompted the need to further examine these experiences and their influence on T&E educators teaching of science content and practices.

Among the observed teachers, a variance in teaching style also emerged. Two teachers presented the lesson almost verbatim from the FoT PowerPoint, while the other six teachers modified the FoT materials and activities for an array of reasons (e.g., lack of funding for suggested materials). Approximately four of the teachers lectured about content for the entire class period, while the other four participants divided the class time between lecture and lab. Five of the participants used the PowerPoints provided by FoT, while the other three either used outside presentations, created their own PowerPoint presentation, or did not use a PowerPoint because they depended on discussion and demonstrations.

The vignettes provided in Appendix O give detailed snapshots of how T&E educators taught targeted science content and practices embedded within FoT. This helped expose differences in what was expected to be taught according to the FoT curriculum (Appendix E), and what was actually observed being taught in dynamic public high school settings. The RTOP ratings revealed a gap in proficiency of expected science content (48%) and practices (29%)

being taught. Seven of the participants reported having difficulty teaching the entire FoT curriculum within the limited time that they had the students. In some schools where teachers only saw students for 45 minutes every other day for a semester, they were forced to choose a few FoT units to teach. This concern was expressed in an interview with Teacher 3, "I chose the energy and transfer over the science because a lot of the time we don't even get through the curriculum in the time that we have." Participants also admitted that they rarely taught the science content (e.g., thermodynamics, nuclear power) in great detail unless it was needed for the end of unit design challenges or subsequent units. Teacher 4 felt comfortable answering student questions about magnetism and gravitational forces from the four physics, two chemistry, one earth science, two electronics, and one electrical engineering courses he completed during his undergraduate studies; however, he also felt pressured to spend more time covering T&E concepts that students needed to apply in proceeding units and would be asked on the FoT end of course assessment. The interviews revealed that six of the teachers believed they were just scratching the surface in regards to the science content being taught. One reason for this was many viewed FoT as a survey course that was meant to expose students to various T&E concepts, and if interested students could take an advanced T&E education course to further examine these concepts.

Five of the teachers expressed some level of discomfort with teaching targeted science concepts such as thermodynamics and fission because they believed it was too advanced for students in FoT. Also, five participants believed they only needed to scratch the surface regarding these concepts, and let the science department teach them in further detail. In fact, four teachers told their students during the lesson that certain science concepts would be covered in more detail within their physics or chemistry classes. In the interviews none of the teachers described teaching these specific concepts in collaboration with their school's science department. However, six participants stated that they collaborated with their physics teachers to borrow equipment and share ideas, but not for the purpose of teaching science and T&E concepts concurrently. Five of the participants assumed students would be able to make the connections between targeted concepts from science class and their application to technological design problems in FoT. For example, during the observations, six instructors mentioned biomass and nuclear energy but did not explain how they occurred from the embedded science content (e.g., atoms, fission). They simply mentioned them, gave the definition of fission, and then continued with the lesson. In these cases students did not appear to make the connection and needed some scaffolding.

These findings contradict the reported survey data which suggest that four of the participants had the higher education preparation to teach these concepts. Three teachers completed an undergraduate physics course, four had a chemistry course, and one had a biotechnology course that should prepare participants for teaching about concepts such as thermodynamics, fission, and biomass. This elicited further investigation regarding the influence of these courses and why T&E educators with these experiences did not demonstrate higher levels of teaching targeted science concepts.

Also revealed through the vignettes (Appendix O) were examples of teachers who demonstrated more appropriate strategies for the teaching of science content and practices than others. One vignette described how students were able to see and understand electromagnetic energy when Teacher 4 used a hand crank generator to light a bulb. Less applicable strategies were seen when Teachers 3 and 6 attempted to clarify the laws of thermodynamics by describing them in the form of imaginary blocks and containers. The vignettes helped corroborate the

RTOP ratings that reported differences like these in the teaching of science content and practices. Furthermore, the survey results also corroborated expected teaching of science concepts based on preparation from undergraduate coursework. Teacher 4 completed four physics, two biology, two chemistry, and one earth science course, while Teacher 3 completed one undergraduate course in biology and space science, and Teacher 6 had completed no undergraduate science coursework. Further analyses examining the influence of amount and types of science courses was conducted later in the study.

Teachers 4 & 5 had the most engaged groups of students, which was apparent from students' observed interest in the lesson and the amount of intriguing questions they posed. These teachers also earned the highest science and T&E practices ratings. Being able to interrelate science and T&E content through engaging practices enhanced student inquiry and fostered their creative designerly thinking (McRobbie, Stein, & Ginns, 2001). The increased interaction between these teachers and their students was apparent in the vignettes. Examples from five of the teachers depicted them presenting large chunks of information, but most of the vignettes for Teachers 4 and 5 had a significant amount of student dialogue. Encouraging student input maintained their interest as they helped determine the focus of the lesson related to the targeted FoT content.

In the observed lessons only two teachers taught the targeted content by grounding it in engineering design or problem-based learning. This would be expected from these participants since one of the them had a bachelor's degree in industrial engineering and the other helped develop the *Standards for Technological Literacy* which emphasize engineering design. Activities from six of the observed lessons included a prescribed set of instructions that merely required the students to mimic what the instructor demonstrated (e.g., soldering a component, wiring an outlet). There may be more open-ended design activities planned at the end of the units, but most of the participants seemed to provide students with the information they needed rather than encouraging the application of higher order thinking skills through predicting, designing, building, testing, and analyzing their ideas. More participants would be expected to integrate engineering design or problem-based learning in their lessons given their preparation experiences. Within the past three years, two other participants either delivered or attended a weeklong FoT in-service, and an additional teacher graduated from a T&E education preparation program. This prompted further investigation of the influence that formal preparation programs and informal training experiences had on teaching science content and practices.

Lastly, in the observation analysis it was difficult to distinguish if Teachers 4 and 5, the highest rated participants, were teaching an applied science or T&E education class. Their ability to intricately integrate science and T&E concepts together was a skill which some of the other teachers had not yet mastered or did not demonstrate. Within the past three years, Teachers 4 and 5 reported reading a significant amount of science education literature, delivering science and T&E workshops, serving on science education committees, and consulting with a science curriculum specialist. Determining the influence these preparation factors had on teaching science and T&E concepts at a fully integrated level is important, hence the further analyses in subsequent sections of this chapter.

As the findings from the RTOP and observations suggest, teachers demonstrated less proficiency in teaching science content and practices than T&E content and practices. This lack of proficiency was not expected according to the breadth and amount of formal science coursework and informal science preparation experiences reported by the eight participants. There were influential preparation factors that could not be recorded through the survey or observations. For this reason a summary of significant qualitative findings that emerged during the interviews are presented in the next section.

Interviews

The first interview results presented used questions 8b, “How do you believe your science courses and labs inform your teaching of the FoT curriculum?” and 8c, “What informal science-related experiences inform your teaching of FoT?” to provide more insight about science preparation experiences that influenced participants’ teaching of science content.

Table 26

Summary of Interview Results for science-related preparation to Teach Science Content

Participant	Interview Question	
	8b	8c
Teacher 1	• High school biology and higher education science courses • Helping with Science Olympiad	• Teaching experience
Teacher 2	• High school chemistry and physics courses	• Father’s influence as an engineer • Tinkering with tools and materials while growing up
Teacher 3	• Did not believe her teacher prep program prepared her to teach science • Biotechnology course did not have a significant impact	• Managing at an amusement park • Doing STEM activities with female elementary school students during her undergraduate studies
Teacher 4	• Undergraduate chemistry and physics courses	• Helping daughter with AP physics homework
Teacher 5	• Importance of receiving science instruction from science educators	• Experience working in construction
Teacher 6	• Stated benefit that more physics in high school would have had	• Experience working at an engineering firm in the summers
Teacher 7	• Did not answer	• Experience working in HVAC
Teacher 8	• High school physics courses	• Tinkering with tools and materials while growing up

Four teachers attributed their knowledge about teaching of science content to their high school coursework while three attributed it to their higher education science coursework.

Teacher 2 believed his high school teachers had the greatest influence, “I’d have to take it back to my 11th grade chemistry year or 12th grade physics year. I had two great teachers. That’s where the majority of it [science content knowledge] came from.” He provided further detail as to why he believed his high school science courses had a greater influence on his teaching of science content than the higher education science courses he completed:

> I don't think my higher education science teachers cared as much, I think they thought it was a mandated course they got to teach as part of a graduation component. So their jobs were secure and they didn't put their heart and effort into teaching it. (Teacher 2, personal communication, October 30, 2014)

Similarly, Teacher 8 believed that his high school physics courses had the greatest influence on his teaching of science content within the curriculum, and Teacher 6 felt that if he had taken physics in high school it would help him teach FoT better because he felt the curriculum relied more on content knowledge of physics than biology. Conversely, Teacher 1 believed his high school biology and higher education science courses were influential in his teaching of science content, along with his experience helping with Science Olympiad. These teachers’ beliefs about the impact of high school and higher education science courses (especially physics) are substantiated in the Spearman’s rho analyses conducted later in this chapter.

Two teachers did believe that their higher education science coursework was most influential in their teaching of science content. Teacher 4 stated that he probably had as much chemistry, physics, and math courses as teachers in those content areas because of his engineering degree requirements. He believed those higher education courses helped him answer impromptu student science related questions that arose. Teacher 5 believed the instructors of his content courses played an important role in his teaching and understanding of science content:

> I recognize truly what science is. The fact that I was able to get that instruction not from a technology education instructor was huge. I got my engineering from engineering, my science from science, my math from math, and my technology from industrial and technology people. (personal communication, November 11, 2014)

One participant, Teacher 3, was unique from the rest in that she did not believe her traditional teacher preparation program prepared her to teach STEM education content. Her program didn't spend a lot of time on science or STEM because it focused heavily on developing technical skills. When asked about the influence of the biotechnology course she took during her undergraduate studies, she said that it was completed in her first semester and the content was forgotten by her fourth year because it was not emphasized or integrated in other aspects of the teacher preparation program.

To obtain more information about informal preparation experiences, interview question 8c asked which informal science experiences influenced participants' teaching of science content. Teacher 1 believed his experiences from teaching over thirty years had the greatest influence on his teaching of science content while Teacher 6 believed his teaching was influenced from his experience doing soil and concrete testing for a geotechnology firm prior to teaching. Teacher 7 found that his work in HVAC, refrigeration, and electricity informed his teaching of science content such as thermodynamics and energy transfer.

One teacher cited learning from their own children as having most significant influence on their teaching of science content. Teacher 4's daughter was taking an Advanced Placement physics course at a nearby school system and often needed help with her homework. He believed this experience increased his science content and pedagogical knowledge.

Teacher 3 believed her experience managing high school students at an amusement park during numerous summers contributed to her preparation to work with students. More specifically, she believed doing STEM activities with elementary level female students as part of her undergraduate program enlightened her teaching of science content.

The second set of interview findings came from questions 8a, “How do you believe your T&E courses and labs inform your teaching of the FoT curriculum?” and 8c, “What informal T&E related experiences inform your teaching of FoT?” to shed more light on the T&E preparation experiences that influenced educators’ teaching of science content.

Table 27

Summary of Interview Results for T&E-related preparation to Teach Science Content

Participant	Interview Question	
	8a	8c
Teacher 1	• Learn from experiences and from others • Higher education coursework.	• Military experience • Experience working in construction • Learning from his two brothers are engineers
Teacher 2	• Based on relationships with students, not preparation coursework	• Father’s influence as an engineer • Tinkering with tools and materials while growing up
Teacher 3	• More time needed to pursue professional development opportunities	• Doing STEM activities with female elementary school students during her undergraduate studies
Teacher 4	• Graduate coursework	• Experience running a pre-fabricated concrete business as an engineer • Experience building his house
Teacher 5	• Observations of high school and higher education teachers as a student	• Experience building houses • Experience building and wiring speaker towers at Beatle Mania • Experience building props for theatre competitions

(continued)

Table 27 Continued

Participant	Interview Question	
	8a	8c
Teacher 6	• Industrial arts coursework but less impact as field moved to T&E	• Experience working at an engineering firm in the summers • Experience in the home remodeling business
Teacher 7	• Experience teaching FoT training sessions • Experience teaching PET courses	• Experience working in HVAC • Experience helping write and rewrite the FoT curriculum for EbD
Teacher 8	• High school technology education courses	• Tinkering with tools and materials while growing up • High school technology education courses

Five participants felt their T&E education courses and labs had a significant effect on their teaching of the FoT curriculum. Teacher 1 viewed himself as a lifelong learner in any new science content he was expected to teach. He felt comfortable in his pedagogical strategies and teaching of content from his bachelor's course work, master's course work, and over 30 years of teaching experience. Teacher 2 did not believe T&E coursework was the most influential factor, rather he felt that teaching ability was the result of one's commitment to learning how to teach a particular content area and building relationships with the students. He believed if teachers really tried to learn how to teach the content and knew their students, they could teach them anything. As a newer educator, Teacher 3 expressed feeling overwhelmed with various meetings and other commitments mandated by her school system. She believed her preparation could be better if she had more time to pursue additional professional development opportunities. Teacher 4 credited the graduate coursework he completed to obtain alternative licensure as responsible for helping him extend the FoT content.

The amount of time passed since completing T&E higher education coursework was an issue highlighted by Teacher 6. He discussed how the industrial arts coursework initially had a big impact on his teaching, but as the field moved toward engineering his industrial preparation experiences became less relevant in helping inform his teaching of science content. The background Teacher 7 had with teaching FoT teacher training helped him modify lessons to apply math and science content within the curriculum as opposed to those new to the curriculum, "I would hate to come to this particular lesson without any background in teaching power and energy or understanding the nature of the FoT curriculum. This would be tough." Teacher 8 identified his high school technology education classes as most influential since they taught him technical skills needed to prepare project materials and demonstrate content to help students.

Further investigation into these informal experiences was provided by interview question 8c which asked, "What about any work or home (informal) related experiences? Did any of those informal T&E experiences inform your teaching of FoT?" Teacher 1 cited his military experience as influential for teaching him anything is possible if you put your mind to it. Teachers 1, 4, 6, and 7 believed their experiences working in technical fields either prior to entering teaching or during their summers had a great influence on their teaching of FoT. Teacher 4 worked in various phases of construction and built most of his house, which he believed was helpful in teaching parts of FoT along with his experience operating a prefabricated concrete business. Teacher 6 believed his teaching was influenced from his experience with soil and concrete testing for a geotechnology firm prior to teaching. Similar to the other teachers he also cited his experience in constructing and remodeling houses as something he draws upon to teach FoT, such as the example he seen in the observation where he related thermodynamics to heat loss in a house.

Teachers 1 and 2 believed learning from family members who were engineers helped influence their knowledge about designing and fixing technological devices. Teacher 1 picked up knowledge from one brother who was an electrical engineer and another brother who was a mechanical engineer, while Teacher 2 learned a lot from tinkering and working on home projects with his father who was a civil engineer. Additionally, Teacher 8 stated that his experiences from tinkering with materials and tools as a student helped inform his teaching of FoT.

Teacher 5 had a variety of unique informal experiences that he believed contributed to his teaching of FoT. He built houses in the summer with his high school industrial arts teacher, and built and wired speaker towers for Beatle Mania at Carnegie Mellon. Additionally, he was involved in building props that had to meet specific design constraints for theatre competitions. He stated that all of these experiences influenced him to view things in his informal life through a design and problem-solving lens:

> There was a whole lot of technical know how that I picked up along the way but most of it came from experiences in construction. What I know now spends a lot of time influencing my informal life because my thinking is totally engaging in how I solve problems. (personal communication, November 11, 2014)

The third summary of interview results presented used the following three questions to provide further detail about science preparation experiences that influenced participants' teaching of science practices:

1. Question 8b, "How do you believe your science courses and labs inform your teaching of the FoT curriculum?"
2. Question 8c, "What informal science related experiences inform your teaching of FoT?" and
3. Question 10, "How prepared are you to model science content through demonstrations and labs?"

Table 28

Summary of Interview Results for science-related preparation to Teach Science Practices

Participant	Interview Question		
	8b	8c	10
Teacher 1	• High school biology and higher education science courses • Helping with Science Olympiad	• Teaching experience • Watching Mr. Physics on the television growing up • Collaboration with physics teacher	• Comfortable but still collaborates with physics teacher when unsure of something
Teacher 2	• High school chemistry and physics courses	• Father's influence as an engineer • Tinkering with tools and materials while growing up	• Comfortable but would like to see exemplar video lessons of teaching science within FoT
Teacher 3	• Biotechnology courses did not have a significant impact	• Managing at an amusement park • Doing STEM activities with female elementary school students during her undergraduate studies	• Uncomfortable teaching science • Believed her teacher prep program was more focused on teaching technical skills than science
Teacher 4	• Experience teaching electronics • Undergraduate chemistry and physics courses	• Helping daughter with AP physics homework • Collaboration with agricultural science and physics teachers	• Comfortable with the basics, but unsure of some science content and how to demonstrate it
Teacher 5	• Importance of receiving science instruction from science educators	• Experience working in construction	• Comfortable but checks with math and science teachers • Would like to see exemplar video lessons of teaching science within FoT
Teacher 6	• Stated benefit that more physics courses in high school would have had	• Experience working at an engineering firm in the summers • Collaboration with Physics teacher	• Somewhat comfortable • Wanted more professional development and demonstrations of teaching science content within FoT

(continued)

Table 28 Continued

Participant	Interview Question		
	8b	8c	10
Teacher 7	• Did not answer	• Experience working in HVAC • Attending state science and T&E conference • Delivering FoT teacher training • Undergraduate science courses	• Comfortable from delivering the teacher training
Teacher 8	• High school physics courses	• Tinkering with tools and materials while growing up • Attending state science and T&E conference	• Uncomfortable • Expressed lack of preparation beyond high school courses

Teacher 8 believed that his high school physics courses had the greatest influence on his teaching of science practices within the curriculum, while Teacher 4 cited his prior teaching experience with electronics as helping inform his knowledge of concepts related to that topic such as magnetism. Novice Teachers 3 and 8 described that they were very uncomfortable teaching science content and demonstrating science practices within FoT. Teacher 3 viewed this as a weakness and identified it as an area of her teaching where she wishes to grow, "I feel like I'm not putting enough emphasis on that [science] part of it. That's where I need to work a little bit harder, on that part." Similar beliefs were shared by Teacher 8 who said that he did not present the laws of thermodynamics that were part of the unit, because he did not have much knowledge on the topic or how to demonstrate it. In regards to demonstrating science content he drew upon what he observed in his high school science courses. Teacher 4 believed his comfort with teaching science concepts came from his undergraduate coursework preparing him to be an engineer; however, he is still unsure about some content and does not know a good way to demonstrate it.

Further insight about the specific informal preparation experiences that informed participants teaching of science practices was teased out through interview question 8c which asked, “What about any work or home (informal) related experiences? Did any of those informal science experiences inform your teaching of FoT?” One participant spoke about his experience delivering science in-service which was consistent with the Spearman’s rho test, but many of the responses revealed experiences not reported in the survey. As mentioned in research question 1, sub-question 1, Teacher 4 found great benefit from helping his daughter with her Advanced Placement physics homework. He felt this experience provided insight about how students are having difficulty learning science content, which influenced his teaching of science practices to help FoT students better understand science concepts:

> It's neat to go through it and see what she's not getting and try and figure out why. A lot of what she does or doesn't get is going to be societal, if they're [students] not seeing a concept and I can pick some of those out they'll be useful. (Teacher 4, personal communication, November 10, 2014)

Two other teachers, one novice and one veteran instructor, stated that their attendance at the state T&E education conference was beneficial. One example provided was learning how to demonstrate the science of wind energy through a design-based windmill activity.

Although Teacher 8 found the weeklong FoT training beneficial, he did not believe it emphasized the teaching of science practices nor did it demonstrate how to teach them. Teacher 6 felt a little more comfortable in regards to teaching science content and demonstrating science practices, but he would still like to receive more professional development on how to meld hands-on T&E activities while also integrating science content, “I think the science content is needed but I don't know that it always matches up.” If he needs assistance he will research how to demonstrate science concepts online or consult his school’s physics teacher on occasion.

Teacher 1 felt comfortable demonstrating science from watching Mr. Physics growing up, but like Teacher 6, if he was unsure how to demonstrate a science concept he would borrow science equipment and lesson ideas from his school’s physics teacher. Teacher 1 also found benefit in his prior teaching experiences, specifically helping with Science Olympiad. He believed this contributed to his teaching of science practices because it taught him methods to adapt and integrate more science demonstrations into FoT lessons. Three other participants stated that they felt very comfortable teaching and demonstrating the science content that is part of FoT. Despite their comfort level with the content they still admitted to researching concepts they were unsure of or asking other teachers for help.

One example Teacher 4 gave of his personal comfort level with science was through his collaborations with the agricultural science teacher next door that focus heavily on teaching about hydroponics. Teacher 4 felt comfortable doing the technical work to run the pumps but was unsure of the nitrate levels and other factors needed to keep the fish and plants alive. He felt having that teacher teach next to him was beneficial for applying both of their STEM education knowledge. Similar to Teachers 1 and 6, he collaborates with the physics teacher at his school quite frequently.

Like Teacher 4, Teacher 7 also perceived himself as well prepared to demonstrate science content and practices due to a blend of his background working in HVAC, a little bit of higher education coursework, and serving as a FoT trainer. Although if he comes upon content he is unsure of, he will research it in preparation to teach it as opposed to visiting his school’s science teachers.

Teacher 5 also reported feeling very comfortable teaching and demonstrating science content, but he still checks in with his math and science colleagues to make sure he is introducing critical vocabulary terms that are appropriate for his students' age and grade level. He described how sometimes his math and science colleagues will come watch his lessons around a particular topic and he will go watch theirs so the content and practices are presented consistently to improve learning in all STEM education disciplines, "Kids shouldn't see them in two different ways and the closer they can see the relationship and the terminology and know the dynamics of that theory or how the principle works the stronger we all are." Observing ways to teach content and practices among science and T&E educators increased collaborative efforts beyond simply talking with science teachers, which many of the other teachers reported doing.

Due to logistical constraints such as time and location, Teachers 2 and 5 expressed that they would like to see videos of exemplar lessons provided in an online professional learning community. Specifically, they would benefit from videos that demonstrated proper methods for integrating science content and demonstrating science practices within FoT lessons. They stated that this could inform the science pedagogical and content knowledge for teachers of all experience levels.

The final synopsis of interview findings came from following four interview prompts to better examine the T&E preparation experiences that impacted participants' teaching of science practices:

1. Question 8a, "How do you believe your T&E courses and labs inform your teaching of the FoT curriculum?"
2. Question 8b, "How do you believe your science courses and labs inform your teaching of the FoT curriculum?"

3. Question 8c, “What informal T&E related experiences inform your teaching of FoT?” and
4. Question 9, “How prepared are you to model science content through demonstrations and labs?”

Table 29

Summary of Interview Results for T&E-related preparation to Teach Science Practices

Participant	Interview Question			
	8a	8b	8c	9
Teacher 1	• Learn from experiences and from others • Higher education coursework.	• Experience working in construction	• Military experience • Experience working in construction • Learning from his two brothers are engineers	• Comfortable doing T&E related demonstrations
Teacher 2	• Based on relationships with students, not preparation coursework	• High school chemistry and physics courses	• Father’s influence as an engineer • Tinkering with tools and materials while growing up	• Improved from experience teaching FoT
Teacher 3	• More time needed to pursue professional development opportunities	• Teaching science practices improved with experience using the FoT curriculum	• Doing STEM activities with female elementary school students during her undergraduate studies	• Continually improving as she teaches FoT
Teacher 4	• Graduate CTE coursework • Experience as an engineer	• Experience teaching electronics • Undergraduate chemistry and physics courses	• Experience running a pre-fabricated concrete business as an engineer	• Cost of materials prohibited him from teaching more science practices

(continued)

Table 29 Continued

Participant	Interview Question			
	8a	8b	8c	9
Teacher 4			• Experience building his house	
Teacher 5	• Preparation from technical and research universities • Observations of high school and higher education teachers as a student	• Would like to see exemplar video lessons of teaching science within FoT	• Experience building houses • Experience building and wiring speaker towers at Beatle Mania • Experience building props for theatre competitions	• Comfortable from technical and research preparation • Professional Learning Community helped him see practices and stay current
Teacher 6	• Industrial arts coursework but less impact as field moved to T&E	• Wanted more professional development and demonstrations of teaching science practices within FoT	• Experience working at an engineering firm in the summers • Experience in the home remodeling business	• Comfortable with content but often modifies practices suggested by FoT because they do not correlate well with the content
Teacher 7	• Experience teaching FoT training sessions • Experience teaching PET courses	• Experience teaching FoT training sessions	• Experience working in HVAC • Experience helping write and rewrite the FoT curriculum for EbD	• Did not answer
Teacher 8	• Hands-on teaching strategies learned through physical education preparation	• Did not believe FoT training session demonstrated how to teach science practices • Experience teaching FoT helped	• Tinkering with tools and materials while growing up • High school technology education courses	• Improved from experience teaching FoT

From the interview it was discovered that Teacher 4 believed his graduate level CTE pedagogy courses, coupled with courses from his engineering background, helped him enhance what is provided in the FoT curriculum materials through demonstrations.

Teacher 5 believed his unique preparation experiences from both technical and research universities prepared him well for various facets of his career. They gave him a good blend of technical skills needed to teach T&E, but also content knowledge in various areas of science and math needed to teach concepts such as engineering design and robotics. As a result of this experience he described characteristics of what Nespor (1987) referred to as a 12-year apprenticeship. He stated, “I knew I wanted to be a teacher and so I would watch and say that’s a part of that teacher or strategy I want to adopt. I think the biggest take away is suspending the content.” In regards to suspending the content he talked about the benefits of observing teaching practices from his higher education instructors in various content areas. From these experiences he was able to create an amalgam of what he deemed as best teaching practices for STEM content.

Teacher 8 stated that the hands-on teaching strategies learned from his preparation to be a physical education teacher prepared him with some of the pedagogical skills needed for the nature of the FoT course. Teacher 4 felt comfortable with most of the science content and giving demonstrations but said he was restricted from doing more due to the cost of materials. Teacher 6 found it difficult to teach science practices due to the disconnect between science content and science practices presented in the curriculum. The example he gave pertained to Unit 3 presenting the laws of thermodynamics, but the design challenge calls for students to construct the most efficient windmill. Even though he was willing to teach the science content in Unit 3, he believed this disconnect made it more difficult because students were not applying the content. Additionally, he said that he will sometimes modify the FoT content and design challenges to address this disconnect, however he tries to follow the curriculum as closely as possible.

Teacher 1 worked in all phases of construction, which he says he applies regularly to demonstrate examples in the FoT curriculum. Teacher 7 had a unique background as a FoT teacher trainer. He credited much of his comfort with teaching the FoT curriculum to this experience, “My preparation in FoT comes from being a trainer quite honestly and teaching other teachers this course and actually working with writing and adapting this course.” In regards to attending the FoT training, Teacher 8 did not believe it presented any practices for how to teach science content.

Teacher 3 believed that she was continually learning how to improve her teaching of T&E concepts as she gained more experience teaching the FoT curriculum. On the same note, Teacher 8 said he felt more comfortable teaching T&E education each year he has taught FoT. Since he was prepared to teach in a different discipline, he believed that teaching FoT every period for the past three years was the greatest experience for refining his T&E teaching skills.

To better learn how to teach science practices Teacher 5 said that he really values professional learning communities, and curriculum materials should be viewed as a resource. To better inform his teaching of science practices he would like to see more professional learning communities sharing videos of exemplar lessons. Teacher 6 stated he would like to see more school system-wide professional development offered to help improve his teaching practices of these newer science concepts he was not prepared to teach in his teacher preparation program.

The findings described above informed what relationships needed to be examined. Data from the TEES-PCK survey, RTOP, observations, and interviews are triangulated in the next section to better understand the strength of relationships that existed among select preparation experiences and teaching of science content and practices.

Research Questions and Sub-Questions

This study was guided by two main research questions and two sub-questions for each of the main research questions. This section details the results of data triangulation necessary to address each research question and sub-question.

Analysis Method and Assumptions

To determine the relationship between select preparation factors reported on the TEES-PCK survey and teachers' science content and practices ratings from Section IV of the RTOP, Spearman's rho analyses were conducted with significance established at the 0.05 level (Appendix O). Spearman's rho measures how strong the linear relationship is between two rank-ordered variables (Weinberg & Abramowitz, 2008), and determines a correlation coefficient based on rankings as opposed to raw data (Muijs, 2011). This correlational measure was deemed most appropriate since it matched the research questions, which examined the degrees of association among observed teaching and preparation variables. Because the observed participants were purposefully selected based on their unique TEES-PCK responses (Appendix H) the data was nonrandomized, resulting in a non-Gaussian population. In addition, the RTOP criterion scores and amount of preparation experience reported were ordinal variables that could be ranked. For the reasons mentioned above Spearman's rho was used to calculate correlational relationships in lieu of Pearson, which is used for continuous variables (Sheskin, 2011). The results of these relationship analyses are reported below according to each research question and sub-question. Following the reported Spearman's rho results for each sub-question are significant findings from the interview responses. Participant interview responses were used to corroborate these findings (Appendix L) and provide further detail about why they believed specific preparation factors had or did not have a significant influence on their teaching of science content and practices. These interview questions elicited further detail than could be extracted through only the TEES-PCK survey and observation ratings.

Research Question 1, Sub-Question 1

The first research sub-question, "What *science-related* preparation experiences inform in-service secondary level T&E educators how to *teach science content* embedded within the FoT unit?" was answered by conducting Spearman's rho correlation tests. Table 30 displays the level of correlation between number of select science courses completed by participants and their teaching of science content rating from Section IV of the RTOP. Both are ranked groups, which is why Spearman's rho was deemed appropriate for these analyses. Some of the select courses shown in Table 30 were found to have significant correlations.

Table 30

Spearman's rho Correlation Table of Number of Science Courses Completed and Teaching of Science Content

Measure	HS Physics	Total HS Science Courses	UG Physics	UG Earth Science	Total UG Science Courses	Grad Physics	Int. Sci. in T&E
Science Content							
r_s	.798	.777	.773	.718	.677	.083	-.387
p	.018	.023	.024	.045	.065	.844	.344
N	8	8	8	8	8	8	8

Note: HS = High School; UG = Undergraduate; Grad = Graduate; Int. = Integrating; Sci. = Science; T&E = Technology and Engineering Education.

The Spearman's rho (.798) between number of physics courses completed in high school and participants' teaching of science content rating was significant (.018) at the 0.05 level. The total number of science courses taken in high school was also found to have a strong positive correlation (.777) and be statistically significant (.023). These results indicate that the more science courses a T&E teacher took in high school, especially physics, the better prepared they could be expected to teach the science content embedded within the FoT curriculum. Further analysis revealed that undergraduate physics courses had a strong correlation (.773) as did undergraduate earth science courses (.718), and they both showed statistical significance of .024 and .045 respectively. The total number of science classes taken in undergraduate coursework was found to have a moderate positive correlation (.677), however it was not significant (.065) at the 0.05 level. These Spearman's rho tests signify that the number of undergraduate physics and earth science courses completed has a tendency to change with T&E educators' teaching of science content. Unlike high school and undergraduate physics courses, the number of those courses taken in teachers' graduate studies had almost no association (.083) with the teaching of science content. Furthermore, undergraduate and graduate coursework examining the integration of science in T&E education did not have a significant relationship (.344) with the teaching of science content observed.

Interview question 8b which asked about any science courses or labs that informed their teaching of FoT was used to provide more detail about these science preparation courses and corroborate the Spearman's rho findings of teaching science content. When asked what science courses or labs informed their teaching of FoT, seven participants supported the findings from the Spearman's rho analyses. Four teachers believed their knowledge about teaching science content was highly influenced by their high school science coursework, while three participants attributed their teaching of science content to higher education coursework. Consistent with the findings from the Spearman's rho, three teachers specifically cited high school physics courses as having a significant influence, while three other teachers believed higher education physics had a significant impact. These results corroborated the statistically significant strong, positive correlation found between high school and undergraduate physics courses, and teaching of science content.

To further examine factors that influence the teaching of science content, Spearman's rho was conducted between select informal science preparation experiences and participants' teaching of science content rating from Section IV of the RTOP. Some of these specific experiences were found to have a significant correlation and are displayed in Table 31.

Table 31

Spearman's rho Correlation Table of Amount of Informal Science Experiences and Teaching of Science Content

Measure	Deliver Sci. In-service	Sci. Committees	Collab. w/ Chem. Teacher	Length of FoT Training	Helped with No Clubs	No Sci. PD
Science Content						
r_s	.765	.704	.679	-.668	.718	-.798
p	.027	.051	.064	.070	.045	.018
N	8	8	8	8	8	8

Note: Sci. = Science; Collab. w/ = Collaborates with; PD = Professional Development.

The delivery of science in-service training had a strong positive correlation (.765) with teaching of science content and was statistically significant (.027). This would suggest that those teachers who deliver science professional development would be expected to demonstrate higher ratings for teaching science content. The number of science committees on which participants served also had a strong correlation (.704) with the teaching of science content, however it was just above the .05 statistical significance threshold (.051). Therefore, it can be assumed that the greater number of science committees on which a T&E teacher serves, the better prepared they may be for teaching science content within FoT. Analysis between collaboration with a chemistry teacher at a T&E educator's school and their teaching of science content revealed a moderate positive correlation (.679) but was not significant (.064). This signifies there is a relationship between the amount of time T&E teachers spent collaborating with chemistry teachers and their observed ratings of teaching certain science content within FoT. The Spearman's rho for not participating in any science professional development substantiates previous findings for this sub-question (Table 30) as it showed a significantly (.018) strong negative correlation (-.798) with observed teaching of science content ratings (Table 31). As a result, participation in science professional development activities and level of teaching science content would be expected to decrease together. In contrast to the other data presented that showed an association between science experiences and increase in science content rating, those who did not help with any after school science clubs had a strong correlation (.718) and significant (.045) association with the observed rating for teaching science content. This means that as the amount of after school science clubs decreased, the rating for teaching of science content would be expected to increase. The Spearman's rho also revealed a moderate negative correlation (-.688) among the length of time teachers spent at FoT training and their science content teaching rating. Although it was not significant (.070), it does propose that the more time spent at FoT training would not increase one's RTOP rating for teaching science content.

To obtain more information about informal preparation experiences, interview question 8c asked which informal science experiences influenced participants' teaching of science content embedded within FoT. Participants shared details about a wealth of influential informal science preparation experiences that were not captured in the survey. Only one participant (Teacher 7) corroborated the statistically significant relationship that delivering science in-service sessions had with teaching science practices. He believed this enhanced his knowledge of the FoT curriculum, allowing him to have a better understanding of the embedded science content. Other participant responses differed from the significant Spearman's rho findings. Four participants cited prior work experience in a STEM-related field as significant, and two participants believed their ability to tinker with scientific tools and materials as a child helped teach them about science concepts.

Research Question 1, Sub-Question 2

The second research sub-question for the first main research question, "What *T&E-related* preparation experiences inform in-service secondary level T&E educators to *teach science content* embedded within the FoT unit?" was answered by again running Spearman's rho analyses since the amount of courses, informal experiences, and RTOP ratings were ordinal. To first investigate this research question, the amount of various T&E courses were analyzed among participants' teaching of science content ratings.

Table 32

Spearman's rho Correlation Table of Number of T&E Education Courses Completed and Teaching of Science Content

Measure	HS IA	HS TE	UG Elec.	UG PET	UG Robotics	Grad PET	Grad Robotics
Science Content							
r_s	.394	-.397	.389	.110	.741	.083	.584
p	.334	.331	.341	.795	.035	.844	.128
N	8	8	8	8	8	8	8

Note: HS = High School; IA = Industrial Arts; TE = Technology Education; UG = Undergraduate; Elec. = Electronics; PET = Power, Energy, and Transportation.

Analyses revealed that the only high school, undergraduate, or graduate courses which significantly impacted T&E educators' teaching of science content were undergraduate robotics courses. There was a strong positive correlation between number of undergraduate robotics courses and teaching of science content; the Spearman's rho was .741 and was significant with a p-value of .035. Further analysis revealed that number of graduate robotics courses had a moderate positive correlation (.584) but was not significant (.128). These findings suggest that the number of higher education robotics courses completed have a tendency to change at a comparable rate to one's teaching of science content within these FoT lessons. Surprisingly, undergraduate (r_s=.110) and graduate (r_s=.083) Power, Energy, and Transportation (PET) courses were found to have negligible insignificant relationships with T&E educators' teaching of science content within the observed lessons. Unlike the strong significant correlations between high school science courses and T&E educators' teaching of science content, the number of high school industrial arts and technology education courses completed were found to have weak and insignificant association with teaching of science content. From this it can be concluded that students taking more T&E courses will not necessarily be better prepared to teach science content embedded within curricula like FoT.

Interview question 8a, which examined T&E teacher preparation courses and labs that informed the teaching of FoT, was used to provide more detail about these T&E courses and corroborate the Spearman's rho findings of their influence on teaching science content. When asked how they believed their T&E education courses and labs informed their teaching of FoT, participant responses varied from the Spearman's rho results. In the correlational analysis the only T&E course found to have a strong positive relationship with teaching science content was undergraduate robotics. However in the interviews, most participants felt their industrial arts or T&E education courses and labs had a significant effect on their teaching of the FoT curriculum. Specifically, Teachers 5 and 8 believed their high school technology education courses were influential, while three participants felt their graduate coursework in this area had a strong impact. None of these courses revealed statistical significance from the Spearman's rho analysis.

In order for the researcher to further examine this sub-question he had to use Spearman's rho to look for strength of relationships between ordinal amounts of informal T&E experiences and ratings for teaching of science content. These experiences, some of which were found to have positive correlations and significant results, are displayed in Table 33.

Table 33

Spearman's rho Correlation Table of Amount of Informal T&E Experiences and Teaching of Science Content

Measure	Collab. w/ T&E Teacher	Mentor T&E Teacher	Deliver T&E In-Service	Hours in T&E Dis. Group	Helped with No Clubs
Science Content					
r_s	.633	.765	.883	.517	.718
p	.092	.027	.004	.190	.045
N	8	8	8	8	8

Note: Clubs = After school clubs; T&E = Technology and Engineering Education; Collab. w/ = Collaborates with; Dis. = Discussion.

The Spearman's rho between amount of time T&E educators spend collaborating with their counterparts and their rating for teaching science content was .633. Although this showed a moderate positive correlation it was not statistically significant (.092), indicating that teaching of science content does not significantly increase from collaborating with T&E teachers. It was found that if a T&E educator mentored another T&E teacher, this had a strong positive correlation (.765) and was statistically significant (.027), meaning that the amount of time spent mentoring a T&E teacher and the mentor's science content rating would increase together. Delivering T&E education in-service also had similar results yielding a very strong positive correlation (.883) and statistical significance (.004) to suggest that FoT teachers' rating for teaching science content will increase with the amount of T&E education in-service they deliver. Additionally, the number of hours that teachers spent in a T&E education discussion group proved to have a moderate positive correlation (.517) but was not significant (.190) at the 0.05 level. This would indicate that teaching of science content may be positively impacted by the number of hours spent in a T&E discussion group, but not at a statistically significant level. Lastly, identical to the relationship reported for helping with after school science clubs and teaching of science content (Table 31), it was determined that those teachers who did not help with any after school T&E clubs had a statistically significant (.045) strong positive correlation (.718) with teaching of science content (Table 33). From this it could be concluded that the amount of time teachers spent helping with T&E clubs had a tendency to increase or decrease at an opposite rate of their demonstrated level of teaching science content.

Further investigation into these informal experiences was provided by interview question 8c which asked about informal T&E experiences that participants believed informed their teaching of FoT. The participating teachers reported a wealth of informal T&E preparation experiences that did not emerge from the survey but informed their teaching of science content within FoT. Teacher 7 was the only participant to support the statistically significant relationship between delivering T&E in-service sessions and teaching science practices. He believed his experience teaching the FoT teacher training sessions in the summers gave him a better understanding of the science content in the curriculum. Other participants provided an array of responses that differed from the Spearman's rho findings. Four participants cited prior work experience in a STEM-related field as significant, and two participants believed their ability to tinker with technological tools and materials as a child gave them a better understanding of science content from its technical application.

Research Question 2, Sub-Question 1

The second main research question focused on T&E educators' teaching of science practices within the FoT curriculum. Within this second research question, the first sub-question, "What *science-related* preparation experiences inform in-service secondary level T&E educators how to *teach science practices* embedded within the FoT unit?" was analyzed by again using Spearman's rho tests. For the first analyses, the correlations between select ordinal science courses and RTOP ratings for demonstrated science practices were investigated (Table 34).

Table 34

Spearman's rho Correlation Table of Number of Science Courses Completed and Teaching of Science Practices

Measure	HS Physics	HS Chemistry	Total HS Science Courses	UG Physics	UG Earth Science	UG Chemistry	Grad Physics	Int. Sci. in T&E
Science Practices								
r_s	.866	.704	.755	.783	.783	.695	.085	-.447
p	.005	.051	.030	.022	.022	.056	.842	.267
N	8	8	8	8	8	8	8	8

Note: HS = High School; UG = Undergraduate; Grad = Graduate; Int. = Integrating; Sci. = Science; T&E = Technology and Engineering Education.

Similar to the Spearman's rho findings for research question one sub-question one (Table 30), there were some comparable results for this research question. Again, high school physics, total high school science, undergraduate physics, and undergraduate earth science courses all showed strong positive correlations with teaching science practices and were significant at the 0.05 level. The item with the strongest correlation (.866) and highest significance (.005) was the amount of high school physics classes completed. Based on these results, a T&E educator's rating for teaching science practices would have a tendency to increase and decrease with all of the courses mentioned above. Also similar to the findings in Table 30 were the insignificant relationship that graduate physics courses (.842) and any higher level education course regarding the integration of science within T&E education (.267) had had with teaching science practices (Table 34). Graduate physics courses had a negligible correlation (.085), and similar to the interesting results from Table 30, courses about integrating science within T&E education also had a moderate negative correlation of -.387 (Table 34).

The analyses for this research question did reveal some findings that differed from research question one, sub-question one. High school chemistry and undergraduate chemistry courses were found to have a strong positive correlation (.704 and .695 respectively), but were both just above the 0.05 threshold for statistical significance (.051 and .056 respectively). Due to the strong positive correlations, these analyses would suggest that T&E educators' teaching of science practices increase or decrease with the number of high school or undergraduate chemistry courses completed.

Interview questions 8b, "How about any science courses and labs you had, how do you believe those inform your teaching of the FoT curriculum" and 10, "What about your preparation to teach the science content in this lesson? How prepared are you to model this content through demonstrations and labs?" helped confirm the strong influence of select high school and higher education science courses that resulted from the Spearman's rho test. Three teachers believed their high school physics courses were influential, while 2 participants felt their undergraduate physics coursework had a significant effect. Even Teacher 6 who did not have any physics courses in high school stated that he believed that would have been beneficial in helping teach science practices embedded within FoT. These claims corroborated the statistical significance revealed from the Spearman's rho. Although high school and undergraduate chemistry courses were not found to be statistically significant, they did have a strong positive correlation with teaching science practices. Teacher 2 supported this finding with his belief that his high school chemistry courses had a substantial impact, while Teacher 4 felt that his undergraduate chemistry courses influence his teaching of science practices.

Furthermore, the interviews revealed that only one participant felt comfortable to teach science practices because of his experience delivering the FoT teacher training sessions each summer. Three participants felt comfortable teaching science practices and still collaborated with the physics teachers at their school, while three other teachers were not comfortable teaching science practices embedded within FoT.

These interview responses helped delve further into how science coursework influenced participants' preparation for teaching science practices. In addition to examining select science courses, the researcher wanted to examine other informal science preparation factors that could influence T&E educators' teaching of science practices. Spearman's rho was again determined adequate for this analysis since the occurrence of experiences and rating of science practices were both ordinal. Table 35 displays the results from these tests.

Table 35

Spearman's rho Correlation Table of Amount of Informal Science Experiences and Teaching of Science Practices

Measure	Deliver Sci. In-service	Sci. Committees	Mixed Conf. Sessions	Length of FoT Training	Helped with No Clubs	No Sci. PD
Science Practices						
r_s	.775	.811	.635	.803	.783	-.635
p	.024	.015	.091	.016	.022	.091
N	8	8	8	8	8	8

Note: Clubs = After school clubs; Sci. = Science; PD = Professional Development; Mixed Conf. Sessions = Attended a mix of Science, and Technology and Engineering Conference Sessions.

Similar to the results found in research question one, sub-question one (Table 31) that examined teaching of science content, there was a strong positive correlation (.775) between delivering science in-service and teaching of science practices significant (.024) at the 0.05 level. This signifies that teaching of science practices can be expected to increase or decrease with the amount of science in-service delivered. The number of science committees served on was found to have a very strong positive correlation (.811) with science practices, however unlike the results from Table 31, this analysis was statistically significant (.015). From this it can be concluded that T&E educators' rating for science practices and number of science committees they serve on increases or decreases together. The Spearman's rho found a moderate positive correlation (.635) between attendance of mixed conferences sessions and teaching of science practices, but it was insignificant (.091) at the 0.05 level. In contrast to the findings reported for science content (Table 31), the length of FoT training revealed a strong positive correlation (.803) with teaching of science practices, which was statistically significant (.016). This indicates that the T&E educators' rating for science practices increases or decreases together with the length of FoT training attended. Additionally, results similar to those shown in Table 31 regarding science content were reported in Table 35, which found that there was a strong positive correlation (.783) between not helping with any after school science clubs and science practices ratings. This elicited a statistical significance of .022, suggesting that higher ratings for teaching of science practices can be expected in conjunction with less time spent helping with after school science clubs. One final analysis showed a moderate negative correlation (-.635) among science practices ratings and not participating in any science professional development. This was not significant (.091), however it does suggest that science practices ratings increase as participation in science professional development decreases.

Further insight about the specific informal science preparation experiences that informed participants teaching of science practices were teased out through interview question 8c. One participant supported the significant finding from the Spearman's rho test regarding delivery of science in-service sessions. He expressed how influential the delivery of FoT teaching trainings were for his own teaching of science practices. Additionally, two teachers cited the importance of attending a state conference with science and T&E education sessions. This corroborates the moderate, positive correlation that mixed conference sessions had with teaching of science practices. Participants also provided influential factors that were not found to be statistically significant in the Spearman's rho analysis. Three participants felt that collaborating with the physics teacher at their school was very helpful, and three teachers believed prior STEM-related work experience helped them teach science practices. No participant interview responses corroborated the statistical significance of serving on science committees or the length of FoT training attended. This lead to the examination of the final research question and sub-question examining the relationship among T&E preparation experiences and teaching of science practices.

Research Question 2, Sub-Question 2

The last research sub-question, "What *T&E-related* preparation experiences inform in-service secondary level T&E educators how to *teach science practices* embedded within the FoT unit?" was answered by once again running Spearman's rho tests because of the ordinal data being analyzed. As with research question one, sub-question two, this question first examined teaching of science practices through its relationship with T&E coursework.

Table 36

Spearman's rho Correlation Table of Number of T&E Education Courses Completed and Teaching of Science Practices

Measure	Degree in IA	UG Elec.	UG PET	UG IA Methods	UG Robotics	Grad PET	Grad Robotics
Science Practices							
r_s	.671	.400	.000	.662	.751	.085	.592
p	.069	.326	1.0	.074	.032	.842	.122
N	8	8	8	8	8	8	8

Note: IA = Industrial Arts; UG = Undergraduate; Elec. = Electronics; PET = Power, Energy, and Transportation; Grad = Graduate.

Similar to the results for teaching of science content (Table 32), the only T&E course found to have a significant influence (.032) on the teaching of science practices was undergraduate robotics (Table 36). This course was found to have a strong positive correlation (.751), meaning that the rating for science practices and number of undergraduate robotics courses completed increase or decrease together. Graduate robotics courses did not have a significant association (.122) with teaching science practices, but did have a moderate positive association (.592). This would also suggest that the number of robotics courses taken at this level would be expected to increase the teaching of science practices within the observed FoT lessons. Additionally, undergraduate PET (.000) and graduate PET (.085) coursework had a negligible relationship with observed science practices, and undergraduate coursework in electronics had a moderate positive correlation (.400) while none were found to be statistically significant. These results indicate that the number of undergraduate and graduate PET, and undergraduate electronics courses do not increase significantly enough to expect increases in science practices ratings. Spearman's rho did find that those who possessed a degree in industrial arts or took methods courses about teaching industrial arts showed strong positive correlations with teaching science practices at .671 and .662 respectively, but were not statistically significant. This suggests that those prepared in industrial arts and who have taken methods courses in this area would be expected to exhibit higher ratings in teaching of science practices related to the FoT lessons observed. Other possible reasons for these results are discussed in Chapter 5.

Interview questions 8a, "How do you believe your T&E education courses and labs inform your teaching of the FoT curriculum?" and 9, "Describe how you feel about your preparation to model the T&E content in this lesson through demonstrations and labs?" helped the researcher ask more detailed questions about the influence of select T&E education courses in regards to teaching science practices. Similar to research question 1, sub-question 2, the only course with a strong positive correlation was undergraduate robotics, which was not corroborated by any of the participants in the interviews. Three teachers who possessed industrial arts degrees did state the significant of their college coursework which supported the moderate, positive correlation revealed in the Spearman's rho analysis. However, Teacher 6 said that despite his industrial arts coursework having a significant impact, it has been less influential as the field has moved from an industry to a T&E focus. Only three participating teachers said they felt comfortable with teaching the science practices embedded within FoT. Despite not revealing significance from the Spearman's rho results, three participants expressed that experience teaching FoT was very influential and was also the greatest factor for improving their teaching of science practices within FoT.

The second portion of this final analysis examined the relationship between informal T&E preparation experiences and teaching of science practices. The findings from these tests are shared in Table 37.

Table 37

Spearman's rho Correlation Table of Amount of Informal Technology and Engineering Experiences and Teaching of Science Practices

Measure	Helped with TSA	Helped with No Clubs	Collab. w/ T&E Teacher	Mentor T&E Teacher	Deliver T&E In-Service	Hours in T&E Dis. Group	T&E Conf. Sessions
Science Practices							
r_s	-.645	.783	.720	.645	.894	.517	-.635
p	.084	.022	.044	.084	.003	.190	.091
N	8	8	8	8	8	8	8

Note: TSA = Technology Student Association; Clubs = After school clubs; T&E = Technology and Engineering Education; Conf. Sessions = Attended a mostly Technology and Engineering Education Conference Sessions; Collab. w/ = Collaborates with.

As displayed in Table 33, the delivery of T&E education in-service and helping with no after school T&E clubs had a statistically significant correlation with teaching of science content. Similar results were uncovered in relation to the teaching of science practices (Table 37). The amount of hours spent delivering T&E education in-service had a very strong positive correlation (.894) with the ratings for science practices and was statistically significant (.003). This indicates that T&E educators who spend more hours delivering T&E education in-service would be expected to demonstrate higher levels science practices. Also consistent with Table 33 was the finding that helping with no after school T&E education clubs had a strong positive relationship (.783) with teaching of science practices and was statistically significant (.022). Ironically, this would suggest that the less T&E after school clubs a teacher helps with, the greater proficiency they would demonstrate in teaching of science practices. Identical to the finding regarding science content was the moderate positive relationship (.517) between hours spent in a T&E education discussion group and demonstrated science practices (Table 37). Although this was not statistically significant (.190), its relationship would suggest hours in these types of discussion groups and science practices tend to increase and decrease together in a non-proportional manner. Spearman's rho analyses also revealed some different influential preparation factors for better teaching of science practices in comparison to teaching of science content. It was found that collaborating with T&E educators had a strong positive correlation (.720) with science practices ratings and was statistically significant (.044) at the 0.05 level. The sheds light on a new finding that science practices ratings would increase with the amount of time spent collaborating among other T&E educators. In Table 33 there was a moderate positive relationship found between this factor and teaching science content but it was not significant. Also presented in that table is the significant correlation between mentoring T&E teachers and science content. In this group of analyses (Table 37) it was found that mentoring another T&E educator had a moderate positive association with teaching science practices but was not statistically significant (.084). This would indicate that mentoring other T&E educators has a insignificant positive effect on T&E educators' teaching of science practices. Further analyses discovered two experiences that had moderate negative correlations with teaching of science practices. The first was helping with a Technology Student Association (TSA) club at the T&E

educator's school. This had a Spearman's rho of -.645 but was not significant (.084). This would suggest that T&E educators with higher science practices ratings would be less likely to have helped with TSA in the past three years. The final Spearman's rho found a moderate negative correlation between science practices and attendance of mostly T&E conference sessions. Therefore, it would be expected to find decreasing science practices as T&E educators attend solely T&E conference sessions as opposed to more mixed sessions like reported in Table 37.

This final sub-question was complemented with interview questions 8b, "How do you believe any science courses and labs you had inform your teaching of the FoT curriculum?" and 8c, "What informal T&E related experiences do you believe inform your teaching of FoT?" which provided more information about the informal T&E preparation experiences that influenced participants teaching of science practices. Although interview question 8b asked about formal science experiences, some participants shared informal T&E education related experiences during their response, hence why it was used to help answer this sub-question.

Sprearman's rho tests between collaborating with T&E educators and delivering T&E in-service produced significant correlations. However, during the interview session only one teacher corroborated the influence of delivering T&E in-service. Various influential factors discussed by participants during the interview were found to be common among participants but were not found significant in the Spearman's rho analyses. Three teachers believed their experience working in construction or engineering prior to teaching was helpful, while two believed experience teaching FoT was beneficial. Additionally, six participants described the resources they needed to help them adequately teach science practices. Five specifically requested professional development in the form of online videos that show how to properly conduct the demonstrations needed to teach science practices within FoT. One teacher cited the cost of materials as prohibitive from incorporating more science practices in his teaching. The requests for additional resources indicated that participants needed help to adequately teach the science practices embedded within the FoT curriculum. Implications for addressing these requests will be presented in Chapter 5.

Triangulation of data from the TEES-PCK survey, RTOP, and interview responses painted a much richer picture of what preparation experiences teachers perceive as beneficial compared to what was found to be significant from the Spearman's rho tests. The most significant findings are summarized in the next section.

Summary of Research Sub-Questions

In the following section a brief summary of the key findings from the Spearman's rho tests and interview responses for each sub-question is provided.

Research Question 1, Sub-Question 1

Findings from the Spearman's rho correlation tests revealed that there were numerous science-related preparation experiences that had a strong positive relationship with participants' teaching of science content. Those experiences included:

- amount of high school physics courses,
- amount of science professional development participated in,
- total high school science courses,
- undergraduate physics courses,
- amount of science in-service delivered,
- undergraduate earth science courses, and
- not helping with science after school clubs

All of the aforementioned preparation experiences had a statistically significant relationship (Tables 30 & 31). Further analysis examining informal science preparation experiences found strong positive correlations between teaching of science content and number of science committees served on, amount of time collaborating with the chemistry teacher at their school, and not helping with any after school science clubs. However, none of these experiences were found to be statistically significant. Additionally, it was found that no science professional development had a statistically significant strong negative correlation with teaching of science content.

Participant interview responses supported the science coursework findings. Most reiterated the influence that high school physics classes had on teaching science content embedded within FoT. Even those who did not have physics in high school stated that they wish they had taken more of it. Their responses about FoT being more reliant on physics as opposed to biology also supported the findings from the Spearman's rho tests which found physics courses to have a statistically significant influence whereas biology courses did not.

In the interviews participants did not mention any of the informal experiences that were found to have strong positive correlations from the Spearman's rho tests. The influential informal science preparation experience cited most among the teachers was experience from teaching and prior jobs. These jobs ranged from working with a geotechnology firm to working with elementary STEM education students through an undergraduate project.

Research Question 1, Sub-Question 2

Results from the Spearman's rho correlation tests revealed that there were numerous T&E-related preparation factors that had a strong positive relationship with participants' teaching of science content. The only formal experience that had a statistically significant correlation with teaching science content was number of undergraduate robotics courses taken. A separate Spearman's rho test examined informal T&E experiences with strong positive correlations that were statistically significant. These experiences included:

- amount of T&E in-service delivered,
- mentoring other T&E teachers, and
- not helping with any after school T&E clubs

Participant interview responses revealed a number of preparation experiences which they believed were influential in their teaching of science content. Interestingly, the only experience found to have a significant relationship (undergraduate robotics courses) was not discussed in any of the participant interviews. The majority of participants cited high school and higher education T&E education courses as being most influential, but due to the evolution of T&E education over the years, they believed professional development was necessary to remain current on new content and practices. One teacher identified their completion and teaching of the FoT teacher training as influential of their science content knowledge. No FoT training, high school T&E education, or higher education T&E education courses were found to have a strong positive correlation except robotics, which was not mentioned by any of the teachers in their interview.

When participants were asked about which informal T&E experiences inform their teaching of science content, half cited their experiences working in technical fields such as construction. Two participants cited family members as influential since they were engineers, and two teachers believed tinkering or playing with materials and tools as a child played helped them develop. A wealth of other various informal T&E experiences were mentioned by one participant which were unique and he believed developed his "technical know how." All of these experiences shared in the interviews were unique from the Spearman's rho test and allowed participants a chance to explain personal experiences that were not collected through the TEES-PCK survey.

Research Question 2, Sub-Question 1

Findings from the Spearman's rho correlation tests revealed that there were numerous science-related preparation experiences that were found to have a statistically significant strong positive relationship with participants' teaching of science practices. Those factors included:

- amount of high school physics courses,
- amount of science committees served on,
- length of FoT training attended,
- amount of undergraduate physics and earth science courses,
- helping with no after school science clubs.
- amount of science in-service delivered, and
- total amount of high school science courses

From the interviews it emerged that most participants had some level of discomfort about teaching science practices within FoT. They identified it as an area they would like to improve if provided the proper resources (e.g., time to collaborate and plan, quality professional development). In regards to coursework which influence their teaching of science practices, the results were similar to research question 1, sub-question 1. They confirmed the strong influence of high school physics courses, and higher education science courses that was found from the correlation test. Also, two participants believed their teaching experience with electronics courses before the curriculum shifted to FoT influenced their teaching of science practices in Units 3 and 4.

Despite the variance in preparation to teach and model science content, almost all participants admitted to collaborating with science teachers (specifically physics) in their school when in need of assistance. One participant described his involvement with teaching science in-service as influential which corroborated the results from the Spearman's rho test. Two participants mentioned the benefit of attending a professional T&E conference with science sessions, which the Spearman's rho revealed was not statistically significant but had a moderate positive correlation. Participants also cited other experiences as influential despite not showing a strong level of correlation from the Spearman's rho analysis. These items included helping family members with science homework, science-related work experience, and collaborating with science teachers. Additionally, most teachers stated the need for various forms of professional development (e.g., online resource materials, exemplar science in FoT demonstration videos on the EbD learning community website, school system training, time to collaboratively plan and teach with physics teachers) to better and more accurately teach science content and practices embedded within FoT. More details about these professional development needs were expressed in responses to interview question 11, which is addressed in Chapter 5.

Research Question 2, Sub-Question 2

Findings from the Spearman's rho correlation tests revealed that there were quite a few T&E preparation factors that had a strong positive relationship with participants' teaching of science practices. The only statistically significant T&E course that showed a strong positive relationship with teaching science practices was the amount of undergraduate robotics courses completed. However, a greater number of informal experiences were found to have strong positive correlations with teaching science practices:

- amount of T&E in-service delivered,

- amount of time spent collaborating with T&E teachers, and
- not helping with any after school T&E clubs.

Like the results in research question 1, sub-question 2, undergraduate robotics was the only course to show significantly positive correlations in the Spearman's rho tests but was never mentioned in the interviews. Participants shared that graduate level CTE pedagogy courses had an influence. Although these courses were not found to have a strong correlation in the Spearman's rho, undergraduate industrial arts methods courses did show a moderate positive correlation. Also, participants believed courses in engineering and T&E research were influential in their teaching of science practices.

The interview questions seeking more information about informal preparation experiences elicited an array of information as they did in research question 1, sub-question 2. Regarding informal T&E experiences, teachers reaffirmed some of the findings from the Spearman's rho test that were found to have strong positive correlations with teaching science practices. Those experiences included delivering T&E education in-service, mentoring and collaborating with T&E educators, and spending time in a T&E discussion group or personal learning community. One participant believed that delivering the FoT teacher training was extremely beneficial, while another who was an attendee did not think the training demonstrated how to teach science practices. Another informal experience participants believed was influential but did not show a significant relationship from the Spearman's rho test was experience teaching the curriculum.

Summary of Findings

The synthesis of data analyzed from the FoT unit plan, online survey, classroom observations, and interviews were presented in Chapter 4 to answer two main research questions and four sub-questions. Existing survey, observation, and interview instruments needed to be adapted to meet the needs of this study; therefore, the pilot study helped to establish instrument reliability and provide the researcher experience using them. After utilizing the pilot study to establish credibility of the instruments, quantitative and qualitative data were mixed throughout the collection and analyses stages.

Demographic Data: Key Findings

The quantitative survey results presented in this chapter provided a snapshot of the vast preparation experiences reported by FoT teachers from a small sample within a Mid-Atlantic state. Demographic data from the survey indicates that participating FoT teachers consisted of mostly:

- Caucasian males,
- mean age of 43,
- mean teaching experience of 13 years,
- 55% taught high school technology education in a suburban setting,
- 73% completed a teacher preparation program,
- 44% possessed at least a master's degree,
- most held degrees in technology education (68%), industrial arts (17%), or administration (15%),
- 84% were certified to teach T&E education,
- 51% had attended some form of FoT training,
- 42% had low self-efficacy and intermediate expected outcomes, and
- 53% had intermediate self efficacy and expected outcomes.

Participants completed an array of courses in their high school, undergraduate, and graduate studies. Among the most frequently reported were:

- high school biology, chemistry, earth science, and industrial arts courses,
- undergraduate biology, electronics, PET, algebra, methods of teaching industrial arts, and methods of teaching T&E education courses,
- graduate level physics, biology, electronics, PET, statistics, methods of teaching industrial arts, and methods of teaching T&E education courses, and
- 73% took a course on integrating science concepts within T&E education.

Lastly, teachers reported participating in a variety of informal preparation experiences, of which the most common were:

- 58% did not help with any after school clubs,
- 40% spent ≤ 35 hours reading T&E literature while 22% spent ≥6 hours reading science literature,
- 75% attended T&E workshops while 65% attended science workshops,
- 42% delivered T&E in-service sessions,
- 73% participated in T&E teacher collaborative networks while 38% participated in science teacher collaborative networks,
- 53% mentored or observing a T&E teacher,
- 67% consulted a T&E curriculum specialist while 33% consulted with a science curriculum specialist,
- 45% served on T&E committees,
- 27% attended state T&E conference while attending mostly (35%) T&E conference sessions, and

- collaborated most frequently with T&E, business, physics, and mathematics educators.

Analyzing these survey data helped to identify and select eight participants with unique preparation characteristics to observe teaching an FoT lesson.

Observation Data: Key Findings

The findings from the RTOP classroom observation ratings indicate that T&E teachers displayed much lower levels of teaching science content and practices than T&E content and practices. Rationales for the ratings of each teacher were provided through detailed observation descriptions and student-teacher vignettes (Appendix O) from the lesson. These vignettes offered authentic classroom examples that showed how teachers provided good instruction in science content and practices, or how they could have enhanced the lesson in these areas. Overall, participants exhibited the following scores on the RTOP:

- highest ratings in T&E content (μ=13.6),
- lowest ratings in teaching of science practices(μ=5.8),
- lesson design and implementation ratings were low (μ=6.6)
- T&E practices rating (μ=7.6) lower than teaching of science content (μ=9.6),
- highest scoring teacher (118) was from the veteran category, and
- lowest rating (18) also achieved by a veteran teacher.

Conclusions drawn from these findings are presented in Chapter 5 along with limitations associated with using the RTOP as it was used in this study. To examine potential preparation experiences that influence these observed teaching characteristics, correlation tests were conducted.

Correlation Data: Key Findings

Spearman's rho analyses were used to look for relationships that existed between the preparation data reported in the survey, and the observed teaching of science content and practices recorded using the RTOP instrument. Corroborative analyses provided more detail about these relationships by mixing qualitative data from the FoT lesson plan analyses, observation audio recordings and notes, and interview data with the Spearman's rho test results. This mixed analysis helped answer the following two overarching research questions guiding this study.

RQ1: To what extent do select teacher preparation factors inform in-service secondary level T&E educators how to teach science content in T&E education classrooms? The five preparation experiences found to have the most significant influence according to p-values ranging from .004 to .024 were:

- amount of T&E in-service delivered,
- number of high school physics courses,
- participation in some form of science professional development,
- total high school science courses, and
- number of undergrad physics courses.

Interviewees confirmed the impact of high school science courses, especially physics. Additional influential factors mentioned in the interviews were prior science and T&E work experience (e.g., construction, engineering), high school and higher education T&E education courses, collaborating with family members who were engineers, and tinkering with materials and tools growing up.

RQ2: To what extent do select teacher preparation factors inform in-service secondary level T&E educators how to teach science practices in T&E education classrooms? The six preparation experiences found to be the most significantly correlated as established from p-values of .003 to .022 were:

- amount of T&E in-service delivered,
- number of high school physics courses,
- amount of science committees involved with,
- length of FoT training attended,
- number of undergraduate physics courses, and
- number of undergraduate earth science courses.

Results from participant interviews supported the significant influence that high school science courses, higher education science courses, and the delivery of science in-service had on their teaching of science practices. Additional influential factors that were highlighted throughout the interviews were prior experience teaching electronics courses, attending professional STEM education association conferences, and collaborating with T&E and physics teachers.

The findings derived from this study clearly indicate that there are specific formal and informal preparation experiences in science and T&E that have a significant influence on the ability of T&E educators to teach science content and practices within FoT. Conclusions, implications, and recommendations drawn from these analyses are discussed in the next chapter.

CHAPTER FIVE: CONCLUSIONS, IMPLICATIONS, AND RECOMMENDATIONS

This chapter discusses conclusions, implications, and recommendations derived from the research. The conclusions presented in this chapter are based on the findings and analyses from the previous chapter, and focus on answering the sub-questions through their respective main research questions. Implications resulting from these conclusions are presented for future research and practice, followed by recommendations to apply these findings to research and practice. Recognizing there are inherent limitations and imposed delimitations of this research, the following conclusions, implication, and recommendations were drawn from data collected in the survey, observations, and interviews.

Conclusions

From the findings presented in Chapter 4 it can be concluded that in spite of having completed sufficient science content coursework, T&E educators did not demonstrate the level of science PCK needed to adequately teach the science content and practices embedded within technology education curricula such as FoT. Conversely, participants did demonstrate adequate levels of T&E PCK needed to teach essential T&E content within the FoT curriculum. While not generalizable to a larger population, the demographics from this study paint a broad picture of those teaching the FoT curriculum within the participating school systems. However, the sample selected for this research was representative of the demographics from national T&E education studies (Ernst, 2014).

Moreover, the content analysis of the curriculum conducted prior to the observations determined that very little science content and practices were intentionally integrated in the FoT Units. Borne out through corroboration from careful analysis of the FoT curriculum, a valid conclusion would be that science is not emphasized consistently throughout the curriculum to help students make the critical connections among STEM disciplines. Further conclusions regarding participants' preparation experiences, or lack thereof, contributing to T&E educators' science PCK are explained in greater detail according to the two main research questions.

Main Research Question 1

The first overarching research question directing this study was "What teacher preparation factors inform in-service secondary level technology and engineering (T&E) educators how to teach *science content* in T&E education classrooms?" and was answered through analyzing two research sub-questions. What follows are detailed explanations of the conclusions drawn from these analyses.

Several science and T&E preparation factors were found to be statistically significant and displayed strong relationships with the teaching of science content (Tables 30, 31, 32, & 33). From this data it was concluded that the key to preparing T&E teachers who are competent in the teaching of science content is ensuring their preparation experiences include an increased amount of high school science courses (especially physics), and undergraduate courses in physics, earth science, and robotics. Additional informal preparation experiences which are significant in preparing T&E teachers to adequately teach science content are increased participation in: science professional development, teaching of science and T&E education in-service sessions, mentoring other T&E educators, work experience in technical fields, and tinkering with tools and materials as a child. According to findings from this study the more one partakes in these experiences, the better prepared they will be to teach science content.

From analysis of interview data it was concluded that the amount of prior work experience in technical fields helps to inform teachers' science content knowledge and technical know-how, which contributes to more proficient teaching of science content. Furthermore, the triangulated data (Tables 26, 27, 31, & 33) led to the conclusion that not helping with after school science or T&E clubs leads to better teaching of science content because teachers can spend this time participating in other significant preparation experiences.

Main Research Question 2

The second overarching research question guiding this study was "What teacher preparation factors inform in-service secondary level T&E educators how to teach *science practices* in T&E education classrooms?" and was answered through the synthesis of two research sub questions. What follows are detailed descriptions about the conclusions drawn from these analyses.

Results from the survey and RTOP instruments revealed that T&E educators are not comfortable with nor adequately prepared for teaching science practices (Tables 21, 22, & 23). This indicates that T&E educators need more preparation on how to teach concepts and/or constructs through science practices, such as labs or demonstrations.

Numerous science and T&E preparation factors were found to be statistically significant and exhibited strong relationships with the teaching of science practices. From these data (Tables 34, 35, 36, & 37) it was concluded that the key to preparing T&E teachers who are competent in the teaching of science practices is ensuring their preparation experiences include an increased amount of high school science courses (especially physics), and undergraduate courses in physics and earth science. Additional informal preparation experiences which are needed to prepare T&E teachers to adequately teach science practices are increased participation in: teaching of science and T&E education in-service sessions, serving on science education committees, length of the FoT training they attend, and mentoring and collaborating with other T&E teachers. The study suggests that the more time T&E educators spend engaged in these experiences, the better prepared they will be for teaching science practices. Lastly, the triangulated data (Tables 28, 29, 35, & 37) concluded that teachers who did not help with after school science or T&E clubs demonstrated better teaching of science practices because they claimed to use this time participating in other significant preparation experiences.

Overlapping Conclusions

Variables which overlapped both main research questions emerged from triangulation of the data (Tables 30, 31, 32, 33, 34, 35, 36, & 37). Conclusions drawn from triangulation of those data contributing to T&E educators' teaching of science content and practices are as follows:

- Amount of T&E in-service delivered and the amount of high school physics courses completed are the two greatest predictors for T&E teachers' ability to teach science content and practices.
- Number of undergraduate physics courses revealed significant correlations with the teaching of science content and practices suggesting that these courses are also strong predictors of one's ability to teach those science concepts addressed in the FoT curriculum.
- Although less significant than the aforementioned experiences, the amount of science in-service delivered is another predictor of T&E educators' proficiency in teaching science content and practices.
- Number of undergraduate robotics courses showed the only statistically significant correlation among T&E coursework and teaching of science content and practices. As confirmed through the interviews, the application of electronics theory in a hands-on context like this is beneficial for teaching the science that is part and parcel of T&E concepts.

- The triangulated data from this study and recent research (Love & Loveland, 2014) indicate that veteran teachers attend more science and T&E conferences than novice teachers, and these experiences have a strong positive relationship with educators' levels of teaching science content and practices.
- From the observations and interviews it can be concluded that knowledge of the FoT curriculum is influential in one's teaching of science content and practices. Teachers 4, 5, and 7 had an increased understanding of the FoT curriculum and received higher RTOP ratings in comparison to other participants which they attributed to their experiences with helping write the EbD assessment items, delivering the FoT training, and contributing to the writing and piloting of lessons. Teachers 3 and 8 who received low RTOP ratings felt more competent at teaching the science content within FoT each year as they gained experience with the curriculum.

The triangulation of data also concluded that the following overlapping variables do not significantly contribute to T&E educators' teaching of science content and practices:

- Graduate level science courses do not have a significant effect on teaching of science content and practices.
- Coursework teaching about the integration of science within T&E is not beneficial as exhibited by its moderately negative relationship with teaching of science content and practices.
- Undergraduate and graduate Power, Electronics, and Transportation (PET), electronics, and electrical engineering courses did not have a significant effect, leading to the conclusion teaching of science content and practices is not

emphasized enough in these courses. It can also be concluded that those delivering these T&E teacher preparation courses are lacking adequate science preparation and PCK to demonstrate the necessary teaching of embedded science concepts.

- The significance of robotics courses completed was not corroborated as influential for teaching of science during the interviews. The importance of these courses was not mentioned by any participants.
- As shown through the Spearman's rho analyses and explained in the interviews, the less time teachers spend helping with science and T&E after school clubs the more proficient they are at teaching science content and practices. Teachers who did not partake in after school clubs stated that they spent that time after school participating in other informal preparation experiences.

These conclusions provide the basis for implications regarding improvement of future research and practice, as presented in the following section.

Implications

The conclusions reached in this study have specific implications for T&E education teacher preparation. This study provides data (Tables 23, 28, 29, & Appendix O) exposing strengths and weaknesses in T&E educators' teaching of science content and practices. Implications to build upon these strengths and address the weaknesses through select preparation experiences are:

1. Data from the observations and interviews indicate that T&E teacher preparation programs are adequately preparing educators to teach key T&E content within T&E curricula like FoT.

2. The observations revealed that all T&E educators attempted to teach science content and practices to some extent regardless of their preparation experiences, and in the interviews they expressed a willingness and interest in teaching embedded science concepts. However, their low RTOP scores imply that the pre- and in-service training, and curricular resources they receive are not adequately helping them teach science content and practices at a higher level.
3. Given the results pertaining to T&E teachers, there is an equal likelihood that because science educators do not have the key technology and/or engineering preparation experiences, they too are likely unprepared to teach the engineering content and practices as mandated by the NGSS.
4. Results from the TEES-PCK suggest the need to recruit younger and more diverse (race and gender) T&E educators, whether through teacher preparation or alternative licensure programs. These individuals could in turn serve as role models to recruit diverse students to become T&E educators (Ilumoka, 2012). This may help enhance STEM literacy for all students and better prepare them for a competitive global economy.
5. Data from the content analysis, observations, and interviews imply that T&E educators are not expected to fully teach science content and practices because it is not emphasized at a level that would maximize on helping students make interdisciplinary connections. This also implies that teachers are not receiving adequate training in teaching science content and practices at the FoT trainings since it is not a major focus of the curriculum.

6. The relationship found between select high school and undergraduate science courses, and T&E educators' teaching of science concepts demonstrate that they are relying on episodic storage to teach how they observed science being taught (Nespor, 1987; Shulman, 2004). This provides important implications for ensuring instructors are teaching the proper content and pedagogical methods in these courses.
7. The insignificant influence that graduate level science coursework had on the teaching of science content and practices implies that science content courses at this level are not a viable means for improving T&E educators teaching of science concepts because: (a) these courses occur later in teacher's educational studies and (b) these courses are not being taught in a manner which helps pre-service teachers determine how to effectively integrate science content and practices into their lessons. This reinforces the importance for teacher preparation programs to require adequate amounts of science coursework early on, specifically at the undergraduate level.
8. As a result of the insignificant influence that undergraduate electronics and PET courses had on teaching the science within FoT lessons on electricity and energy, these courses are not emphasizing the teaching of pertinent science concepts. Additionally, the significance of undergraduate robotics courses implies that other courses should emphasize similar methods for applying science content.
9. Given the negative association with coursework teaching how to integrate science concepts within T&E education, such courses are inaccurately teaching how to integrate science concepts within T&E education.
10. Triangulation of data indicates that more opportunities for T&E educators to attend and deliver science professional development sessions, serve on science education

committees, and mentor other T&E teachers should be provided to increase their teaching of content and practices that results from collaborative interactions.

11. The triangulated data from this study and other recent research (Love & Loveland, 2014) revealed implications for state science and T&E conferences to enhance T&E educators' science PCK from interactions with science educators.
12. Not participating in after school clubs revealed the importance of T&E educators carefully allocating their time to preparation experiences that are most beneficial for them. This indicates the importance of designing succinct in-service preparation experiences that demonstrate the proper methods to teach science content and practices.
13. Given the influence that curricular knowledge and experience had on delivering science concepts within FoT, educating T&E teachers about specific curricula they will be expected to teach is important so they can devote more focus to improving their PCK.

Recommendations are given in the next section to guide researchers and practitioners in addressing these implications.

Recommendations

Based on the implications of this study the following actions are recommended for researchers, T&E educators, supervisors/administrators, and teacher educators to improve the teaching of science content and practices within T&E education.

Recommendations for Researchers

The following recommendations for further research resulted from the findings and conclusions of this study.

1. To enhance consistency among observation ratings, an Operationalized RTOP Criteria Rubric should be created for Sections III and V based upon criterion from the RTOP Reference Manual (Sawada et al., 2000).
2. To remove redundancy, maintain a higher level of attention from participants for the entire interview, and focus on select preparation factors that influence the teaching of science content and practices, the following interview questions should be condensed:
   - 5a and 7,
   - 6a, 7a, 8a, and 8b, and
   - 8a, 9, and 10
3. To increase response rates in future studies, the length of the TEES-PCK survey should be shortened to only include items necessary for those specific studies.
4. Allowing more opportunities for participants to demonstrate teaching of content and practices is needed. Teachers should be observed for a minimum of two to three class periods in future studies.
5. The Spearman's rho tests conducted among select preparation factors and observation scores in this study do not show causality; therefore, further analysis is needed to investigate the level of causality or linkage among these factors.
6. The relationship among graduate level science courses and teaching of science concepts warrants further studies investigating the insignificant influence these courses were found to have on teaching science content and practices.
7. Given the absence of statistical significance between teaching science and higher education courses completed in electronics and PET, further research must be

conducted to examine the science PCK of T&E teacher educators delivering these courses and their emphasis on embedded science concepts.

8. With the recent implementation of the NGSS, a replication study should be conducted to examine select preparation factors that inform science educators' teaching of engineering content and practices.
9. Although it was not part of this study, classroom observations revealed T&E educators did not demonstrate the level of PCK needed to adequately teach mathematics content and practices embedded within FoT. A content analysis examining these embedded concepts should be conducted to help add a mathematics section to the modified RTOP used in this study. Theoretically, this would result in an instrument that could examine T&E educators' STEM education PCK, and it should be used in a replication study to investigate T&E educators' teaching of mathematics content and practices.

Recommendations for Practitioners

The following recommendations generated from the findings and conclusions of this study are geared toward T&E educators, supervisors/administrators, and teacher educators.

1. To increase diversity in T&E education, teacher preparation institutions should implement strategies for recruiting an increased amount of female and minority students and faculty while also working to retain these individuals.
2. The data calls for revisions to the FoT curriculum to intentionally integrate miniature science labs or demonstrations that explicitly help students make connections to T&E concepts across FoT units. Such revisions should be aligned with the *Standards for Technological Literacy* benchmarks and NGSS disciplinary core ideas for grade band 9-12. In addition, FoT teachers must be taught how to properly teach these science

and T&E concepts concurrently during FoT training and school system in-service sessions.

3. Triangulated data from the RTOP and interviews suggest reducing the amount of units to cover in the FoT curriculum since it serves as a survey course to introduce students to the core technologies. Reducing the number of units would allow T&E educators more time to teach embedded science concepts in greater depth.
4. As determined by the Spearman's rho analyses and corroborated through the interviews, the greatest influence of teaching science content and practices was amount of high school and higher education physics courses completed. Therefore, T&E educators should take additional physics courses at these levels to better prepare them for teaching science concepts embedded in T&E curricula.
5. Given data from this study and other recent studies (Litowitz, 2013, 2014) a minimum of two undergraduate physics courses and one earth science course are needed to adequately teach the science concepts embedded within T&E education. It is also recommended that teacher preparation programs require students to complete at least one biology or biotechnology course.
6. As shown from the survey, interviews, and Spearman's rho analyses, various forms of T&E and science education professional development are significantly influential in one's ability to teach science concepts. These professional development sessions must be designed to develop knowledge about the curriculum as well as explicitly demonstrate the appropriate methods to teach science content and practices within T&E curricula.

7. From the interviews teachers cited the need for an online repository of videos that demonstrate the proper methods to teach science content and practices embedded within T&E curricula.
8. School systems should initiate and provide mentoring opportunities for T&E educators to collaborate with each other and science educators.
9. T&E educators should seek opportunities and be encouraged by their administrators to serve on science education committees.
10. Administrators and school systems should encourage and support T&E educators, especially novice T&E teachers, to attend state science and T&E conferences.
11. In addition to providing support for teachers to attend state science and T&E conferences, school systems must offer more science professional development opportunities at times when T&E educators can be required to attend.
12. Administrators and school systems need to be mindful when requesting teachers to allocate time toward after school activities so they can participate in additional preparation experiences that better enhance their teaching of science content and practices.
13. To help decrease the curricular knowledge learning curve and allow new teachers to focus on improving their science PCK, T&E teacher preparation programs should offer coursework exposing their students to the various state and national curricula they may be expected to teach.

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ADDENDUM

In acknowledgement of the requirement to share this research with participating school systems, this addendum was created to explicitly caution schools, administrators, teachers, and researchers about the use of data or instruments derived from this study. The addendum presents limitations regarding the generalizability of the findings, and precautions for interpreting the data and using the instruments.

Participants in this study were limited to high school level T&E educators teaching FoT within 12 school systems from a Mid-Atlantic state. Although many but not all school systems within the state agreed to participate, the distribution of the T&E teachers was disproportionate. Despite attempting to obtain a reasonable sample to examine the problem, the results cannot be generalized to teachers from the entire state or other states. Additionally, many researchers have shown PCK to be topic specific (Phillips et al., 2009; Rohaan et al., 2011; Williams & Lockley, 2012), therefore findings from this study cannot be generalized beyond the teaching of science content and practices within the FoT curriculum. For a more generalizable study, further research should seek to include statewide, nationwide, and international T&E educator participants.

As Sawada et al. (2000) cautioned, the RTOP instrument should not be used to evaluate teachers, which was also not the intended purpose for the modified RTOP employed in this study. It was utilized strictly to examine T&E educator's level of teaching science content and practices within the FoT curriculum. Despite the low observation scores recorded for many participants (Table 23), this should not be viewed as an indication of their overall teaching ability. When interviewed about how they believed the lesson went, many participants cited student engagement and classroom management as key factors for their decision. While these items play a role in scoring some of the RTOP criterion, they were not the sole focus of this study to answer the research questions and sub-questions. Administrators and school systems may place more emphasis on these items when evaluating these teachers. The low mean score (59.4/140) for participants in this study should not be misinterpreted as indicating they were poor teachers. Rather, it should only be used to draw conclusions about their level of teaching science content and practices for that observed lesson. RTOP ratings for these teachers could vary based on different curricula or lessons. Observations of participants teaching lessons from two distinct curricula could help further determine the influence that curricular knowledge (Shulman, 1987) plays in teaching science content and practices.

Furthermore, it must be cautioned that the statistical significance found among select preparation factors and observation scores from the Spearman's rho tests do not indicate that these criterion are linked. They merely suggest a relationship exists between these specific factors, meaning that as one variable increases, the other variable increases or decreases with it. Further analysis is needed to determine the level of causality or linkage among these factors.

APPENDICES

APPENDIX A

Virginia Tech Institutional Review Board (IRB) Approval Letter

VirginiaTech

Office of Research Compliance
Institutational Review Board
North End Center, Suite 4120, Virginia Tech
300 Turner Street NW
Blacksburg, Virginia 24061
540/231-4606 Fax 540/231-0959
email irb@vt.edu
website http://www.irb.vt.edu

MEMORANDUM

DATE: April 16, 2014

TO: John Wells, Tyler Scott Love

FROM: Virginia Tech Institutional Review Board (FWA00000572, expires April 25, 2018)

PROTOCOL TITLE: An Examination of the Preparation Experiences that Contribute to the Teaching Strategies Demonstrated by Technology and Engineering Educators

IRB NUMBER: **14-217**

Effective April 15, 2014, the Virginia Tech Institution Review Board (IRB) Chair, David M Moore, approved the New Application request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at:

http://www.irb.vt.edu/pages/responsibilities.htm

(Please review responsibilities before the commencement of your research.)

PROTOCOL INFORMATION:

Approved As:	**Expedited, under 45 CFR 46.110 category(ies) 5,6,7**
Protocol Approval Date:	**April 15, 2014**
Protocol Expiration Date:	**April 14, 2015**
Continuing Review Due Date*:	**March 31, 2015**

*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

FEDERALLY FUNDED RESEARCH REQUIREMENTS:

Per federal regulations, 45 CFR 46.103(f), the IRB is required to compare all federally funded grant proposals/work statements to the IRB protocol(s) which cover the human research activities included in the proposal / work statement before funds are released. Note that this requirement does not apply to Exempt and Interim IRB protocols, or grants for which VT is not the primary awardee.

The table on the following page indicates whether grant proposals are related to this IRB protocol, and which of the listed proposals, if any, have been compared to this IRB protocol, if required.

Invent the Future

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
An equal opportunity, affirmative action institution

APPENDIX B

Virginia Tech IRB Amendment Request Approval Letter

Office of Research Compliance
Institutional Review Board
North End Center, Suite 4120, Virginia Tech
300 Turner Street NW
Blacksburg, Virginia 24061
540/231-4606 Fax 540/231-0959
email irb@vt.edu
website http://www.irb.vt.edu

MEMORANDUM

DATE: September 4, 2014

TO: John Wells, Tyler Scott Love

FROM: Virginia Tech Institutional Review Board (FWA00000572, expires April 25, 2018)

PROTOCOL TITLE: An Examination of the Preparation Experiences that Contribute to the Teaching Strategies Demonstrated by Technology and Engineering Educators

IRB NUMBER: **14-217**

Effective September 4, 2014, the Virginia Tech Institution Review Board (IRB) Chair, David M Moore, approved the Amendment request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at:

http://www.irb.vt.edu/pages/responsibilities.htm

(Please review responsibilities before the commencement of your research.)

PROTOCOL INFORMATION:

Approved As:	**Expedited, under 45 CFR 46.110 category(ies) 5,6,7**
Protocol Approval Date:	**April 15, 2014**
Protocol Expiration Date:	**April 14, 2015**
Continuing Review Due Date*:	**March 31, 2015**

*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

FEDERALLY FUNDED RESEARCH REQUIREMENTS:

Per federal regulations, 45 CFR 46.103(f), the IRB is required to compare all federally funded grant proposals/work statements to the IRB protocol(s) which cover the human research activities included in the proposal / work statement before funds are released. Note that this requirement does not apply to Exempt and Interim IRB protocols, or grants for which VT is not the primary awardee.

The table on the following page indicates whether grant proposals are related to this IRB protocol, and which of the listed proposals, if any, have been compared to this IRB protocol, if required.

APPENDIX C

Prize Pack Request to Kelvin® Educational

Virginia Tech
College of Liberal Arts and Human Sciences

Integrative STEM Education Program
317 War Memorial Hall (0313)
Blacksburg, Virginia 24061
www.soe.vt.edu/istemed

June 28, 2014

Mr. Tyler S. Love
Graduate Assistant, Ph.D. Candidate
905 Allendale Court
Blacksburg, VA 24060
tslove@vt.edu

Avi Hadar
CEO
Kelvin® Company
280 Adams Blvd
Farmingdale, NY 11735

Dear Mr. Hadar,

My name is Tyler Love and I am currently a graduate assistant pursuing my Ph.D. in Integrative STEM education at Virginia Tech. I completed my undergraduate degree in Technology Education at the University of Maryland Eastern Shore (UMES), and it was there that I met Mike Shealey. Upon graduation from UMES I taught technology education in the Maryland Public School System and frequently ordered materials from Kelvin® to help prepare students to be more STEM literate citizens. I am currently in the final year of my Ph.D. program and will be collecting data this fall about technology educators for my dissertation.

As you may be aware, the Next Generation Science Standards have called for science educators to teach engineering design without input from technology educators and how they have been teaching it since the release of the Standards for Technological Literacy in 2000. My dissertation is investigating the other side of this issue: How technology educators are teaching the science concepts that are part of the engineering lessons they deliver. Specifically I'm focusing on instructors who teach the Engineering by Design curriculum from ITEEA, which is rich in math and science concepts delivered through engaging engineering design activities like those sold by Kelvin®. This study will require teachers to voluntarily participate in a survey, a classroom observation, and an interview during their busy school day. To show my appreciation for their willingness to participate, I would like to raffle off some gift cards for them to buy classroom materials from Kelvin®. I was wondering if Kelvin® would be willing to donate six gift cards for $50 as an incentive for technology educators to participate in this study which aims to advance teaching and learning in STEM education. For your generosity and support, I would include your name within the acknowledgements section of my dissertation, thanking you for the gift cards. Thank you and Kelvin® for your consideration and supporting STEM education teachers and students.

Sincerely,

Tyler S. Love

Tyler S. Love

Invent the Future

APPENDIX D

Teacher Recruitment Letter

VirginiaTech
College of Liberal Arts
and Human Sciences

Integrative STEM Education Program
317 War Memorial Hall (0313), Blacksburg, Virginia 24061
Email: tslove@vt.edu
www.soe.vt.edu/istemed

Dear Technology Educator,

My name is Tyler Love and I am a doctoral candidate in the Integrative STEM Education program at Virginia Tech conducting research for my dissertation. You are receiving this recruitment letter because you were identified as a high school Technology and Engineering educator who teaches the International Technology and Engineering Education Association's (ITEEA) Foundations of Technology (FoT) curriculum. What follows is a brief description of the study, and should you have any questions or concerns feel free to contact me at tslove@vt.edu. I look forward to receiving your survey response. The survey can be accessed at: https://virginiatech.qualtrics.com/SE/?SID=SV_5hzzShGLoEhg2tn

Title of Study: An Examination of the Preparation Experiences that Contribute to the Teaching Strategies Demonstrated by Technology and Engineering Educators (IRB #14-217)

Research Investigators:
Dr. John Wells, Assoc. Prof, Integrative STEM Education (540.231.8471/jgwells@vt.edu)
Tyler S. Love, Ph.D. Candidate, Integrative STEM Education (717.304.5869/tslove@vt.edu)

I. General Information Regarding Research Studies
A research study is an organized investigation designed to reveal new information about a problem or question. The research goal of a study is to use the information gained from the study to improve our understanding regarding a specific aspect of the human condition. Below you will find details specific to this study. Participation within this study is voluntary.

II. Purpose of this Research
The purpose of this study is to examine strategies that Technology and Engineering educators use to teach the FoT curriculum. This study will investigate potential connections between Technology and Engineering educators' formal and informal teacher preparation experiences and the strategies they use to teach.

III. Procedures
Approval to conduct research has been obtained from your school system. As a result, participants will be contacted via email to complete a short online survey. After completing the online survey participants may be contacted to schedule a date and time for the informal observation of a lesson at their school. Prior to engaging in the observation, participants will be asked to acknowledge their verbal consent. During the observation the teacher will be audio recorded while the researcher observes and takes notes to later analyze their teaching strategies. At the completion of the observation, a brief semi-structured interview will be conducted with the participant and audio recorded to describe their teacher preparation experiences and reflect on the lesson. The data collection procedures described above will take place between September and December 2014.

Integrative STEM Education Program
317 War Memorial Hall (0313), Blacksburg, Virginia 24061
Email: tslove@vt.edu
www.soe.vt.edu/istemed

IV. Risks
There are minimal to no risks associated with participation in this study. However, there is always some possibility that previously unknown or uncommon risks be associated with your personal participation within this study. Therefore, you should report any concerns to the researcher.

V. Benefits
There are no tangible benefits for participating within this study. This research will instead contribute to the body of new knowledge regarding Technology and Engineering Education.

VI. Compensation
Participants who complete the online survey will be entered in a drawing for one of six gift cards to buy $50 worth of classroom materials from Kelvin.

VII. Confidentiality
Each participant will be assigned a participant number and/or pseudonym within written records or reports. The identifying information of all participants and school systems will be confidential. The researcher will not divulge the participants' real names at any point within the study. Only the researcher will have access to participant names and information. The researcher will secure and store all sources of identifiable information. Sources of study data will be retained until all presentations, publications, reports, and professional development resulting from the study are complete, or for a minimum of 5 years. At no time will the researchers release the results of the study to anyone other than individuals working on the project without participant written consent. However, because the Institutional Review Board (IRB) is responsible for the oversight of the protection of human subjects involved in research, it is possible that they may view this study's collected data for auditing purposes.

VIII. Freedom to Withdraw
Participants are free to withdraw from this study at any time without penalty.

IX. Participant's Responsibilities
You voluntarily agree to participate in this study. You have the following responsibilities: Complete a brief online demographic and teaching preparation survey. If randomly selected, allow the researcher to observe a lesson at your school and answer interview questions following the lesson.

A committee to protect participants' rights and welfare reviews all research on human volunteers. For questions or concerns about the rights of study participants you may contact the Virginia Tech Institutional Review Board:

Dr. David M. Moore
Chair, Virginia Tech Institutional Review Board for the Protection of Human Subjects
(540) 231-4606
moored@vt.edu
www.irb.vt.edu

APPENDIX E

FoT Content Analyses

Unit 3: Energy and Power

Day 1

Science Content Lesson Observations

Term	# 6	# 7	# 8	# 9	# 10
0^{th} Law of Thermodynamics					
1^{st} Law of Thermodynamics					
Kinetic Energy					
Potential Energy					
Energy Transfer					
2^{nd} Law of Thermodynamics					
Work					
Internal Energy					
3^{rd} Law of Thermodynamics					

T&E Content Lesson Observations

Term	# 11	# 12	# 13	# 14	# 15
0^{th} Law of Thermodynamics					
1^{st} Law of Thermodynamics					
Kinetic Energy					
Potential Energy					
Energy Transfer					
2^{nd} Law of Thermodynamics					
Work					
Internal Energy					
3^{rd} Law of Thermodynamics					

Science Practices Lesson Observations

Term	# 16	# 17	# 18	# 19	# 20
0th Law of Thermodynamics					
1st Law of Thermodynamics					
Kinetic Energy					
Potential Energy					
Energy Transfer					
2nd Law of Thermodynamics					
Work					
Internal Energy					
3rd Law of Thermodynamics					

T&E Practices Lesson Observations

Term	# 21	# 22	# 23	# 24	# 25
0th Law of Thermodynamics					
1st Law of Thermodynamics					
Kinetic Energy					
Potential Energy					
Energy Transfer					
2nd Law of Thermodynamics					
Work					
Internal Energy					
3rd Law of Thermodynamics					

Day 2

Science Content Lesson Observations

Term	# 6	# 7	# 8	# 9	# 10
Conversion of Energy					
Source					
Process					
Load					
Combustion					
Atoms					
Vibration/ Movement of Atoms					
Conductor					
Molecules					
Bonds					
Nucleus					

T&E Content Lesson Observations

Term	# 11	# 12	# 13	# 14	# 15
Conversion of Energy					
Source					
Process					
Load					
Combustion					
Atoms					
Vibration/ Movement of Atoms					
Conductor					
Molecules					
Bonds					
Nucleus					

Science Practices Lesson Observations

Term	# 16	# 17	# 18	# 19	# 20
Conversion of Energy					
Source					
Process					
Load					
Combustion					
Atoms					
Vibration/ Movement of Atoms					
Conductor					
Molecules					
Bonds					
Nucleus					

T&E Practices Lesson Observations

Term	# 21	# 22	# 23	# 24	# 25
Conversion of Energy					
Source					
Process					
Load					
Combustion					
Atoms					
Vibration/ Movement of Atoms					
Conductor					
Molecules					
Bonds					
Nucleus					

Day 3

Science Content Lesson Observations

Term	# 6	# 7	# 8	# 9	# 10
Thermal Energy					
Radiant Energy					
Electrical Energy					
Mechanical Energy					
Chemical Energy					
Electromagnetic Energy					
Transverse Waves					
Biomass					
Nonrenewable Energy					
Fossil Fuels					
Emissions					
Hybrid Vehicle					
Uranium					
Fission					
Hydroelectric Power					
Converting					
Energy Flow Diagram					
Sankey diagram					

T&E Content Lesson Observations

Term	# 11	# 12	# 13	# 14	# 15
Thermal Energy					
Radiant Energy					
Electrical Energy					
Mechanical Energy					
Chemical Energy					
Electromagnetic Energy					
Transverse Waves					
Biomass					
Nonrenewable Energy					
Fossil Fuels					
Emissions					
Hybrid Vehicle					
Uranium					
Fission					
Hydroelectric Power					
Converting					
Energy Flow Diagram					
Sankey diagram					

Science Practices Lesson Observations

Term	# 16	# 17	# 18	# 19	# 20
Thermal Energy					
Radiant Energy					
Electrical Energy					
Mechanical Energy					
Chemical Energy					
Electromagnetic Energy					
Transverse Waves					
Biomass					
Nonrenewable Energy					
Fossil Fuels					
Emissions					
Hybrid Vehicle					
Uranium					
Fission					
Hydroelectric Power					
Converting					
Energy Flow Diagram					
Sankey diagram					

T&E Practices Lesson Observations

Term	# 21	# 22	# 23	# 24	# 25
Thermal Energy					
Radiant Energy					
Electrical Energy					
Mechanical Energy					
Chemical Energy					
Electromagnetic Energy					
Transverse Waves					
Biomass					
Nonrenewable Energy					
Fossil Fuels					
Emissions					
Hybrid Vehicle					
Uranium					
Fission					
Hydroelectric Power					
Converting					
Energy Flow Diagram					
Sankey diagram					

Unit 4: Troubleshooting (Electronics)

Day 1

Science Content Lesson Observations

Term	# 6	# 7	# 8	# 9	# 10
Tolerance					
Diode					
Resistor					
LED					
Switch					
Electrons					
Flow of Electrons					
Direct Current					
Alternating Current					
Atom					
Proton					
Electron					
Ion					
Neutron					
Insulator					
Conductor					
Semiconductor					

T&E Content Lesson Observations

Term	# 11	# 12	# 13	# 14	# 15
Tolerance					
Diode					
Resistor					
LED					
Switch					
Electrons					
Flow of Electrons					
Direct Current					
Alternating Current					
Atom					
Proton					
Electron					
Ion					
Neutron					
Insulator					
Conductor					
Semiconductor					

Science Practices Lesson Observations

Term	# 16	# 17	# 18	# 19	# 20
Tolerance					
Diode					
Resistor					
LED					
Switch					
Electrons					
Flow of Electrons					
Direct Current					
Alternating Current					
Atom					
Proton					
Electron					
Ion					
Neutron					
Insulator					
Conductor					
Semiconductor					

T&E Practices Lesson Observations

Term	# 21	# 22	# 23	# 24	# 25
Tolerance					
Diode					
Resistor					
LED					
Switch					
Electrons					
Flow of Electrons					
Direct Current					
Alternating Current					
Atom					
Proton					
Electron					
Ion					
Neutron					
Insulator					
Conductor					
Semiconductor					

Day 2

Science Content Lesson Observations

Term	# 6	# 7	# 8	# 9	# 10
Ohm's Law					
Voltage					
Current					
Resistance					
Series Circuit					
Parallel Circuit					
Multimeter					
Flow Chart					
Energy Source/Battery					
Negative					
Positive					
Opposite Charge					
Repel					
Imbalance					
Valance ring					
Rings					
Amps					

T&E Content Lesson Observations

Term	# 11	# 12	# 13	# 14	# 15
Ohm's Law					
Voltage					
Current					
Resistance					
Series Circuit					
Parallel Circuit					
Multimeter					
Flow Chart					
Energy Source/Battery					
Negative					
Positive					
Opposite Charge					
Repel					
Imbalance					
Valance ring					
Rings					
Amps					

Science Practices Lesson Observations

Term	# 16	# 17	# 18	# 19	# 20
Ohm's Law					
Voltage					
Current					
Resistance					
Series Circuit					
Parallel Circuit					
Multimeter					
Flow Chart					
Energy Source/Battery					
Negative					
Positive					
Opposite Charge					
Repel					
Imbalance					
Valance ring					
Rings					
Amps					

T&E Practices Lesson Observations

Term	# 21	# 22	# 23	# 24	# 25
Ohm's Law					
Voltage					
Current					
Resistance					
Series Circuit					
Parallel Circuit					
Multimeter					
Flow Chart					
Energy Source/Battery					
Negative					
Positive					
Opposite Charge					
Repel					
Imbalance					
Valance ring					
Rings					
Amps					

Day 3

Science Content Lesson Observations

Term	# 6	# 7	# 8	# 9	# 10
Capacitor					
Potentiometer					
Photocell					
Capacitor					
Speaker					
Diode					
SCR					
NPN					
PNP					
Oscillator					
Watt					
Schematic					

T&E Content Lesson Observations

Term	# 11	# 12	# 13	# 14	# 15
Capacitor					
Potentiometer					
Photocell					
Capacitor					
Speaker					
Diode					
SCR					
NPN					
PNP					
Oscillator					
Watt					
Schematic					

Science Practices Lesson Observations

Term	# 16	# 17	# 18	# 19	# 20
Capacitor					
Potentiometer					
Photocell					
Capacitor					
Speaker					
Diode					
SCR					
NPN					
PNP					
Oscillator					
Watt					
Schematic					

T&E Practices Lesson Observations

Term	# 21	# 22	# 23	# 24	# 25
Capacitor					
Potentiometer					
Photocell					
Capacitor					
Speaker					
Diode					
SCR					
NPN					
PNP					
Oscillator					
Watt					
Schematic					

APPENDIX F

Permission to Use the STEBI Instrument

VirginiaTech
Invent the Future

Tyler S Love <tslove@vt.edu>

STEBI Permission and Scoring Guide

6 messages

Tyler S Love <tslove@vt.edu> Sun, Mar 2, 2014 at 7:40 PM
To: iriggs@csusb.edu, enochsl@onid.orst.edu

Dr. Riggs and Dr. Enochs,

I am writing for permission to use your STEBI (1990) instrument in my dissertation survey. I was also wondering if you could please send me the scoring guide or direct me to where I can find it.

Thank You,
Tyler S. Love
Graduate Assistant, Ph.D. Candidate
Integrative STEM Education Program
Virginia Tech

LARRYENOCHS <enochsl@onid.orst.edu> Sun, Mar 2, 2014 at 8:47 PM
To: Tyler S Love <tslove@vt.edu>

No problem. It should be in the article. If not let me know.

Larry G Enochs
Professor Emeritus
Science and Mathematics Education
Oregon State University
Corvallis, OR 97331

APPENDIX G

TEES-PCK Survey Instrument

Survey Exported from Qualtrics

Welcome Thank you for your interest in completing this survey. It is being conducted by Tyler Love for his dissertation and will be used to examine STEM teaching and learning as well as conduct research that may be published. Your participation is completely voluntary and anonymous.   This survey consists of 8 sections of questions, each with a different focus. The progress bar at the bottom will show how far along you've advanced through the entire survey. Please pay attention to the focus of each section. You may save your survey responses at any point and complete the remaining questions at your convenience. The entire survey takes about 20 minutes, and those that complete it will be entered in a drawing to win one of six Kelvin® prize packs which includes $50 of classroom materials. Thank you for participating in this survey and your contribution to help learn more about STEM education.

Section 1 In order to contact participants who are selected for the non-evaluative classroom observation and interview portion of the study, I'm asking you to please provide your name and school email address. All identifying information will be removed from the data before it is shared with anyone to ensure anonymity of the participants.

1.1 What is your First and Last name?

1.2 What is your school email address at which you may be contacted?

Section 2 The next 25 questions ask about you as a Technology and Engineering education (T&E) teacher, or the outcome you would expect due to a T&E educator.

2.1 Please indicate the degree to which you agree or disagree with each statement below by selecting the appropriate letters to the right of each statement.

SA= Strongly Agree **A**= Agree **UN**= Uncertain **D**= Disagree **SD**= Strongly Disagree

When a student does better than usual in T&E, it is often because the teacher exerted a little extra effort. (1)	❍ SA (1)	❍ A (2)	❍ UN (3)	❍ D (4)	❍ SD (5)
I am continually finding better ways to teach T&E. (2)	❍ SA (1)	❍ A (2)	❍ UN (3)	❍ D (4)	❍ SD (5)
Even when I try very hard, I don't teach T&E as well as I do most subjects. (3)	❍ SA (1)	❍ A (2)	❍ UN (3)	❍ D (4)	❍ SD (5)
When the T&E grades of students improve, it is most often due to their teacher having found a more effective teaching approach. (4)	❍ SA (1)	❍ A (2)	❍ UN (3)	❍ D (4)	❍ SD (5)
I know the steps necessary to teach T&E concepts effectively. (5)	❍ SA (1)	❍ A (2)	❍ UN (3)	❍ D (4)	❍ SD (5)
I am not very effective in monitoring T&E design activities. (6)	❍ SA (1)	❍ A (2)	❍ UN (3)	❍ D (4)	❍ SD (5)
If students are underachieving in T&E, it is most likely due to ineffective T&E teaching. (7)	❍ SA (1)	❍ A (2)	❍ UN (3)	❍ D (4)	❍ SD (5)
I generally teach T&E ineffectively. (8)	❍ SA (1)	❍ A (2)	❍ UN (3)	❍ D (4)	❍ SD (5)

The inadequacy of a student's T&E background can be overcome by good teaching. (9)	❍ SA (1)	❍ A (2)	❍ UN (3)	❍ D (4)	❍ SD (5)
The low T&E achievement of some students cannot generally be blamed on their teachers. (10)	❍ SA (1)	❍ A (2)	❍ UN (3)	❍ D (4)	❍ SD (5)
When a low achieving child progresses in T&E, it is usually due to extra attention given by the teacher. (11)	❍ SA (1)	❍ A (2)	❍ UN (3)	❍ D (4)	❍ SD (5)
I understand T&E concepts well enough to be effective in teaching elementary T&E. (12)	❍ SA (1)	❍ A (2)	❍ UN (3)	❍ D (4)	❍ SD (5)
Increased effort in T&E teaching produces little change in some students' T&E achievement. (13)	❍ SA (1)	❍ A (2)	❍ UN (3)	❍ D (4)	❍ SD (5)
The teacher is generally responsible for the achievement of students in T&E. (14)	❍ SA (1)	❍ A (2)	❍ UN (3)	❍ D (4)	❍ SD (5)
Students' achievement in T&E is directly related to their teacher's effectiveness in T&E teaching. (15)	❍ SA (1)	❍ A (2)	❍ UN (3)	❍ D (4)	❍ SD (5)
If parents comment that their child is showing more interest in T&E at school, it is probably due to the performance of the child's teacher. (16)	❍ SA (1)	❍ A (2)	❍ UN (3)	❍ D (4)	❍ SD (5)

I find it difficult to explain to students why designs in T&E activities work. (17)	❍ SA (1)	❍ A (2)	❍ UN (3)	❍ D (4)	❍ SD (5)
I am typically able to answer students' T&E questions. (18)	❍ SA (1)	❍ A (2)	❍ UN (3)	❍ D (4)	❍ SD (5)
I wonder if I have the necessary skills to teach T&E. (19)	❍ SA (1)	❍ A (2)	❍ UN (3)	❍ D (4)	❍ SD (5)
Effectiveness in T&E teaching has little influence on the achievement of students with low motivation. (20)	❍ SA (1)	❍ A (2)	❍ UN (3)	❍ D (4)	❍ SD (5)
Given a choice, I would not invite the principal to evaluate my T&E teaching. (21)	❍ SA (1)	❍ A (2)	❍ UN (3)	❍ D (4)	❍ SD (5)
When a student has difficulty understanding a T&E concept, I am usually at a loss as to how to help the student understand it better. (22)	❍ SA (1)	❍ A (2)	❍ UN (3)	❍ D (4)	❍ SD (5)
When teaching T&E, I usually welcome student questions. (23)	❍ SA (1)	❍ A (2)	❍ UN (3)	❍ D (4)	❍ SD (5)
I don't know what to do to turn students on to T&E. (24)	❍ SA (1)	❍ A (2)	❍ UN (3)	❍ D (4)	❍ SD (5)
Even teachers with good T&E teaching abilities cannot help some kids learn T&E. (25)	❍ SA (1)	❍ A (2)	❍ UN (3)	❍ D (4)	❍ SD (5)

Section 3 These next set of 3 questions ask about your formal teacher preparation experience

3.1 Please check the statement that best describes your path into teaching:

- ❍ Completed a teacher education program from a college or university prior to my first teaching position (1)
- ❍ Was a career changer and participated in an alternative certification program. My previous career(s) were (please specify): (2) ____________________
- ❍ Did not have any formal teaching training (3) ____________________
- ❍ Other (Please explain) (4) ____________________

3.2 Which of the following statuses best describes your current educational level?

- ❍ Associate's Degree (1)
- ❍ Bachelor's Degree (2)
- ❍ Master's Degree (3)
- ❍ Master's +30 credits (4)
- ❍ Master's +60 credits (5)
- ❍ Educational Specialist (6)
- ❍ Doctorate (7)

3.3 In which areas do you hold the following degrees? Check all that apply for each degree level.

	Associate's (1)	Bachelor's (2)	Graduate Certificate (3)	Master's (4)	EdS (5)	Doctorate (6)
Industrial Arts (13)	❑	❑	❑	❑	❑	❑
Technology Education (1)	❑	❑	❑	❑	❑	❑
Business Education (7)	❑	❑	❑	❑	❑	❑
Curriculum and Instruction (9)	❑	❑	❑	❑	❑	❑
Administration (Educational Leadership) (10)	❑	❑	❑	❑	❑	❑
Physics (2)	❑	❑	❑	❑	❑	❑
Biology (3)	❑	❑	❑	❑	❑	❑
Chemistry (4)	❑	❑	❑	❑	❑	❑
Earth Science (5)	❑	❑	❑	❑	❑	❑
Space Science (6)	❑	❑	❑	❑	❑	❑
Mathematics Education (8)	❑	❑	❑	❑	❑	❑
Other (please specify): (11)	❑	❑	❑	❑	❑	❑
Other (please specify) (12)	❑	❑	❑	❑	❑	❑

Section 4 The following set of 4 questions ask about your UNDERGRADUATE preparation experience.

4.1 Please select the number of science courses in the following areas that you completed as part of your undergraduate studies?

	0 (1)	1 (2)	2 (3)	3 (4)	4+ (5)
Physics (1)	❍	❍	❍	❍	❍
Biology (2)	❍	❍	❍	❍	❍
Chemistry (3)	❍	❍	❍	❍	❍
Earth Science (4)	❍	❍	❍	❍	❍
Space Science (5)	❍	❍	❍	❍	❍
Other (please specify) (6)	❍	❍	❍	❍	❍
Other (please specify) (7)	❍	❍	❍	❍	❍

4.2 Please select the number of technology education courses in the following areas that you completed as part of your undergraduate studies?

	0 (1)	1 (2)	2 (3)	3 (4)	4+ (5)
Electronics (1)	❍	❍	❍	❍	❍
Electrical Engineering (2)	❍	❍	❍	❍	❍
Power (Energy) and Transportation (3)	❍	❍	❍	❍	❍
Biotechnology (4)	❍	❍	❍	❍	❍
Robotics (5)	❍	❍	❍	❍	❍
Other (please specify) (6)	❍	❍	❍	❍	❍
Other (please specify) (7)	❍	❍	❍	❍	❍

4.3 Please select the number of math courses in the following areas that you completed as part of your undergraduate studies?

	0 (1)	1 (2)	2 (3)	3 (4)	4+ (5)
Algebra (1)	❍	❍	❍	❍	❍
Geometry (2)	❍	❍	❍	❍	❍
Pre Calculus (3)	❍	❍	❍	❍	❍
Calculus (4)	❍	❍	❍	❍	❍
Statistics (5)	❍	❍	❍	❍	❍
Other (please specify) (6)	❍	❍	❍	❍	❍
Other (please specify) (7)	❍	❍	❍	❍	❍

4.4 Please select the number of education courses in the following areas that you completed as part of your undergraduate studies?

	0 (1)	1 (2)	2 (3)	3 (4)	4+ (5)
Methods of teaching industrial arts (1)	❍	❍	❍	❍	❍
Methods of teaching technology education (2)	❍	❍	❍	❍	❍
Methods of teaching science (3)	❍	❍	❍	❍	❍
Methods of teaching mathematics (4)	❍	❍	❍	❍	❍
Other (please specify) (5)	❍	❍	❍	❍	❍
Other (please specify) (6)	❍	❍	❍	❍	❍

4.5 If you completed any certification or licensure programs which were NOT counted as undergraduate or graduate level credits, please describe them in the box below (e.g., 5th year certification only program, apprenticeship, professional engineering exam, etc.). If this does not apply to you please continue to the next section.

Section 5 These next 5 questions ask about your GRADUATE preparation experience.

5.1 Please select the number of science courses in the following areas that you completed as part of your graduate studies?

	0 (1)	1 (2)	2 (3)	3 (4)	4+ (5)
Physics (1)	❍	❍	❍	❍	❍
Biology (2)	❍	❍	❍	❍	❍
Chemistry (3)	❍	❍	❍	❍	❍
Earth Science (4)	❍	❍	❍	❍	❍
Space Science (5)	❍	❍	❍	❍	❍
Other (please specify) (6)	❍	❍	❍	❍	❍
Other (please specify) (7)	❍	❍	❍	❍	❍

5.2 Please select the number of technology education courses in the following areas that you completed as part of your graduate studies?

	0 (1)	1 (2)	2 (3)	3 (4)	4+ (5)
Electronics (1)	❍	❍	❍	❍	❍
Electrical Engineering (2)	❍	❍	❍	❍	❍
Power (Energy) and Transportation (3)	❍	❍	❍	❍	❍
Biotechnology (4)	❍	❍	❍	❍	❍
Robotics (5)	❍	❍	❍	❍	❍
Other (please specify) (6)	❍	❍	❍	❍	❍
Other (please specify) (7)	❍	❍	❍	❍	❍

5.3 Please select the number of math courses in the following areas that you completed as part of your graduate studies?

	0 (1)	1 (2)	2 (3)	3 (4)	4+ (5)
Algebra (1)	❍	❍	❍	❍	❍
Geometry (2)	❍	❍	❍	❍	❍
Pre Calculus (3)	❍	❍	❍	❍	❍
Calculus (4)	❍	❍	❍	❍	❍
Statistics (5)	❍	❍	❍	❍	❍
Other (please specify) (6)	❍	❍	❍	❍	❍
Other (please specify) (7)	❍	❍	❍	❍	❍

5.4 Please select the number of education courses in the following areas that you completed as part of your graduate studies?

	0 (1)	1 (2)	2 (3)	3 (4)	4+ (5)
Methods of teaching industrial arts (1)	❍	❍	❍	❍	❍
Methods of teaching technology education (2)	❍	❍	❍	❍	❍
Methods of teaching science (3)	❍	❍	❍	❍	❍
Methods of teaching mathematics (4)	❍	❍	❍	❍	❍
Other (please specify) (5)	❍	❍	❍	❍	❍
Other (please specify) (6)	❍	❍	❍	❍	❍

5.5 Have you ever taken an undergraduate or graduate course which discussed methods for integrating science concepts within technology education curricula?
- ❍ Yes (1)
- ❍ No (2)

Section 6 The next 5 sets of questions deal with your informal, NON-COLLABORATIVE preparation experiences.

6.1 How many of the following courses did you complete in high school?

	0 (1)	1 (2)	2 (3)	3 (4)	4+ (5)
Industrial Arts (1)	❍	❍	❍	❍	❍
Technology Education (2)	❍	❍	❍	❍	❍
Biology (3)	❍	❍	❍	❍	❍
Chemistry (4)	❍	❍	❍	❍	❍
Physics (5)	❍	❍	❍	❍	❍
Earth Science (6)	❍	❍	❍	❍	❍

6.2 In the past three years have you helped facilitate any of the following clubs/after school activities:
- ❑ Technology Student Association (1)
- ❑ First Robotics (2)
- ❑ Vex Robotics (3)
- ❑ Other Robotics Club (Please specify) (4) ____________________
- ❑ Lego League (5)
- ❑ State Engineering Challenges (6)
- ❑ Math Engineering Science Achievement (MESA) (7)
- ❑ Odyssey of the Mind (8)
- ❑ SkillsUSA (11)
- ❑ Other Activities (Please specify) (9) ____________________
- ❑ None (10)

6.3 Over the past three years, please indicate how many hours you have spent engaged in independent readings (e.g., educational journals or education teaching resources) in the following fields:

	0 (1)	>6 (2)	6-15 (3)	16-35 (4)	35+ (5)
Science Education (1)	❍	❍	❍	❍	❍
Technology Education (2)	❍	❍	❍	❍	❍

6.4 During the past 3 years, please indicate the number of professional development activities you participated in related to the teaching of science within technology education. Check the approximate number of courses/meetings for each activity.

	0 (1)	1 (2)	2 (3)	3 (4)	4 (5)	5 (6)	6+ (7)
Higher Education courses (1)	❍	❍	❍	❍	❍	❍	❍
Workshop or In-service Training (2)	❍	❍	❍	❍	❍	❍	❍
Summer Institute (3)	❍	❍	❍	❍	❍	❍	❍
Professional Association/Conference (4)	❍	❍	❍	❍	❍	❍	❍
Observational visit to another school's science or STEM facility (5)	❍	❍	❍	❍	❍	❍	❍

6.5 During the past three years, please indicate the number of professional development activities you participated in related to the teaching of technology education. Check the approximate number of courses/meetings for each activity.

	0 (1)	1 (2)	2 (3)	3 (4)	4 (5)	5 (6)	6+ (7)
Higher Education Courses (1)	❍	❍	❍	❍	❍	❍	❍
Workshop or In-service Training (2)	❍	❍	❍	❍	❍	❍	❍
Summer Institute (3)	❍	❍	❍	❍	❍	❍	❍
Professional Association/Conference (4)	❍	❍	❍	❍	❍	❍	❍
Observational visit to another school's technology education or STEM facility (5)	❍	❍	❍	❍	❍	❍	❍

Section 7 The next set of 8 questions deal with your informal, COLLABORATIVE preparation experiences.

7.1 Please select all of the following activities and in which field you have participated within the past three years:

	Science Education (1)	Technology Education (2)
Served on a district or school committee in: (1)	❑	❑
Acted as a peer teaching coach or mentor to other teachers in: (2)	❑	❑
Delivered an in-service workshop or course related to: (3)	❑	❑
Did not participate in these activities in this field. (4)	❑	❑

7.2 During the past 3 years, please indicate the number of committee or task forces you've participated in which focused on curriculum, instruction, or student assessment regarding:

	0 (1)	1 (2)	2 (3)	3 (4)	4 (5)	5 (6)	6+ (7)
Science Education (1)	❍	❍	❍	❍	❍	❍	❍
Technology Education (2)	❍	❍	❍	❍	❍	❍	❍

7.3 Over the past three years, please indicate how many hours of each professional development activity you participated in related to the teaching of science within technology education. Check approximately how many hours for each activity.

	0 (1)	>6 (2)	6-15 (3)	16-35 (4)	35+ (5)
Mentoring and/or peer observation of a science class/lab within your school (1)	❍	❍	❍	❍	❍
Regularly scheduled discussion or study group (2)	❍	❍	❍	❍	❍
Teacher collaborative network (includes online idea gardens, websites, or list serves) (3)	❍	❍	❍	❍	❍
Consultation with a science curriculum specialist (4)	❍	❍	❍	❍	❍

7.4 Over the past three years, please indicate how many hours of each professional development activity you participated in related to the teaching of technology education. Check approximately how many hours for each activity.

	0 (1)	>6 (2)	6-15 (3)	16-35 (4)	35+ (5)
Mentoring and/or peer observation of a technology education class/lab within your school (1)	❍	❍	❍	❍	❍
Regularly scheduled discussion or study group (2)	❍	❍	❍	❍	❍
Teacher collaborative network (includes online idea gardens, websites, or list serves) (3)	❍	❍	❍	❍	❍
Consultation with a science curriculum specialist (4)	❍	❍	❍	❍	❍
Consultation with a technology education curriculum specialist (5)	❍	❍	❍	❍	❍

7.5 Please select any of the following conferences you have attended in the past three years that have impacted your STEM knowledge:

- ❑ State science association conference (1)
- ❑ State technology education association conference (2)
- ❑ National science association conference (3)
- ❑ National technology education association annual conference (4)
- ❑ Others (Please specify) (5) ____________________
- ❑ Have not attended any conferences in the past three years (6)

7.6 When attending professional association conferences, what type of sessions do you predominantly attend?

- ❍ Mostly technology and engineering education sessions (1)
- ❍ Mostly science education sessions (2)
- ❍ A mix of science, technology, and engineering sessions (3)
- ❍ Other sessions (Please specify) (4) ____________________
- ❍ Not sure (5)

7.7 If you collaborate or network (discuss course content, teaching practices, or plan lessons) with other teachers at your school or other schools, please indicate how often you do so with teachers from those respective areas.

	Daily (1)	2-3 times a week (2)	Once a week (3)	Every two weeks (4)	Once a month (5)	Once a semester (6)	Once a school year (7)	Never (8)
Technology Education (12)	❑	❑	❑	❑	❑	❑	❑	❑
Physics (4)	❑	❑	❑	❑	❑	❑	❑	❑
Biology (3)	❑	❑	❑	❑	❑	❑	❑	❑
Chemistry (2)	❑	❑	❑	❑	❑	❑	❑	❑
Earth Science (5)	❑	❑	❑	❑	❑	❑	❑	❑
Space Science (6)	❑	❑	❑	❑	❑	❑	❑	❑
Business Education (7)	❑	❑	❑	❑	❑	❑	❑	❑
Family and Consumer Science (8)	❑	❑	❑	❑	❑	❑	❑	❑
Mathematics (1)	❑	❑	❑	❑	❑	❑	❑	❑
Other (please specify) (10)	❑	❑	❑	❑	❑	❑	❑	❑
Other (please specify) (11)	❑	❑	❑	❑	❑	❑	❑	❑

Section 8 Lastly, these final questions ask for important demographic information. Please try to answer all of these questions as you complete this survey.

8.1 What gender do you identify as?
- ❍ Male (1)
- ❍ Female (2)

8.2 What ethnicity do you identify as?
❍ White/Caucasian (1)
❍ African American, non-Hispanic (2)
❍ Latin American (3)
❍ Asian (4)
❍ Native American (5)
❍ Pacific Islander (6)
❍ Middle Eastern (7)
❍ Other (Please name) (8) ____________________

8.3 What is your age? (Please enter as a numerical value, not as a word)

8.4 Which setting(s) did you grow up in as a child? (Select all that apply)
❑ Urban (1)
❑ Suburban (2)
❑ Rural (3)

8.5 Which setting best describes the school district you currently teach in?
❍ Urban (1)
❍ Suburban (2)
❍ Rural (3)

8.6 Including this year, how many total years have you taught? (Please enter as a numerical value, not as a word)

8.7 Please select all school setting(s) you have taught in during your career, and Including this year specify the number of years you have you taught in each setting. (Please enter years as a numerical value, not as a word)
❑ Urban (4) ____________________
❑ Suburban (5) ____________________
❑ Rural (6) ____________________

8.8 Including this year, please select and specify how many years have you taught technology education at the following levels (Please enter years as a numerical value, not as a word):
❑ Elementary School (1) ____________________
❑ Middle School (2) ____________________
❑ High School (3) ____________________

8.9 Including this year, please select and specify how many years have you taught science education at the following levels (Please enter the years as a numerical value, not as a word). If you have not taught a science class please skip this question.

- ❑ Elementary School (1) ____________________
- ❑ Middle School (2) ____________________
- ❑ High School (3) ____________________

8.10 Are there any other content areas that you have taught in your teaching career, and if so how long did you teach that content. Please enter the years in numerical values, not as words. (If none, skip to the next question)

Content Area (1)
Years (2)
Content Area (3)
Years (4)
Content Area (5)
Years (6)
Content Area (7)
Years (8)

8.11 Select all subject areas which you are certified to teach:

- ❑ Technology Education (1)
- ❑ Physics (2)
- ❑ Biology (3)
- ❑ Chemistry (4)
- ❑ Earth Science (5)
- ❑ Space Science (6)
- ❑ Business Education (7)
- ❑ Mathematics (8)
- ❑ Other (Please specify) (9) ____________________

8.12 How many years have you been teaching the Foundations of Technology curriculum? (Please enter as a numerical value, not as a word)

8.13 How long was the training/professional development you attended to learn how to teach the Foundations of Technology Curriculum?

- ❍ Did not attend (5)
- ❍ Half Day (1)
- ❍ Full Day (2)
- ❍ 2-3 days (3)
- ❍ 1 week (4)
- ❍ Attended more than one FoT training/PD program (please specify type and length of each) (6) ____________________

APPENDIX H

Purposeful Selection Results from the Survey Data

Participant	Total years teaching?	Years teaching FoT?	STEBI PE score	STEBI OE score	HS Industrial Arts Classes	HS Tech Ed Classes	HS Biology Classes	HS Chemistry Classes	HS Physics Classes	HS Earth Science Classes
Novice										
Participant 1	3	3	23	33	1	5	3	2	2	2
Participant 2	2	2	17	27	1	5	1	1	1	1
Participant 3	2	2	27	25	2	2	3	3	2	2
Participant 4	7	5	15	32	1	1	5	3	1	1
Participant 5	5	5	21	31	1	3	3	3	4	1
Participant 6	7	4	28	36	1	1	2	2	1	2
Participant 7	2	2	22	37	3	4	2	2	2	2
Participant 8	3	3	18	30	2	3	2	2	2	2
Participant 9	4	4	15	23	1	4	3	3	3	1
Participant 10	3	3	20	28	2	1	2	2	3	2
Participant 11	3	2	24	24	5	5	5	5	5	5
Participant 12	4	4	21	28	5	5	2	2	1	3
Participant 13	1	1	25	27	1	1	3	1	1	1
Participant 14	3	3	22	28	3	1	2	2	2	2
Participant 15	7	3	22	43	0	1	3	2	2	1
Participant 16	6	3	35	32	2	2	2	1	1	2
Participant 17	4	3	28	33	3	5	2	2	3	2
Participant 18	3	2	24	30	3	2	2	2	2	2
Mode	3	3	22	28	1	1	2	2	2	2
Intermediate										
Participant 19	15	2	27	32	1	1	2	1	1	1
Participant 20	9	4	21	22	2	1	2	2	2	3
Participant 21	13	5	13	31	1	1	3	3	2	2
Participant 22	13	6	15	43	5	5	2	2	2	2
Participant 23	12	1	13	26	3	3	2	3	2	2
Participant 24	7	7	16	36	3	3	2	2	2	2
Participant 25	10	8	26	35	5	5	2	2	2	1
Participant 26	7	7	31	34	4	4	2	2	2	2
Participant 27	9	1	31	28	5	1	2	1	1	2
Participant 28	9	3	35	36	2	1	2	2	1	2
Participant 29	11	6	22	29	5	4	2	2	2	2
Participant 30	10	10	20	43	1	1	2	2	2	1
Participant 31	14	1	38	34	1	1	2	2	2	1
Participant 32	12	6	20	32	1	1	2	2	2	2
Participant 33	11	11	16	35	1	5	2	1	1	2
Participant 34	10	5	41	35	1	1	2	2	2	2
Participant 35	10	10	29	32	5	5	3	2	1	3
Participant 36	7	7	17	37	2	1	2	2	2	2
Mode	10	6	13	32	1	1	2	2	2	2
Veteran										
Participant 37	30	22	13	23	5	1	2	1	1	1
Participant 38	29	20	18	40	5	1	2	3	3	1
Participant 39	21	6	19	30	5	1	2	2	2	1
Participant 40	28	10	25	32	4	1	2	2	1	1
Participant 41	18	3	40	34	2	1	3	2	2	2
Participant 42	40	3	14	31	1	1	2	2	2	1
Participant 43	17	10	18	32	1	1	2	2	2	2
Participant 44	20	5	18	32	5	1	2	2	1	2
Participant 45	23	8	22	30	2	1	2	2	1	2
Participant 46	19	5	35	31	5	5	2	3	3	2
Participant 47	24	10	23	31	3	1	3	2	1	2
Participant 48	33	4	13	28	5	1	2	2	2	2
Participant 49	33	1	20	32	5	1	4	2	1	2
Participant 50	32	12	25	27	5	2	4	2	2	2
Participant 51	29	2	22	38	2	1	2	1	1	3
Participant 52	20	5	28	38	1	2	5	3	2	4
Participant 53	19	2	20	30	5	1	2	2	2	2
Participant 54	16	4	27	38	2	2	2	2	1	2
Participant 55	18	5	32	40	1	1	2	2	1	2
Mode	29	5	18	32	5	1	2	2	1	2
Mode for All	7	3	22	32	1	1	2	2	2	2
Mean for All	13.22	5.29	23.09	32.07	2.71	2.20	2.40	2.07	1.82	1.89
Median for All	10	4	22	32	2	1	2	2	2	2

Participant	Path into teaching:	Describe other path into teaching:	Current Education Level	Associates in Industrial Arts	B.S. in Industrial Arts	Master's in Industrial Arts	Grad Certificate in Tech Ed	B.S. in Tech Ed	Masters in Tech Ed	EdS in Tech Ed
Novice										
Participant 1	1	0	3	0	0	0	0	0	1	0
Participant 2	1	0	2	0	0	0	0	1	0	0
Participant 3	1	0	2	0	0	0	0	1	0	0
Participant 4	4	Career chang	3	0	0	0	1	0	0	0
Participant 5	1	0	2	0	0	0	0	1	0	0
Participant 6	1	0	3	0	0	0	0	0	0	0
Participant 7	1	0	2	0	0	0	0	0	0	0
Participant 8	1	0	2	0	0	0	1	0	0	0
Participant 9	3	No, but had i	5	0	1	0	0	0	1	0
Participant 10	2	Nasa guidanc	3	0	0	0	0	0	0	0
Participant 11	1	0	3	0	0	0	0	0	0	0
Participant 12	1	0	3	0	0	0	0	1	1	0
Participant 13	2	Director of T	3	0	0	0	0	0	0	0
Participant 14	1	0	2	0	0	0	0	0	0	0
Participant 15	4	Began Colleg	3	0	0	0	0	1	1	0
Participant 16	2	Business rela	4	0	0	0	0	0	0	0
Participant 17	1	0	2	0	0	0	0	1	0	0
Participant 18	1	0	2	0	0	0	0	0	0	0
Mode	1	0	3	0	0	0	0	0	0	0
Intermediate										
Participant 19	2	Photojournal	4	0	0	0	0	0	0	0
Participant 20	2	Landscape D	3	0	0	0	0	0	0	0
Participant 21	2	Industrial En	3	1	0	0	1	0	0	0
Participant 22	1	0	5	0	1	0	0	1	1	0
Participant 23	1	0	4	0	1	0	0	1	1	0
Participant 24	1	0	3	0	0	0	0	1	0	0
Participant 25	1	0	3	0	0	0	1	0	0	0
Participant 26	1	0	3	0	0	0	0	1	0	0
Participant 27	1	0	3	0	0	0	0	0	0	0
Participant 28	1	0	2	0	0	0	0	0	0	0
Participant 29	1	0	4	0	0	0	0	0	0	0
Participant 30	1	0	2	0	0	0	0	1	0	0
Participant 31	1	0	5	0	0	0	0	0	0	0
Participant 32	1	0	4	0	0	0	0	0	0	0
Participant 33	1	0	3	0	0	0	0	1	0	0
Participant 34	3	0	3	0	0	0	0	0	0	0
Participant 35	1	0	3	0	0	0	0	0	1	0
Participant 36	1	0	2	0	0	0	0	1	0	0
Mode	1	0	3	0	0	0	0	0	0	0
Veteran										
Participant 37	1	0	3	0	1	1	0	1	1	0
Participant 38	1	0	3	0	1	0	0	1	1	0
Participant 39	4	BA In Psycolc	2	0	0	0	0	1	0	0
Participant 40	3	Taught in the	4	0	0	0	0	0	0	1
Participant 41	1	0	3	0	0	0	0	0	0	0
Participant 42	1	0	7	0	0	0	0	0	1	0
Participant 43	1	0	5	0	0	0	1	0	0	0
Participant 44	1	0	3	0	0	1	0	0	1	0
Participant 45	2	Military, Law	4	0	0	0	0	0	1	0
Participant 46	1	0	3	0	0	0	0	1	0	0
Participant 47	1	0	3	0	0	0	0	1	0	0
Participant 48	1	0	3	0	0	1	0	0	1	0
Participant 49	2	Business	5	0	0	0	0	0	0	1
Participant 50	1	0	4	0	1	0	0	0	1	0
Participant 51	1	0	4	0	0	0	0	1	0	0
Participant 52	2	Military	2	0	0	0	1	1	0	0
Participant 53	1	0	4	0	0	0	0	0	1	0
Participant 54	1	0	2	0	0	0	0	1	0	0
Participant 55	1	0	7	0	0	0	0	0	0	0
Mode	1	0	3	0	0	0	0	0	0	0
Mode for All	1	0	3	0	0	0	0	0	0	0
Mean for All	1.44	0.00	3.25	0.02	0.11	0.05	0.11	0.38	0.27	0.04
Median for All	1	0	3	0	0	0	0	0	0	0

Participant	Associate's in Business Ed	B.S. in Business Ed	Grad Certificate in Business Ed	B.S. in Math Education	Masters in Math Ed	B.S. in C&I	Masters in C&I	Grad Cert in Administration (Educational Leadership)	Masters in Administration (Educational Leadership)	Doctorate in Administration (Educational Leadership)
Novice										
Participant 1	0	0	0	0	0	0	0	0	0	0
Participant 2	0	0	0	0	0	1	0	0	0	0
Participant 3	0	0	0	0	0	0	0	0	0	0
Participant 4	0	1	0	0	0	0	1	0	0	0
Participant 5	0	0	0	1	0	0	0	0	0	0
Participant 6	0	0	0	0	0	0	0	0	0	0
Participant 7	0	0	0	0	0	0	0	0	0	0
Participant 8	0	0	0	0	0	0	0	0	0	0
Participant 9	0	0	1	0	0	0	0	0	0	0
Participant 10	0	0	0	0	0	0	0	0	0	0
Participant 11	0	0	0	0	0	0	0	0	0	0
Participant 12	0	0	0	0	0	0	0	0	0	0
Participant 13	0	0	0	0	0	0	0	0	0	0
Participant 14	0	0	0	0	0	0	0	0	0	0
Participant 15	0	0	0	0	0	0	0	0	0	0
Participant 16	0	0	0	0	0	0	0	0	0	0
Participant 17	0	0	0	0	0	0	0	0	0	0
Participant 18	0	0	0	0	0	0	0	0	0	0
Mode	0	0	0	0	0	0	0	0	0	0
Intermediate										
Participant 19	0	0	0	0	0	0	0	0	0	0
Participant 20	0	0	0	0	0	0	1	0	0	0
Participant 21	0	0	0	0	0	0	0	0	0	0
Participant 22	0	0	0	0	0	1	0	0	0	0
Participant 23	0	0	0	0	0	0	1	0	1	0
Participant 24	0	0	0	0	0	0	0	0	1	0
Participant 25	0	1	0	0	0	0	0	0	0	0
Participant 26	0	0	0	0	0	0	0	0	1	0
Participant 27	0	0	0	0	0	0	0	0	0	0
Participant 28	0	1	0	0	0	0	0	0	0	0
Participant 29	1	0	0	0	0	0	1	1	0	0
Participant 30	0	0	0	0	0	0	0	0	0	0
Participant 31	0	0	0	0	1	0	0	0	0	0
Participant 32	0	0	0	0	0	0	0	0	0	0
Participant 33	0	0	0	0	0	0	0	0	1	0
Participant 34	0	0	0	0	0	0	0	0	0	0
Participant 35	0	0	0	0	0	0	0	0	0	0
Participant 36	0	0	0	0	0	0	0	0	0	0
Mode	0	0	0	0	0	0	0	0	0	0
Veteran										
Participant 37	0	0	0	0	0	0	0	0	0	0
Participant 38	0	0	0	0	0	0	0	0	0	0
Participant 39	0	0	0	0	0	0	0	0	0	0
Participant 40	0	0	0	0	0	0	0	0	0	0
Participant 41	0	0	0	0	0	0	0	0	1	0
Participant 42	1	0	0	0	0	0	0	0	1	1
Participant 43	0	0	0	0	0	0	0	1	0	0
Participant 44	0	0	0	0	0	0	0	0	0	0
Participant 45	0	0	0	0	0	0	0	1	0	0
Participant 46	0	0	0	0	0	0	0	0	0	0
Participant 47	0	0	0	0	0	0	0	0	1	0
Participant 48	0	0	0	0	0	0	0	0	0	0
Participant 49	0	0	0	0	0	0	0	0	0	0
Participant 50	0	0	0	0	0	0	0	0	0	0
Participant 51	0	0	0	0	0	0	0	0	0	0
Participant 52	0	0	0	0	0	0	0	0	0	0
Participant 53	0	0	0	0	0	0	0	0	0	0
Participant 54	0	1	0	0	0	0	0	0	0	0
Participant 55	0	1	0	0	0	0	1	0	0	0
Mode	0	0	0	0	0	0	0	0	0	0
Mode for All	0	0	0	0	0	0	0	0	0	0
Mean for All	0.04	0.09	0.02	0.02	0.02	0.04	0.09	0.05	0.13	0.02
Median for All	0	0	0	0	0	0	0	0	0	0

Participant	Associates in other	B.S. in other	Master's in other	Doctorate in Counseling	Physics courses in Undergrad	Biology courses in Undergrad	Chemistry courses in Undergrad	Earth Science courses in Undergrad	Space Science courses in Undergrad	Number of other science courses in Undergrad
Novice										
Participant 1	0	0	0	0	1	2	3	1	1	1
Participant 2	0	0	0	0	1	2	1	1	2	1
Participant 3	0	Physical Educ	0	0	1	3	2	1	1	1
Participant 4	0	0	0	0	1	1	1	1	1	1
Participant 5	0	0	0	0	2	2	2	2	1	1
Participant 6	0	Business Adn	Teaching	0	1	1	2	2	1	1
Participant 7	0	Architecture,	0	0	2	1	1	1	1	1
Participant 8	0	Physical Educ	0	0	1	2	2	2	1	1
Participant 9	0	Networking-	0	0	1	2	1	2	1	1
Participant 10	0	Engineering,	Engineering	0	5	4	4	3	5	1
Participant 11	0	0	Computer Sc	0	5	5	5	5	5	1
Participant 12	0	0	0	0	2	1	2	1	2	2
Participant 13	0	Computer Sc	Information a	0	3	3	2	1	1	1
Participant 14	Social Studie:	0	0	0	2	1	1	1	1	2
Participant 15	0	0	0	0	2	2	2	1	1	1
Participant 16	0	0	0	0	1	1	1	1	1	1
Participant 17	0	0	0	0	2	1	1	2	1	1
Participant 18	0	1 in Behavior	0	0	1	2	1	2	2	1
Mode	0	0	0	0	1	2	1	1	1	1
Intermediate										
Participant 19	0	Art	Art Educatior	0	2	2	1	1	1	1
Participant 20	0	Horticulture	0	0	3	3	3	2	1	1
Participant 21	0	0	0	0	5	3	3	2	1	1
Participant 22	0	0	0	0	3	1	1	1	1	1
Participant 23	0	0	0	0	3	2	2	1	1	1
Participant 24	0	Physical Educ	0	0	1	1	2	1	1	1
Participant 25	0	0	0	0	2	2	2	1	5	1
Participant 26	0	0	0	0	1	2	2	1	1	1
Participant 27	0	Kenisiology	0	0	1	3	2	2	1	3
Participant 28	0	0	0	0	1	2	1	1	1	1
Participant 29	Information !	Comp. Info. !	0	0	1	2	1	2	1	1
Participant 30	Minor - Industrial Design		0	0	3	1	1	3	1	1
Participant 31	0	Computer Sc	0	0	2	1	1	1	1	1
Participant 32	0	Elementary E	Education wi	0	1	1	1	2	1	1
Participant 33	0	0	0	0	1	3	1	1	1	1
Participant 34	Marketing	0	MAEd	0	1	1	1	1	1	1
Participant 35	0	0	0	0	3	3	1	2	1	1
Participant 36	0	0	0	0	2	2	2	2	1	1
Mode	0	0	0	0	1	2	1	1	1	1
Veteran										
Participant 37	0	0	0	0	2	2	2	2	2	1
Participant 38	0	0	0	0	2	1	2	1	1	1
Participant 39	0	Psychology	0	0	1	2	1	2	2	1
Participant 40	0	0	Theology	0	1	1	1	1	1	1
Participant 41	0	Health and P	0	0	2	5	2	2	2	2
Participant 42	0	Distributive E	0	0	2	1	2	1	1	1
Participant 43	0	0	Edu Tech	0	3	2	1	1	1	1
Participant 44	0	0	0	0	3	1	1	1	1	1
Participant 45	0	0	Political Scier	0	1	3	2	2	1	1
Participant 46	0	0	0	0	3	1	3	1	1	1
Participant 47	0	0	0	0	3	1	2	1	1	1
Participant 48	0	0	0	0	3	2	2	2	1	1
Participant 49	0	Business, Wc	0	0	1	2	2	2	1	1
Participant 50	0	History, Socio	0	0	1	2	1	2	1	1
Participant 51	0	0	MAEd	0	1	3	1	1	1	1
Participant 52	0	0	0	0	1	3	3	3	1	1
Participant 53	0	Industrial Tec	0	0	3	3	3	2	1	1
Participant 54	0	0	0	0	1	2	1	2	2	1
Participant 55	0	0	0	1	1	4	2	2	1	1
Mode	0	0	0	0	1	2	2	2	1	1
Mode for All	0	0	0	0	1	2	1	1	1	1
Mean for All	0.00	0.00	0.00	0.02	1.91	2.04	1.75	1.60	1.35	1.09
Median for All	0	0	0	0	2	2	2	1	1	1

Participant	Name of Other science courses in Undergrad	Number of other science courses in Undergrad	Name of Other science courses in Undergrad	Electronics Courses in Undergrad	Electrical Engineering Courses in Undergrad	Power (Energy) and Transportation Courses in Undergrad	Biotechnology Courses in Undergrad	Robotics Courses in Undergrad	Number of other tech ed courses in Undergrad	Name of other tech ed courses in Undergrad
Novice										
Participant 1	0	1	0	3	1	3	2	2	5	Material pro
Participant 2	0	1	0	3	2	2	2	1	1	0
Participant 3	0	1	0	1	1	1	1	1	1	0
Participant 4	0	1	0	1	1	1	1	1	1	0
Participant 5	0	1	0	1	1	1	1	2	1	0
Participant 6	0	1	0	1	1	1	1	1	1	0
Participant 7	0	1	0	1	1	1	1	1	4	Wood Shop
Participant 8	0	1	0	2	1	1	1	1	1	0
Participant 9	0	1	0	2	1	2	1	1	5	Computer Pr
Participant 10	0	5	Engineering	5	5	4	4	4	1	0
Participant 11	0	1	0	5	5	5	5	5	1	0
Participant 12	Ecology	1	0	3	2	4	1	2	2	Polymers
Participant 13	0	1	0	1	1	1	1	1	1	0
Participant 14	Geology	1	0	1	1	1	1	1	1	0
Participant 15	0	1	0	3	1	2	1	1	1	0
Participant 16	0	1	0	1	1	1	1	1	1	0
Participant 17	0	1	0	2	2	2	2	2	1	0
Participant 18	0	1	0	1	1	1	1	1	1	0
Mode	0	1	0	1	1	1	1	1	1	0
Intermediate										
Participant 19	0	1	0	1	1	1	1	1	1	0
Participant 20	0	1	0	1	1	1	1	1	1	0
Participant 21	0	1	0	3	2	1	1	3	1	0
Participant 22	0	1	0	5	2	5	1	2	3	Metals + Ma
Participant 23	0	1	0	3	1	4	1	2	1	0
Participant 24	0	1	0	1	1	1	1	1	1	0
Participant 25	0	1	0	1	1	1	1	1	1	0
Participant 26	0	1	0	2	1	2	2	2	1	0
Participant 27	Anatomy & P	2	Zoology	1	1	1	1	1	1	0
Participant 28	0	1	0	1	1	1	1	1	1	0
Participant 29	0	1	0	1	1	2	1	1	1	0
Participant 30	0	1	0	3	1	2	1	2	4	Info/Comm T
Participant 31	0	1	0	1	1	1	1	1	1	0
Participant 32	0	1	0	1	1	1	1	1	1	0
Participant 33	0	1	0	2	2	3	1	1	3	Manufacturi
Participant 34	0	1	0	1	1	1	1	1	1	0
Participant 35	0	1	0	3	1	2	2	2	1	0
Participant 36	0	1	0	3	3	3	1	2	4	Materials
Mode	0	1	0	1	1	1	1	1	1	0
Veteran										
Participant 37	0	1	0	3	2	3	1	1	1	0
Participant 38	0	1	0	3	1	2	1	1	1	0
Participant 39	0	1	0	2	1	2	1	1	1	0
Participant 40	0	1	0	1	1	1	1	1	1	0
Participant 41	Kinesiology	2	Exercise Phys	1	1	1	1	1	1	0
Participant 42	0	1	0	1	1	1	1	1	1	0
Participant 43	0	1	0	1	1	1	1	1	1	0
Participant 44	0	1	0	3	1	2	1	1	4	Drafting
Participant 45	0	1	0	1	2	1	2	1	1	0
Participant 46	0	1	0	3	3	3	1	2	1	0
Participant 47	0	1	0	2	1	2	1	2	1	0
Participant 48	0	1	0	3	1	2	1	2	3	Manufacturi
Participant 49	0	1	0	1	1	1	1	1	1	0
Participant 50	0	1	0	2	1	2	2	1	2	Metalworkin
Participant 51	0	1	0	2	1	2	1	1	2	Communicat
Participant 52	0	1	0	2	1	2	2	2	1	0
Participant 53	0	1	0	2	2	1	1	1	5	Foundry, She
Participant 54	0	1	0	2	2	2	1	1	1	0
Participant 55	0	1	0	1	1	1	1	1	1	0
Mode	0	1	0	2	1	2	1	1	1	0
Mode for All	0	1	0	1	1	1	1	1	1	0
Mean for All	0.00	1.11	0.00	1.95	1.40	1.80	1.27	1.42	1.60	0.00
Median for All	0	1	0	2	1	1	1	1	1	0

Participant	Number of other tech ed courses in Undergrad	Name of other tech ed courses in Undergrad	Algebra courses in Undergrad	Geometry courses in Undergrad	Pre Calc courses in Undergrad	Calculus courses in Undergrad	Statistics courses in Undergrad	Number of other math courses in Undergrad	Name of other math courses in Undergrad	Methods of teaching industrial arts in Undergrad
Novice										
Participant 1	4	Drafting and	1	1	1	1	2	2	Math for nor	1
Participant 2	1	0	2	1	1	1	2	1	0	1
Participant 3	1	0	2	1	1	1	2	2	Finite Math	1
Participant 4	1	0	3	1	1	1	2	1	0	1
Participant 5	1	0	5	4	4	4	4	1	0	1
Participant 6	1	0	2	1	1	2	2	1	0	1
Participant 7	1	0	1	1	1	2	1	1	0	1
Participant 8	1	0	2	1	1	1	1	1	0	1
Participant 9	1	0	2	2	1	2	2	1	0	1
Participant 10	1	0	3	3	2	5	3	1	0	1
Participant 11	1	0	5	5	5	5	5	1	0	5
Participant 12	5	Material Fab	2	2	1	1	1	1	0	2
Participant 13	1	0	1	1	1	3	3	1	0	1
Participant 14	1	0	2	1	1	1	1	1	0	1
Participant 15	1	0	2	1	2	1	1	1	0	1
Participant 16	1	0	1	1	1	1	1	1	0	1
Participant 17	1	0	2	1	2	1	1	1	0	4
Participant 18	1	0	3	2	1	2	2	1	0	1
Mode	1	0	2	1	1	1	2	1	0	1
Intermediate										
Participant 19	1	0	2	2	1	1	1	1	0	1
Participant 20	1	0	1	1	1	3	2	1	0	1
Participant 21	1	0	1	2	2	4	3	1	0	2
Participant 22	3	Materials	2	2	2	1	2	1	0	2
Participant 23	1	0	2	2	1	1	2	1	0	4
Participant 24	1	0	2	1	1	1	1	1	0	1
Participant 25	1	0	2	1	1	1	2	1	0	3
Participant 26	1	0	2	2	1	1	1	1	0	1
Participant 27	1	0	3	1	1	1	1	1	0	1
Participant 28	1	0	2	2	2	2	2	1	0	1
Participant 29	1	0	3	2	2	1	2	1	0	1
Participant 30	2	Construction	1	2	1	2	2	1	0	1
Participant 31	1	0	1	1	1	5	2	1	0	1
Participant 32	1	0	2	1	1	1	1	1	0	1
Participant 33	2	Materials	1	1	1	1	1	3	0	1
Participant 34	1	0	1	1	2	2	2	1	0	1
Participant 35	1	0	3	2	1	1	2	1	0	2
Participant 36	5	Drafting and	2	1	1	1	2	1	0	1
Mode	1	0	2	2	1	1	2	1	0	1
Veteran										
Participant 37	1	0	3	2	2	2	2	1	0	3
Participant 38	1	0	2	1	1	1	1	1	0	2
Participant 39	1	0	1	1	1	1	4	1	0	1
Participant 40	1	0	2	2	1	1	2	1	0	1
Participant 41	1	0	1	1	2	1	3	1	0	1
Participant 42	1	0	2	2	1	1	2	1	0	1
Participant 43	1	0	2	2	2	1	2	1	0	1
Participant 44	3	Woodworkin	2	1	1	1	2	1	0	2
Participant 45	1	0	2	2	1	1	2	1	0	1
Participant 46	1	0	3	2	1	1	1	1	0	1
Participant 47	1	0	1	1	1	1	1	3	Technical Ma	1
Participant 48	2	Construction	3	2	1	1	1	1	0	2
Participant 49	1	0	2	2	2	2	2	1	0	1
Participant 50	3	Drafting & CA	1	1	2	1	2	1	0	2
Participant 51	4	Drafting & CA	3	2	2	1	2	1	0	1
Participant 52	1	0	2	3	1	1	2	1	0	1
Participant 53	1	0	3	3	3	1	3	1	0	2
Participant 54	1	0	2	2	1	2	2	1	0	2
Participant 55	1	0	2	2	1	1	1	1	0	1
Mode	1	0	2	2	1	1	2	1	0	1
Mode for All	1	0	2	1	1	1	2	1	0	1
Mean for All	1.42	0.00	2.05	1.65	1.42	1.58	1.89	1.11	0.00	1.44
Median for All	1	0	2	2	1	1	2	1	0	1

Participant	Methods of teaching tech ed in undergrad	Methods of teaching science in undergrad	Methods of teaching mathematics in undergrad	Number of other Methods courses in undergrad	Name of other Methods courses in undergrad	Number of other Methods courses in undergrad	Name of other Methods courses in undergrad	Certification or licensure programs	Physics courses in Grad school	Biology courses in Grad school
Novice										
Participant 1	3	1	1	1	0	1	0	0	1	1
Participant 2	2	1	1	1	0	1	0	0	1	1
Participant 3	1	1	1	2	Methods of t	2	Met Phys Edu	0	1	1
Participant 4	1	1	1	1	0	1	0	National Boa	1	1
Participant 5	2	2	5	1	0	1	0	PLTW Certific	1	1
Participant 6	1	1	1	1	0	1	0	PLTW IED Tra	1	1
Participant 7	1	2	2	5	Elementary E	1	Special Educa	0	1	1
Participant 8	1	1	1	1	0	1	0	0	1	1
Participant 9	1	1	1	1	0	1	0	0	1	1
Participant 10	1	1	1	5	Methods of t	1	0	0	1	1
Participant 11	5	5	5	1	0	1	0	0	5	5
Participant 12	3	1	1	1	0	1	0	0	1	1
Participant 13	1	1	1	1	0	1	0	0	1	1
Participant 14	1	1	1	1	0	1	0	PLTW POE &	1	1
Participant 15	3	1	1	1	0	1	0	0	1	1
Participant 16	1	1	1	1	0	1	0	0	1	1
Participant 17	4	2	2	1	0	1	0	0	1	1
Participant 18	1	1	1	1	0	1	0	Microsoft Sys	1	1
Mode	1	1	1	1	0	1	0	0	1	1
Intermediate										
Participant 19	1	1	1	1	0	1	0	0	1	1
Participant 20	1	1	1	1	0	1	0	0	1	1
Participant 21	2	1	1	1	0	1	0	0	1	1
Participant 22	2	1	1	5	General	1	0	Electrician M	1	1
Participant 23	3	1	1	1	0	1	0	0	1	1
Participant 24	1	1	1	1	0	1	0	Technology E	1	1
Participant 25	2	2	1	1	0	1	0	0	2	2
Participant 26	2	1	1	1	0	1	0	0	1	1
Participant 27	1	1	1	1	0	1	0	0	1	1
Participant 28	1	1	1	1	0	1	0	MOS certifica	1	1
Participant 29	1	1	2	1	0	1	0	MHIC certific	1	1
Participant 30	1	1	1	2	Educating Ex	2	History of Ed	Min Ind Desi	1	1
Participant 31	1	1	1	1	0	1	0	0	2	1
Participant 32	2	2	2	1	0	1	0	PLTW Intro to	1	1
Participant 33	2	1	1	1	0	1	0	0	1	1
Participant 34	1	1	1	1	0	1	0	0	1	1
Participant 35	2	1	1	1	0	1	0	0	1	1
Participant 36	3	1	1	1	0	1	0	0	1	1
Mode	1	1	1	1	0	1	0	0	1	1
Veteran										
Participant 37	3	1	1	1	0	1	0	0	1	1
Participant 38	2	1	1	1	0	1	0	0	1	1
Participant 39	2	1	1	1	0	1	0	0	1	1
Participant 40	2	1	1	1	0	1	0	national Boa	1	2
Participant 41	1	1	1	1	0	1	0	0	1	1
Participant 42	1	1	1	4	Teaching Me	3	Distributive E	NCCER Certif	1	1
Participant 43	1	2	2	1	0	1	0	0	1	1
Participant 44	2	1	1	2	Assessment \	2	Classroom m	None	1	1
Participant 45	1	1	1	1	0	1	0	0	1	1
Participant 46	4	1	1	1	0	1	0	0	1	1
Participant 47	5	1	1	1	0	1	0	0	1	1
Participant 48	2	1	1	1	0	1	0	A&S I and II	1	1
Participant 49	1	1	1	1	0	1	0	0	1	1
Participant 50	2	1	1	2	History Ed m	1	0	0	1	1
Participant 51	3	1	1	1	0	1	0	US Army Sou	1	1
Participant 52	2	2	2	1	0	1	0	0	1	1
Participant 53	3	1	1	2	Shop organiz	1	0	0	1	1
Participant 54	2	1	1	1	0	1	0	0	1	2
Participant 55	1	1	1	1		1	0	0	1	1
Mode	2	1	1	1	0	1	0	0	1	1
Mode for All	1	1	1	1	0	1	0	0	1	1
Mean for All	1.85	1.20	1.25	1.36	0.00	1.09	0.00	0.00	1.11	1.13
Median for All	2	1	1	1	0	1	0	0	1	1

Participant	Chemistry courses in Grad school	Earth Science courses in grad school	Space Science courses in grad school	Number of other science courses in Grad school	Name of other science courses in Grad school	Electronics courses in Grad school	Electrical Engineering courses in Grad school	Power (Energy) and Transportation courses in Grad school	Biotechnology courses in Grad school	Robotics courses in Grad school
Novice										
Participant 1	1	1	1	1	0	1	1	1	1	1
Participant 2	1	1	1	1	0	1	1	1	1	1
Participant 3	1	1	1	1	0	1	1	1	1	1
Participant 4	1	1	1	1	0	1	1	1	1	1
Participant 5	1	1	1	1	0	1	1	1	1	1
Participant 6	1	1	1	1	0	1	1	1	1	1
Participant 7	1	1	1	1	0	1	1	1	1	1
Participant 8	1	1	1	1	0	1	1	1	1	1
Participant 9	1	1	1	1	0	1	1	1	1	1
Participant 10	1	1	2	5	Aerospace m	1	5	1	1	1
Participant 11	5	5	5	1	0	5	5	5	5	5
Participant 12	1	1	1	1	0	2	1	2	1	1
Participant 13	1	1	1	1	0	1	1	1	1	1
Participant 14	1	1	1	1	0	1	1	1	1	1
Participant 15	1	1	1	1	0	1	1	1	1	1
Participant 16	1	1	1	1	0	1	1	1	1	1
Participant 17	1	1	1	1	0	1	1	1	1	1
Participant 18	1	1	1	1	0	1	1	1	1	1
Mode	1	1	1	1	0	1	1	1	1	1
Intermediate										
Participant 19	1	1	1	1	0	1	1	1	1	1
Participant 20	1	1	1	1	0	1	1	1	1	1
Participant 21	1	1	1	1	0	1	1	1	1	1
Participant 22	1	1	1	1	0	1	1	1	1	1
Participant 23	1	1	1	1	0	2	1	3	1	2
Participant 24	1	1	1	1	0	1	1	1	1	1
Participant 25	2	1	1	1	0	1	1	2	1	1
Participant 26	1	1	1	1	0	1	1	1	1	1
Participant 27	1	1	1	1	0	1	1	1	1	1
Participant 28	1	1	1	1	0	1	1	1	1	1
Participant 29	1	1	1	1	0	2	1	1	1	1
Participant 30	1	1	1	2	Kinesiology	1	1	1	1	1
Participant 31	1	1	1	1	0	1	1	1	1	1
Participant 32	1	1	1	1	0	1	1	1	1	1
Participant 33	1	1	1	1	0	1	1	1	1	1
Participant 34	1	1	1	1	0	1	1	1	1	1
Participant 35	1	1	1	1	0	2	2	2	2	3
Participant 36	1	1	1	1	0	1	1	1	1	1
Mode	1	1	1	1	0	1	1	1	1	1
Veteran										
Participant 37	1	1	1	1	0	1	1	1	1	1
Participant 38	1	1	1	1	0	1	1	1	1	1
Participant 39	1	1	1	1	0	1	1	1	1	1
Participant 40	1	1	1	1	0	1	1	1	1	1
Participant 41	1	1	1	1	0	1	1	1	1	1
Participant 42	1	1	1	1	0	1	1	1	1	1
Participant 43	1	1	1	1	0	1	1	1	1	1
Participant 44	1	1	1	1	0	1	1	1	1	1
Participant 45	1	1	1	1	0	1	1	1	1	1
Participant 46	1	1	1	1	0	1	1	1	1	1
Participant 47	1	1	1	1	0	1	1	1	1	1
Participant 48	1	1	2	1	0	1	1	1	1	2
Participant 49	1	1	1	1	0	1	1	1	1	1
Participant 50	1	1	1	1	0	2	1	2	2	1
Participant 51	1	1	1	1	0	1	1	1	1	1
Participant 52	1	1	1	1	0	1	1	1	1	1
Participant 53	1	1	1	1	0	2	1	2	1	1
Participant 54	2	2	1	1	0	2	2	2	1	1
Participant 55	1	1	1	1	0	1	1	1	1	1
Mode	1	1	1	1	0	1	1	1	1	1
Mode for All	1	1	1	1	0	1	1	1	1	1
Mean for All	1.11	1.09	1.11	1.09	0.00	1.20	1.18	1.22	1.11	1.15
Median for All	1	1	1	1	0	1	1	1	1	1

Participant	Number of other tech ed courses in Grad school	Name of other tech ed courses in Grad school	Number of other tech ed courses in Grad school	Name of other tech ed courses in Grad school	Algebra courses in Grad school	Geometry courses in Grad school	Pre Calculus courses in Grad school	Calculus courses in Grad school	Statistics courses in Grad school	Number of other math courses in Grad school
Novice										
Participant 1	3	Curriculum a	2	Conducting r	1	1	1	1	2	2
Participant 2	1	0	1	0	1	1	1	1	1	1
Participant 3	1	0	1	0	1	1	1	1	1	1
Participant 4	1	0	1	0	1	1	1	1	1	1
Participant 5	1	0	1	0	1	1	1	1	1	1
Participant 6	1	0	1	0	1	1	1	1	1	1
Participant 7	1	0	1	0	1	1	1	1	1	1
Participant 8	1	0	1	0	1	1	1	1	1	1
Participant 9	3	Distributed S	1	0	1	1	1	1	1	2
Participant 10	1	0	1	0	1	1	1	1	1	1
Participant 11	1	0	1	0	5	5	5	5	5	1
Participant 12	2	Classroom/La	2	Philosophy o	1	1	1	1	1	1
Participant 13	1	0	1	0	1	1	1	1	2	1
Participant 14	1	0	1	0	1	1	1	1	1	1
Participant 15	2	Globilization	1	0	1	1	1	1	1	1
Participant 16	1	0	1	0	1	1	1	1	2	1
Participant 17	1	0	1	0	1	1	1	1	1	1
Participant 18	1	0	1	0	1	1	1	1	1	1
Mode	1	0	1	0	1	1	1	1	1	1
Intermediate										
Participant 19	1	0	1	0	1	1	1	1	1	1
Participant 20	1	0	1	0	1	1	1	1	2	1
Participant 21	1	0	1	0	1	1	1	1	1	1
Participant 22	1	0	1	0	1	1	1	1	1	1
Participant 23	1	0	1	0	1	1	1	1	1	1
Participant 24	1	0	1	0	1	1	1	1	2	1
Participant 25	1	0	1	0	1	1	1	1	1	1
Participant 26	1	0	1	0	1	1	1	1	1	1
Participant 27	1	0	1	0	1	1	1	1	1	1
Participant 28	1	0	1	0	1	1	1	1	2	1
Participant 29	1	0	1	0	1	1	1	1	1	1
Participant 30	1	0	1	0	1	1	1	1	1	1
Participant 31	1	0	1	0	1	2	2	1	2	1
Participant 32	1	0	1	0	1	1	1	1	1	1
Participant 33	1	0	1	0	1	1	1	1	1	1
Participant 34	1	0	1	0	1	1	1	1	1	1
Participant 35	1	0	1	0	1	1	1	1	1	1
Participant 36	1	0	1	0	1	1	1	1	1	1
Mode	1	0	1	0	1	1	1	1	1	1
Veteran										
Participant 37	1	0	1	0	1	1	1	1	1	1
Participant 38	5	Technology (	1	0	1	1	1	1	2	1
Participant 39	1	0	1	0	1	1	1	1	1	1
Participant 40	1	0	1	0	1	1	1	1	1	1
Participant 41	1	0	1	0	1	1	1	1	2	1
Participant 42	5	Vocational &	1	0	2	1	1	1	3	1
Participant 43	1	0	1	0	1	1	1	1	1	1
Participant 44	1	0	1	0	1	1	1	1	1	1
Participant 45	1	0	1	0	1	1	1	1	2	1
Participant 46	1	0	1	0	1	1	1	1	1	1
Participant 47	1	0	1	0	1	1	1	1	1	1
Participant 48	1	0	1	0	1	1	1	1	1	1
Participant 49	1	0	1	0	1	1	2	1	2	1
Participant 50	2	History of Te	1	0	1	1	1	1	1	1
Participant 51	1	0	1	0	1	1	1	1	1	1
Participant 52	1	0	1	0	1	1	1	1	1	1
Participant 53	1	0	1	0	1	1	1	1	2	1
Participant 54	1	0	1	0	2	2	1	2	2	1
Participant 55	1	0	1	0	1	1	1	1	2	1
Mode	1	0	1	0	1	1	1	1	1	1
Mode for All	1	0	1	0	1	1	1	1	1	1
Mean for All	1.27	0.00	1.04	0.00	1.11	1.11	1.11	1.09	1.36	1.04
Median for All	1	0	1	0	1	1	1	1	1	1

Participant	Name of other math courses in Grad school	Number of other math courses in Grad school	Name of other math courses in Grad school	Methods of teaching industrial arts courses in Grad school	Methods of teaching tech ed courses in Grad school	Methods of teaching science courses in Grad school	Methods of teaching mathematics courses in Grad school	Number of other methods courses in Grad school	Name of other methods courses in Grad school	Number of other methods courses in Grad school
Novice										
Participant 1	Institutional	1	0	1	3	1	1	1	0	1
Participant 2	0	1	0	1	1	1	1	1	0	1
Participant 3	0	1	0	1	1	1	1	1	0	1
Participant 4	0	1	0	1	1	1	1	1	0	1
Participant 5	0	1	0	1	2	2	2	1	0	1
Participant 6	0	1	0	1	1	1	1	1	0	1
Participant 7	0	1	0	1	1	1	1	1	0	1
Participant 8	0	1	0	1	1	1	1	1	0	1
Participant 9	Financial ma	1	0	1	1	1	1	1	0	1
Participant 10	0	1	0	1	1	1	1	1	0	1
Participant 11	0	1	0	5	5	5	5	1	0	1
Participant 12	0	1	0	2	3	1	1	3	Assessment i	2
Participant 13	0	1	0	1	1	1	1	1	0	1
Participant 14	0	1	0	1	1	1	1	1	0	1
Participant 15	0	1	0	1	3	1	1	1	0	1
Participant 16	0	1	0	1	1	1	1	1	0	1
Participant 17	0	1	0	1	1	1	1	1	0	1
Participant 18	0	1	0	1	1	1	1	1	0	1
Mode	0	1	0	1	1	1	1	1	0	1
Intermediate										
Participant 19	0	1	0	1	1	1	1	3	Art Methods	1
Participant 20	0	1	0	1	1	1	1	5	Pedagogy	1
Participant 21	0	1	0	2	2	1	1	1	0	1
Participant 22	0	1	0	1	1	1	1	1	0	1
Participant 23	0	1	0	3	3	1	1	1	0	1
Participant 24	0	1	0	1	1	1	1	1	0	1
Participant 25	0	1	0	1	3	1	1	1	0	1
Participant 26	0	1	0	1	1	1	1	1	0	1
Participant 27	0	1	0	1	1	1	1	1	0	1
Participant 28	0	1	0	1	2	1	1	1	0	1
Participant 29	0	1	0	1	1	1	1	4	Various Educ	4
Participant 30	0	1	0	1	1	1	1	2	Distance Edu	1
Participant 31	0	1	0	1	1	1	5	1	0	1
Participant 32	0	1	0	1	4	2	2	1	0	1
Participant 33	0	1	0	1	1	1	1	1	0	1
Participant 34	0	1	0	1	1	1	1	1	0	1
Participant 35	0	1	0	3	5	1	1	1	0	1
Participant 36	0	1	0	1	1	1	1	1	0	1
Mode	0	1	0	1	1	1	1	1	0	1
Veteran										
Participant 37	0	1	0	3	3	1	1	1	0	1
Participant 38	0	1	0	1	5	1	1	1	0	1
Participant 39	0	1	0	1	2	1	1	1	0	1
Participant 40	0	1	0	2	3	1	1	1	0	1
Participant 41	0	1	0	1	1	1	1	1	0	1
Participant 42	0	1	0	1	5		1	1	0	1
Participant 43	0	1	0	1	1	1	1	1	0	1
Participant 44	0	1	0	2	2	1	1	1	0	1
Participant 45	0	1	0	1	1	1	1	1	0	1
Participant 46	0	1	0	1	5	1	1	1	0	1
Participant 47	0	1	0	1	1	1	1	1	0	1
Participant 48	0	1	0	3	3	1	1	1	0	1
Participant 49	0	1	0	1	1	1	1	1	0	1
Participant 50	0	1	0	2	2	1	1	1	0	1
Participant 51	0	1	0	1	2	1	1	3	Technical Rea	2
Participant 52	0	1	0	1	2	1	1	1	0	1
Participant 53	0	1	0	2	2	1	1	1	0	1
Participant 54	0	1	0	2	2	1	1	1	0	1
Participant 55	0	1	0	1	2	1	1	1	0	1
Mode	0	1	0	1	2	1	1	1	0	1
Mode for All	0	1	0	1	1	1	1	1	0	1
Mean for All	0.00	1.00	0.00	1.35	1.91	1.11	1.18	1.25	0.00	1.09
Median for All	0	1	0	1	1	1	1	1	0	1

Participant	Name of other methods courses in Grad school	Higher Ed course in methods for integrating science in tech ed?	Helped with TSA	Helped with First Robotics	Helped with Vex Robotics	Helped with Other Robotics	Helped with Lego League	Helped with State Engineering Challenges	Helped with MESA	Helped with Odyssey of the Mind
Novice										
Participant 1	0	2	0	0	0	0	0	0	0	0
Participant 2	0	2	1	0	0	0	0	0	0	0
Participant 3	0	2	0	0	0	0	0	0	0	0
Participant 4	0	2	0	0	0	0	0	0	0	0
Participant 5	0	2	0	0	0	0	0	0	0	0
Participant 6	0	2	0	0	0	0	0	0	0	0
Participant 7	0	2	0	0	0	0	0	0	0	0
Participant 8	0	2	0	0	0	0	0	0	0	0
Participant 9	0	2	0	0	0	0	0	0	0	0
Participant 10	0	2	1	0	1	0	0	0	0	0
Participant 11	0	1	1	1	0	0	0	0	0	0
Participant 12	Research	1	1	0	0	0	0	0	0	0
Participant 13	0	2	0	0	0	0	0	0	0	0
Participant 14	0	2	0	0	0	0	0	0	0	0
Participant 15	0	1	0	0	0	0	1	0	0	0
Participant 16	0	2	0	0	0	0	0	0	0	0
Participant 17	0	2	1	0	1	0	0	0	0	0
Participant 18	0	2	0	0	0	0	0	0	0	0
Mode	0	2	0	0	0	0	0	0	0	0
Intermediate										
Participant 19	0	2	0	0	0	0	0	0	0	0
Participant 20	0	2	0	0	0	0	0	0	0	0
Participant 21	0	1	0	0	0	0	0	0	0	0
Participant 22	0	2	0	1	0	0	0	0	0	0
Participant 23	0	2	0	0	1	0	0	0	0	0
Participant 24	0	2	0	0	0	0	0	0	0	0
Participant 25	0	1	0	0	1	0	0	1	0	0
Participant 26	0	2	0	0	1	0	0	0	0	0
Participant 27	0	2	0	0	0	0	0	0	0	0
Participant 28	0	2	0	0	0	0	0	0	0	0
Participant 29	SPED & Read	2	0	0	1	0	0	1	0	0
Participant 30	0	2	0	0	0	0	0	0	0	0
Participant 31	0	2	0	0	0	0	0	0	0	0
Participant 32	0	2	0	0	0	0	0	0	0	0
Participant 33	0	1	0	0	0	0	0	0	0	0
Participant 34	0	2	0	0	0	0	0	0	0	0
Participant 35	0	2	0	0	1	0	0	0	0	0
Participant 36	0	2	0	1	1	0	1	0	1	0
Mode	0	2	0	0	0	0	0	0	0	0
Veteran										
Participant 37	0	1	0	0	0	0	0	0	0	0
Participant 38	0	1	0	0	0	0	0	0	0	0
Participant 39	0	2	0	0	0	0	0	0	0	0
Participant 40	0	1	0	1	0	0	0	0	0	0
Participant 41	0	2	0	0	0	0	0	0	0	0
Participant 42	0	1	0	0	0	0	0	0	0	0
Participant 43	0	1	0	0	0	0	0	0	0	0
Participant 44	0	1	0	0	0	0	0	0	0	0
Participant 45	0	2	0	0	0	0	0	0	0	0
Participant 46	0	2	0	0	0	0	0	0	0	0
Participant 47	0	2	0	0	0	1	0	0	0	0
Participant 48	0	1	0	0	0	0	0	0	0	0
Participant 49	0	2	0	0	0	0	0	0	0	0
Participant 50	0	1	0	1	0	0	0	1	1	0
Participant 51	Research	2	1	0	0	0	0	0	0	1
Participant 52	0	1	1	0	0	0	0	0	0	0
Participant 53	0	2	0	0	0	0	0	0	0	0
Participant 54	0	1	0	0	0	0	0	0	0	0
Participant 55	0	2	0	0	0	0	0	0	0	0
Mode	0	1	0	0	0	0	0	0	0	0
Mode for All	0	2	0	0	0	0	0	0	0	0
Mean for All	0.00	1.71	0.13	0.09	0.15	0.02	0.04	0.05	0.04	0.02
Median for All	0	2	0	0	0	0	0	0	0	0

Participant	Helped with SkillsUSA	Helped with other	Helped with No Activities	Hours Engaged in readings in Science Education	Hours Engaged in readings in Technology Education	PD - College courses teaching sci in tech ed	PD - Workshop or In-service Training about teaching sci in tech ed	PD - Summer Institute about teaching sci in tech ed	PD - Professional Association/Conference about teaching sci in tech ed	PD- Observational visit to another school's science or STEM facility
Novice										
Participant 1	0	0	1	2	5	1	2	1	1	1
Participant 2	0	0	0	1	1	1	1	1	1	1
Participant 3	0	0	1	1	3	1	5	1	1	1
Participant 4	0	0	1	5	5	1	1	1	1	1
Participant 5	0	0	1	2	2	1	1	4	2	3
Participant 6	0	0	1	2	3	1	1	1	1	1
Participant 7	0	0	1	1	4	7	2	1	1	1
Participant 8	0	0	1	2	3	1	3	1	1	3
Participant 9	0	0	1	5	5	5	3	2	4	3
Participant 10	0	0	0	3	5	1	7	2	3	1
Participant 11	0	0	0	5	5	7	7	7	7	7
Participant 12	0	0	0	2	5	4	3	1	1	1
Participant 13	0	0	1	5	5	1	1	1	2	1
Participant 14	0	0	1	3	5	1	7	6	1	1
Participant 15	0	0	0	2	2	1	4	4	1	1
Participant 16	0	0	1	1	4	2	4	1	3	1
Participant 17	0	0	0	5	5	1	7	3	1	2
Participant 18	0	Debate Tear	0	5	5	1	4	3	3	3
Mode	0	0	1	2	5	1	1	1	1	1
Intermediate										
Participant 19	0	Photography	0	1	3	1	1	1	1	1
Participant 20	0	0	1	4	3	1	3	1	1	1
Participant 21	0	0	1	2	2	3	4	3	1	1
Participant 22	0	0	0	1	2	1	1	1	1	1
Participant 23	0	0	0	1	3	1	2	1	2	4
Participant 24	0	0	1	2	2	3	7	1	1	1
Participant 25	0	0	0	5	5	7	7	7	7	1
Participant 26	0	0	1	3	3	1	2	1	1	2
Participant 27	0	0	1	3	5	1	2	1	1	1
Participant 28	0	0	1	1	1	1	1	1	1	1
Participant 29	0	FBLA, NTHS a	0	1	4	1	3	1	2	2
Participant 30	0	0	1	1	2	1	1	1	1	1
Participant 31	0	0	1	1	1	1	1	1	1	1
Participant 32	0	0	1	1	2	1	4	3	1	2
Participant 33	1	0	0	1	1	1	2	1	1	1
Participant 34	0	0	1	1	1	1	2	2	1	1
Participant 35	0	0	0	1	3	1	2	2	1	1
Participant 36	0	0	0	1	5	1	1	1	1	1
Mode	0	0	1	1	3	1	1	1	1	1
Veteran										
Participant 37	0	0	1	1	1	1	1	1	1	2
Participant 38	0	0	1	2	3	1	1	1	1	1
Participant 39	0	0	1	1	5	1	7	1	4	1
Participant 40	0	0	0	5	5	1	3	2	1	2
Participant 41	0	0	1	2	2	1	1	1	1	1
Participant 42	0	0	1	5	5	1	7	3	1	3
Participant 43	0	STEM club	0	2	5	1	2	4	3	1
Participant 44	0	Engineering (	0	5	5	1	1	1	2	1
Participant 45	0	0	1	3	5	1	7	2	2	2
Participant 46	0	0	1	3	5	1	3	1	1	1
Participant 47	0	0	0	1	2	1	3	1	1	3
Participant 48	0	0	1	2	3	1	1	1	1	1
Participant 49	0	FBLA	0	1	4	1	1	1	1	1
Participant 50	0	0	0	1	4	1	1	2	2	2
Participant 51	0	MD Science (	0	5	5	1	3	1	1	1
Participant 52	0	0	0	1	4	1	3	2	1	1
Participant 53	0	0	1	5	5	2	4	1	3	1
Participant 54	0	0	1	1	4	3	1	1	1	1
Participant 55	0	0	1	1	2	1	2	1	1	1
Mode	0	0	1	1	5	1	1	1	1	1
Mode for All	0	0	1	1	5	1	1	1	1	1
Mean for All	0.02	0.00	0.58	2.36	3.53	1.60	2.93	1.80	1.64	1.53
Median for All	0	0	1	2	4	1	2	1	1	1

Participant	PD - College courses teaching tech ed	PD - Workshop or In-service Training about teaching tech ed	PD - Summer Institute about teaching tech ed	PD - Professional Association/Conference about teaching tech ed	PD- Observational visit to another school's technology education or STEM facility	Served on a district or school committee in Science Ed	Served on a district or school committee in Tech Ed	Acted as a peer teaching coach or mentor to other teachers in science ed	Acted as a peer teaching coach or mentor to other teachers in tech ed	Delivered an in-service workshop or course related to science ed
Novice										
Participant 1	1	2	1	1	1	0	0	0	0	0
Participant 2	7	3	1	3	2	0	0	0	0	0
Participant 3	1	5	1	1	1	0	0	0	0	0
Participant 4	3	4	1	1	1	0	1	0	1	0
Participant 5	1	2	4	2	3	0	0	0	0	0
Participant 6	1	3	1	1	1	0	0	0	0	0
Participant 7	1	1	1	1	1	0	0	0	0	0
Participant 8	1	7	1	1	4	0	0	0	1	0
Participant 9	5	3	2	4	3	0	0	0	0	0
Participant 10	3	7	3	1	1	0	1	0	1	0
Participant 11	7	7	7	7	7	0	1	0	1	0
Participant 12	4	7	1	1	1	0	0	0	0	0
Participant 13	1	1	1	1	1	0	0	0	0	0
Participant 14	1	1	3	1	1	0	0	0	0	0
Participant 15	1	3	1	1	1	0	0	0	1	0
Participant 16	2	3	3	2	2	0	1	0	1	0
Participant 17	1	7	3	1	2	0	0	0	0	0
Participant 18	1	4	3	3	3	0	1	0	1	0
Mode	1	3	1	1	1	0	0	0	0	0
Intermediate										
Participant 19	1	7	2	2	2	0	1	0	0	0
Participant 20	1	5	2	1	3	0	0	0	1	0
Participant 21	5	3	1	1	1	1	1	0	1	1
Participant 22	1	4	4	1	1	0	1	0	1	0
Participant 23	1	4	1	3	4	0	1	0	1	0
Participant 24	1	7	1	1	1	0	0	0	0	0
Participant 25	7	7	7	7	1	1	1	0	1	0
Participant 26	1	3	1	1	1	0	0	0	0	0
Participant 27	1	2	1	1	1	0	0	0	0	0
Participant 28	1	1	2	1	1	0	0	0	0	0
Participant 29	2	4	3	4	2	0	1	0	1	0
Participant 30	1	4	2	1	1	0	1	0	1	0
Participant 31	1	2	1	1	1	0	0	0	0	0
Participant 32	1	4	3	1	2	0	1	0	1	0
Participant 33	1	1	3	1	1	0	1	0	1	0
Participant 34	1	1	1	1	1	0	0	0	1	0
Participant 35	1	5	2	1	3	0	1	0	1	0
Participant 36	1	1	1	1	1	0	1	0	0	0
Mode	1	4	1	1	1	0	1	0	1	0
Veteran										
Participant 37	1	1	1	4	1	0	1	1	0	0
Participant 38	1	3	1	1	1	0	1	0	0	0
Participant 39	1	7	1	4	1	0	0	0	1	0
Participant 40	1	2	1	2	1	0	1	0	0	0
Participant 41	1	1	1	1	1	0	0	0	0	0
Participant 42	1	6	3	1	5	0	0	0	0	0
Participant 43	1	2	4	3	1	0	1	0	1	0
Participant 44	3	4	3	4	1	0	0	0	1	0
Participant 45	1	7	2	2	2	0	1	0	1	0
Participant 46	1	1	1	1	1	0	0	0	0	0
Participant 47	1	1	1	1	1	0	1	0	1	0
Participant 48	1	1	1	1	1	0	1	0	1	1
Participant 49	1	1	2	1	1	0	0	0	0	0
Participant 50	1	2	1	2	2	0	1	0	1	0
Participant 51	1	7	1	1	1	0	1	0	1	0
Participant 52	1	2	2	1	1	0	0	0	1	0
Participant 53	1	7	1	3	1	0	1	0	1	0
Participant 54	3	1	1	1	1	0	0	0	1	0
Participant 55	1	2	1	1	1	0	0	0	0	0
Mode	1	1	1	1	1	0	1	0	1	0
Mode for All	1	1	1	1	1	0	0	0	1	0
Mean for All	1.71	3.51	1.91	1.78	1.62	0.04	0.47	0.02	0.53	0.04
Median for All	1	3	1	1	1	0	0	0	1	0

Participant	Delivered an in-service workshop or course related to tech ed	Did not participate in PD activities in Science Education	Did not participate in PD activities in Tech Ed	Number of Science Education committees/ task forces on	Number of Tech Ed committees/ task forces on	Hours mentoring and/or peer observation of a science class/lab	Hours in science discussion or study group	Hours in science teacher collaborative network (i.e. idea gardens, list serves)	Hours consulting with a science curriculum specialist to teach science	Hours mentoring and/or peer observation of a tech ed class/lab
Novice										
Participant 1	1	0	0	2	2	1	1	1	1	1
Participant 2	0	1	1	1	1	1	1	1	1	2
Participant 3	0	1	1	1	1	1	1	1	1	2
Participant 4	0	1	0	1	4	2	1	4	2	5
Participant 5	1	1	0	1	3	1	1	2	1	2
Participant 6	0	1	1	1	1	1	1	1	1	2
Participant 7	0	1	1	1	1	1	2	2	2	2
Participant 8	0	1	0	1	4	2	2	2	2	3
Participant 9	1	0	0	1	2	5	5	2	1	5
Participant 10	1	1	0	1	2	1	1	3	3	5
Participant 11	1	0	1	7	7	5	5	5	5	5
Participant 12	1	0	0	1	1	1	3	2	1	1
Participant 13	0	1	1	1	1	1	1	1	1	1
Participant 14	0	0	0	1	1	2	3	3	3	5
Participant 15	1	0	0	2	0	0	1	2	2	1
Participant 16	1	0	1	0	0	0	1	1	1	2
Participant 17	0	1	1	0	0	0	1	1	1	1
Participant 18	1	0	0	2	3	1	3	5	2	2
Mode	1	1	0	1	1	1	1	1	1	2
Intermediate										
Participant 19	0	0	0	1	2	1	1	1	1	2
Participant 20	0	1	0	2	2	1	2	1	2	2
Participant 21	1	0	0	3	4	4	3	2	2	4
Participant 22	0	1	0	1	1	1	1	1	1	5
Participant 23	1	1	0	1	4	1	2	1	2	4
Participant 24	0	1	1	1	1	2	2	2	2	2
Participant 25	1	0	0	3	7	3	3	3	3	5
Participant 26	0	1	1	1	1	1	1	2	1	1
Participant 27	0	1	1	1	1	1	1	1	1	1
Participant 28	0	1	1	1	1	1	1	1	1	1
Participant 29	1	1	0	2	7	1	1	1	1	4
Participant 30	0	1	0	1	1	1	1	1	1	2
Participant 31	0	1	1	1	1	1	1	1	1	1
Participant 32	1	1	0	2	4	1	1	1	1	5
Participant 33	1	1	0	0	2	0	1	1	1	3
Participant 34	0	1	0	0	1	0	1	1	1	1
Participant 35	0	1	0	0	1	0	1	1	1	3
Participant 36	0	1	0	0	0	0	1	1	1	1
Mode	0	1	0	1	1	1	1	1	1	1
Veteran										
Participant 37	1	1	0	1	2	2	2	2	2	2
Participant 38	0	1	0	1	2	1	1	1	1	2
Participant 39	1	0	0	1	1	1	3	1	1	1
Participant 40	0	1	0	1	2	1	2	2	2	3
Participant 41	0	0	0	1	1	1	1	1	1	1
Participant 42	0	1	1	1	1	1	5	5	1	1
Participant 43	1	1	0	1	3	1	1	1	2	1
Participant 44	1	0	0	1	2	1	1	1	1	3
Participant 45	0	1	0	1	3	1	1	3	1	3
Participant 46	0	1	1	1	3	1	1	1	1	2
Participant 47	1	1	1	1	1	1	1	1	1	4
Participant 48	1	0	0	5	3	1	1	1	1	3
Participant 49	0	1	1	0	0	0	1	1	1	2
Participant 50	1	0	0	0	1	0	2	1	1	2
Participant 51	0	0	0	0	1	0	1	3	1	3
Participant 52	1	1	0	0	1	0	1	1	1	1
Participant 53	0	1	1	0	3	0	1	1	1	5
Participant 54	0	0	0	0	0	0	1	2	1	1
Participant 55	0	1	1	1	1	1	1	2	1	2
Mode	0	1	0	1	1	1	1	1	1	2
Mode for All	0	1	0	1	1	1	1	1	1	2
Mean for All	0.42	0.67	0.35	1.15	1.93	1.09	1.58	1.69	1.40	2.47
Median for All	0	1	0	1	1	1	1	1	1	2

Participant	Hours in tech ed discussion or study group	Hours in tech ed teacher collaborative network (i.e. idea gardens, list serves)	Hours consulting with a science curriculum specialist to teach tech ed	Hours consulting with a tech ed curriculum specialist to teach tech ed	Conferences attended in the past three years	Other conferences attended	Sessions attended at conferences	Collaborate with Tech Ed teachers	Collaborate with Physics teachers	Collaborate with Math teachers
Novice										
Participant 1	1	1	1	3	4	NEA Impleme	3	4	6	8
Participant 2	1	2	1	1	6	0	1	2	1	1
Participant 3	2	1	1	2	6	0	1	2	8	8
Participant 4	1	5	2	5	6	0	5	2	6	6
Participant 5	2	3	2	2	5	PLTW	1	1	4	4
Participant 6	1	4	1	2	6	0	5	3	8	8
Participant 7	2	2	1	1	6	0	5	3	8	7
Participant 8	2	5	2	3	5	State T&E	3	1	7	7
Participant 9	5	2	1	2	2,3	0	1	1	8	8
Participant 10	5	5	3	3	6	0	5	1	5	5
Participant 11	5	5	5	5	6	0	1	1	8	8
Participant 12	3	2	1	1	6	0	5	3	8	8
Participant 13	1	1	1	1	2	0	3	5	8	8
Participant 14	2	1	1	2	6	0	5	2	5	5
Participant 15	4	3	2	3	6	0	3	2	5	4
Participant 16	2	3	2	3	6	0	5	8	8	8
Participant 17	3	1	1	1	6	0	1	1	2	2
Participant 18	5	5	2	3	2	0	1	2	8	4
Mode	2	1	1	3	6	0	1	2	8	8
Intermediate										
Participant 19	1	1	1	2	2,4	0	1	2	8	8
Participant 20	2	1	1	2	6	0	3	2	8	8
Participant 21	3	3	2	2	6	0	3	3	6	5
Participant 22	5	5	1	5	6	0	1	1	7	8
Participant 23	4	3	1	4	5	State T&E	3	1	8	6
Participant 24	2	2	2	2	6	0	5	1	6	6
Participant 25	5	5	5	5	2,3	0	1	2	3	6
Participant 26	1	5	1	1	6	0	5	1	6	8
Participant 27	1	1	1	2	6	0	5	4	8	8
Participant 28	1	2	1	1	6	0	5	5	8	8
Participant 29	3	2	1	2	1,2	2 State PDS,	1	2	8	8
Participant 30	1	2	2	1	6	0	5	1	6	8
Participant 31	1	2	1	1	6	0	5	2	8	8
Participant 32	5	5	2	4	6	0	5	1	5	5
Participant 33	1	1	1	2	2	0	1	1	8	8
Participant 34	1	2	1	1	6	0	5	1	8	8
Participant 35	3	5	2	2	6	0	5	5	7	6
Participant 36	1	1	1	1	6	0	4	8	8	8
Mode	1	2	1	2	6	0	5	1	8	8
Veteran										
Participant 37	2	2	2	2	6	0	5	1	8	8
Participant 38	2	2	1	1	6	0	5	1	8	8
Participant 39	2	1	1	1	2	0	1	2	8	8
Participant 40	2	4	2	2	2	0	1	2	5	6
Participant 41	1	1	1	1	6	0	5	8	8	8
Participant 42	5	5	1	3	5	Local techno	1	2	8	6
Participant 43	1	2	1	2	1,2	0	3	4	6	6
Participant 44	4	2	1	1	2	0	1	2	8	8
Participant 45	1	3	1	3	6	0	5	1	3	3
Participant 46	2	1	1	2	6	0	5	1	4	4
Participant 47	1	4	2	2	6	0	5	2	6	6
Participant 48	2	2	2	1	3	AP College Bo	3	4	7	4
Participant 49	2	2	1	2	6	0	5	2	8	8
Participant 50	2	1	1	2	2,4	0	1	4	7	6
Participant 51	1	3	1	2	4	0	1	1	5	5
Participant 52	1	1	1	1	6	0	3	3	8	8
Participant 53	5	5	1	2	2	0	1	1	8	8
Participant 54	1	2	1	2	6	0	5	8	8	8
Participant 55	1	2	1	1	6	0	5	6	8	8
Mode	2	2	1	2	6	0	5	1	8	8
Mode for All	1	2	1	2	6	0	5	1	8	8
Mean for All	2.29	2.62	1.45	2.11	5.20	0.00	3.24	2.58	6.73	6.64
Median for All	2	2	1	2	6	0	3	2	8	8

Participant	Collaborate with Chemistry teachers	Collaborate with Biology teachers	Collaborate with Earth Science teachers	Collaborate with Space Science teachers	Collaborate with Business Education teachers	Collaborate with Family and Consumer science teachers	Collaborate with other teachers how often?	Collaborate with other teachers in what area?	What gender do you identify as?	What ethnicity do you identify as?
Novice										
Participant 1	5	5	8	8	6	8	8	0	1	1
Participant 2	1	1	1	1	1	1	8	0	2	1
Participant 3	8	8	8	8	3	8	8	0	1	1
Participant 4	6	6	6	8	8	8	8	0	2	1
Participant 5	5	8	8	8	5	8	8	0	2	1
Participant 6	8	8	8	8	8	8	8	0	2	1
Participant 7	8	8	8	8	8	8	8	0	1	1
Participant 8	7	7	7	7	7	7	8	0	1	8
Participant 9	8	8	8	8	1	8	8	0	1	8
Participant 10	7	5	5	5	5	7	5	Social scienc	2	1
Participant 11	8	8	8	8	8	8	4	0	2	1
Participant 12	8	8	8	8	8	8	1	0	1	1
Participant 13	8	8	8	8	8	8	8	0	2	1
Participant 14	7	7	6	8	6	7	8	0	1	1
Participant 15	5	5	5	5	2	5	8	0	1	1
Participant 16	8	8	8	8	8	8	8	0	1	1
Participant 17	8	2	8	8	8	8	8	0	1	1
Participant 18	8	8	5	8	3	3	8	0	1	1
Mode	8	8	8	8	8	8	8	0	1	1
Intermediate										
Participant 19	8	8	8	8	5	2	8	0	2	1
Participant 20	3	8	3	8	3	8	2	Agriscience	1	1
Participant 21	8	8	8	8	8	8	8	0	1	1
Participant 22	8	7	7	8	8	8	8	0	1	1
Participant 23	8	8	6	8	6	8	6	English	2	1
Participant 24	6	6	6	6	3	3	8	0	1	1
Participant 25	6	8	8	8	2	5	8	0	1	1
Participant 26	8	8	8	8	3	8	8	0	1	1
Participant 27	8	8	8	8	8	8	8	0	1	1
Participant 28	8	8	8	8	2	8	8	0	2	1
Participant 29	8	8	8	8	5	8	8	0	1	1
Participant 30	8	8	8	8	8	8	1	0	1	1
Participant 31	8	8	8	8	8	8	5	0	2	1
Participant 32	8	5	8	8	4	8	8	0	1	1
Participant 33	8	8	8	8	8	8	8	0	2	1
Participant 34	8	8	8	8	2	8	8	0	1	1
Participant 35	8	8	8	8	8	8	8	0	1	1
Participant 36	8	8	8	8	8	8	1	History	1	1
Mode	8	8	8	8	8	8	8	0	1	1
Veteran										
Participant 37	8	8	8	8	8	8	8	0	1	1
Participant 38	8	8	8	8	8	8	8	0	1	1
Participant 39	8	8	8	8	8	8	8	0	1	1
Participant 40	7	7	7	8	5	4	8	0	1	1
Participant 41	8	8	8	8	8	8	8	0	1	4
Participant 42	8	8	6	6	5	8	8	0	1	1
Participant 43	8	8	8	8	6	8	8	0	2	1
Participant 44	8	8	8	8	8	8	8	0	1	1
Participant 45	5	3	5	5	5	5	8	0	1	1
Participant 46	4	4	4	4	8	8	8	0	1	1
Participant 47	6	6	6	6	3	6	1	Career Educa	1	1
Participant 48	8	7	6	5	8	8	2	0	1	1
Participant 49	8	8	8	8	2	8	8	0	1	1
Participant 50	8	7	8	8	7	7	8	0	1	1
Participant 51	8	8	8	8	8	8	8	0	1	1
Participant 52	8	8	8	8	8	4	8	0	1	1
Participant 53	8	8	5	6	8	8	8	0	1	1
Participant 54	8	8	8	8	8	8	8	0	2	1
Participant 55	8	8	8	8	5	8	8	0	2	2
Mode	8	8	8	8	8	8	8	0	1	1
Mode for All	8	8	8	8	8	8	8	0	1	1
Mean for All	7.27	7.16	7.13	7.42	5.96	7.16	7.05	0.00	1.27	1.33
Median for All	8	8	8	8	7	8	8	0	1	1

Participant	What ethnicity do you identify as other?	What is your age? (Please enter as a numerical value, not as a / word)	Which setting did you grow up in?	Which setting do you currently teach in?	Years taught in Urban setting?	Years taught in Suburban setting?	Years taught in Rural setting?	Years taught Tech Ed at MS level	Years taught Tech Ed at HS level	Years taught science ed at Elementary Level
Novice										
Participant 1	0	28	2,3	2	0	3	0	0	3	0
Participant 2	0	24	3	2	0	2	0	0	2	0
Participant 3	0	26	2	1	2	0	0	0	2	0
Participant 4	0	48	2	1	6	1	0	0	5	0
Participant 5	0	26	2,3	2	0	5	0	0	5	0
Participant 6	0	30	2	2	0	7	0	0	7	0
Participant 7	0	25	2	2	0	2	0	0	2	0
Participant 8	African Amer	25	2	1	3	0	0	0	3	0
Participant 9	Ugandan-Am	50	1	1	4	0	0	1	3	0
Participant 10	0	47	1	2	0	3	0	0	3	0
Participant 11	0	34	3	3	0	0	0	0	3	0
Participant 12	0	27	3	2	0	4	0	0	4	0
Participant 13	0	48	2	2	0	1	0	0	1	0
Participant 14	0	28	2,3	2	0	3	0	0	3	0
Participant 15	0	39	3	3	0	0	7	7	7	0
Participant 16	0	34	2	3	0	0	6	0	4	0
Participant 17	0	26	2,3	1	3	0	1	1	4	0
Participant 18	0	54	2	2	0	3	0	0	2	0
Mode	0	26	2	2	0	0	0	0	3	0
Intermediate										
Participant 19	0	60	2	2	0	15	0	0	15	0
Participant 20	0	55	2	3	0	0	9	0	4	0
Participant 21	0	47	2	2	0	13	0	0	13	0
Participant 22	0	35	3	2	0	13	0	0	13	0
Participant 23	0	37	2	2	11	0	0	6	6	0
Participant 24	0	50	3	3	0	0	0	0	7	0
Participant 25	0	47	2	1	10	0	0	0	8	0
Participant 26	0	30	3	2	4	3	0	0	7	0
Participant 27	0	46	1	1	9	0	0	0	1	0
Participant 28	0	48	2,3	2	0	0	0	0	3	0
Participant 29	0	38	3	2	0	10	1	0	7	0
Participant 30	0	32	2	2	0	10	0	0	10	0
Participant 31	0	38	2	1	11	3	0	0	1	0
Participant 32	0	37	1,2	2	0	12	0	0	6	5
Participant 33	0	33	2	2	0	11	0	3	11	0
Participant 34	0	36	3	3	0	0	10	0	6	0
Participant 35	0	33	2	2	0	10	0	1	10	0
Participant 36	0	28	1,2	3	0	0	7	0	7	0
Mode	0	47	2	2	0	0	0	0	7	0
Veteran										
Participant 37	0	53	3	3	0	0	0	0	30	0
Participant 38	0	50	3	1	29	0	0	0	29	0
Participant 39	0	61	2	2	0	21	0	0	21	0
Participant 40	0	59	2	2	14	14	0	0	10	0
Participant 41	0	39	1	2	0	12	6	0	3	0
Participant 42	0	65	2	1	12	12	16	1	36	0
Participant 43	0	48	2	2	2	15	0	1	10	6
Participant 44	0	54	3	2	0	18	2	2	18	0
Participant 45	0	52	2	3	12	3	8	0	8	0
Participant 46	0	41	3	3	0	0	19	19	19	0
Participant 47	0	48	3	2	0	24	0	5	19	0
Participant 48	0	56	2	1	23	10	0	19	14	0
Participant 49	0	59	1	1	4	29	0	0	1	0
Participant 50	0	63	2	2	0	30	2	2	32	0
Participant 51	0	62	3	2	0	29	0	0	24	0
Participant 52	0	51	1	3	0	0	20	0	5	0
Participant 53	0	66	1,2	1	11	0	8	7	12	0
Participant 54	0	41	2	3	0	0	16	0	4	0
Participant 55	0	55	3	2	2	15	1	0	5	0
Mode	0	59	2	2	0	0	0	0	10	0
Mode for All	0	48	2	2	0	0	0	0	3	0
Mean for All	0.00	43.13	2.21	1.98	3.13	6.65	2.53	1.36	9.05	0.20
Median for All	0	46	2	2	0	3	0	0	6	0

Participant	Years taught science ed at the high school level	Years taught other content areas	Name of other content areas taught	Years taught other content areas	Name of other content areas taught	Years taught other content areas	Name of other content areas taught	Certified to teach Tech Ed?	Certified to teach Earth Science?	Certified to teach Business Ed?
Novice										
Participant 1	0	0	0	0	0	0	0	1	0	0
Participant 2	0	0	0	0	0	0	0	1	0	0
Participant 3	0	0	0	0	0	0	0	1	0	0
Participant 4	0	2	English	1	Business Edu	0	0	1	0	1
Participant 5	0	5	Math	3	Engineering	0	0	1	0	0
Participant 6	0	3	FACS	0	0	0	0	1	0	1
Participant 7	0	0	0	0	0	0	0	1	0	0
Participant 8	0	0	0	0	0	0	0	0	0	0
Participant 9	0	0	0	0	0	0	0	0	0	0
Participant 10	0	0	0	0	0	0	0	1	0	0
Participant 11	3	0	0	0	0	0	0	1	0	0
Participant 12	0	0	0	0	0	0	0	1	0	0
Participant 13	0	0	0	0	0	0	0	1	0	0
Participant 14	0	0	0	0	0	0	0	0	0	0
Participant 15	0	0	0	0	0	0	0	1	0	0
Participant 16	0	6	Business	3	Personal Fina	3	Keyboarding,	1	0	1
Participant 17	0	0	0	0	0	0	0	1	0	0
Participant 18	0	2	Social Studie	2	Computer Re	0	0	1	0	0
Mode	0	0	0	0	0	0	0	1	0	0
Intermediate										
Participant 19	0	3	Art	0	0	0	0	0	0	0
Participant 20	9	9	Agriscience	0	0	0	0	1	0	0
Participant 21	2	0	0	0	0	0	0	1	0	0
Participant 22	0	0	0	0	0	0	0	1	0	0
Participant 23	0	2	Photography	0	0	0	0	1	0	0
Participant 24	0	3	Physical Educ	0	0	0	0	1	0	0
Participant 25	1	2	Business	2	Computer Sc	0	0	1	0	1
Participant 26	0	0	0	0	0	0	0	1	0	0
Participant 27	0	8	Physical Educ	0	0	0	0	1	0	0
Participant 28	0	0	0	0	0	0	0	0	0	1
Participant 29	0	4	Business and	0	0	0	0	1	0	0
Participant 30	0	0	0	0	0	0	0	1	0	0
Participant 31	0	11	Math	3	Computer Sc	0	0	0	0	0
Participant 32	0	5	Elementary E	1	Social Studie	0	0	1	0	0
Participant 33	0	0	0	0	0	0	0	1	0	0
Participant 34	0	3	MS Compute	7	HS Business I	0	0	0	0	1
Participant 35	0	10	FoT	4	Intro to Engi	0	0	1	0	0
Participant 36	0	0	0	0	0	0	0	1	0	0
Mode	0	0	0	0	0	0	0	1	0	0
Veteran										
Participant 37	0	0	0	0	0	0	0	1	0	0
Participant 38	0	1	Applied Matl	8	World of Wo	2	Contempora	1	0	0
Participant 39	0	0	0	0	0	0	0	1	0	0
Participant 40	0	8	History	0	0	0	0	1	0	0
Participant 41	0	18	Health and P	0	0	0	0	0	0	0
Participant 42	0	2	Substitute te	1	Special Educ	0	0	1	0	1
Participant 43	0	2	Math	0	0	0	0	1	0	0
Participant 44	0	0	0	0	0	0	0	1	0	0
Participant 45	0	0	0	0	0	0	0	1	0	0
Participant 46	0	0	0	0	0	0	0	1	0	0
Participant 47	0	7	Career Educa	1	Photography	0	0	1	0	0
Participant 48	0	4	Career Ed	0	0	0	0	1	0	0
Participant 49	0	32	Business	0	0	0	0	1	0	1
Participant 50	0	2	Math	2	Social Studie	0	0	1	0	0
Participant 51	0	0	0	0	0	0	0	1	0	0
Participant 52	0	0	0	0	0	0	0	1	0	0
Participant 53	0	1	Photography	1	Journalism	0	0	1	1	0
Participant 54	0	2	Marketing	10	Computer Sc	0	0	1	0	1
Participant 55	0	2	Reading	18	Business Edu	0	0	0	0	1
Mode	0	0	0	0	0	0	0	1	0	0
Mode for All	0	0	0	0	0	0	0	1	0	0
Mean for All	0.27	2.89	0.00	1.22	0.00	0.09	0.00	0.84	0.02	0.18
Median for All	0	1	0	0	0	0	0	1	0	0

Participant	Certified to teach Math Ed?	Certified to teach other content?	Length of FoT training attended?	Other Length of FoT training attended?	Total Above Average Ratings among group	Total Below Average Ratings among group	Total Score
Novice							
Participant 1	0	0	4	0	31	7	24
Participant 2	0	0	4	0	25	19	**6**
Participant 3	0	Physical Ed/H	5	0	18	10	**8**
Participant 4	0	English	6	0 Prior to tea	41	6	35
Participant 5	1	0	1	0	48	7	**41**
Participant 6	0	FACS	2	0	16	6	10
Participant 7	0	Elementary a	5	0	21	11	10
Participant 8	0	Physical Edu	4	0	34	6	28
Participant 9	0	Soon getting	6	Can't remem	44	7	37
Participant 10	1	0	5	0	55	3	**52**
Participant 11	0	0	6	0	75	5	**70**
Participant 12	0	0	4	0	39	10	29
Participant 13	0	0	5	0	18	13	**5**
Participant 14	0	Social Studie	5	0	24	6	18
Participant 15	0	0	1	0	38	11	27
Participant 16	0	0	5	0	29	10	19
Participant 17	0	0	3	0	34	9	25
Participant 18	0	Social Studie	4	0	40	6	34
Mode	0	0	5	0	18	6	**10**
Intermediate							
Participant 19	0	Art, ESOL	4	0	22	9	13
Participant 20	0	Agriscience	4	0	34	9	25
Participant 21	0	0	1	0	41	8	33
Participant 22	0	0	5	0	29	5	24
Participant 23	0	0	2	0	42	5	**37**
Participant 24	0	Physical Educ	4	0	32	7	25
Participant 25	0	0	4	0	54	7	**47**
Participant 26	0	0	4	0	21	7	14
Participant 27	0	Physical educ	6	There was nc	16	11	**5**
Participant 28	0	0	4	0	15	11	**4**
Participant 29	0	Computer Sc	6	FOT Training	38	4	34
Participant 30	0	0	5	0	23	7	16
Participant 31	1	Computer Sc	5	0	20	15	**5**
Participant 32	0	Social Studie	6	FoT Best Prac	35	5	30
Participant 33	0	Marketing	5	0	23	11	12
Participant 34	0	0	1	0	12	13	**-1**
Participant 35	0	0	6	College cours	39	4	**35**
Participant 36	0	0	2	0	18	12	**6**
Mode	0	0	4	0	23	7	**25**
Veteran							
Participant 37	0	0	5	0	30	8	22
Participant 38	0	0	5	0	22	11	11
Participant 39	0	0	4	0	17	13	**4**
Participant 40	0	Carpentry	4	0	36	10	**26**
Participant 41	0	Health and P	5	0	21	22	**-1**
Participant 42	0	Marketing, C	6	3 Summer In	45	14	**31**
Participant 43	0	El Ed	4	0	30	12	18
Participant 44	0	Industrial Art	3	0	27	13	14
Participant 45	0	Social Studie	4	0	36	12	24
Participant 46	0	0	3	0	27	11	16
Participant 47	0	Career Educa	5	0	31	16	15
Participant 48	0	All Subjects E	1	0	37	10	**27**
Participant 49	0	0	4	0	22	14	**8**
Participant 50	0	Data Process	6	College cours	44	11	**33**
Participant 51	0	Social Studie	6	Done as inse	31	11	20
Participant 52	1	0	2	0	27	18	**9**
Participant 53	0	0	1	0	45	7	**38**
Participant 54	0	0	4	0	27	15	12
Participant 55	0	0	4	0	21	16	**5**
Mode	0	0	4	0	27	11	**#N/A**
Mode for All	0	0	4	0	21	11	5
Mean for All	0.07	0.00	4.09	0.00	31.27	9.93	21.35
Median for All	0	0	4	0	30	10	20

APPENDIX I

Unique Characteristics among Observed Participants

Table 38

Unique Characteristics among Observed Participants

Participant	Unique Preparation Experiences
Teacher 1	*Background:* This teacher was a male veteran teacher in their 60s with 30 years of teaching experience, and the past two of those years he has taught FoT. He grew up in a rural setting and taught T&E education at a suburban high school. As a child he enjoyed tinkering with his father's model trains and tools in their basement, which he attributed to his interest in learning how things worked and pursuing a career in T&E education. Prior to entering teaching he served in the armed forces and worked in construction while earning his bachelor's degree in industrial education and a minor in geography. Additionally, he has a master's in technology education and is certified to teach both technology education and social studies education. He reported high self-efficacy and expected outcome scores among other veteran teachers. *Coursework:* He completed a half-day online in-service training on how to teach the FoT curriculum. Teacher 1 reported taking a high amount of earth science classes in high school, and in his undergraduate studies he completed a high amount of biology, drafting/CADD, and technology education methods classes. As part of his graduate studies he completed a high amount of technical reading and research classes. *Additional Experiences:* Within the past three years he has helped with TSA, Odyssey of the Mind, and served as a Science Olympiad coach. This teacher stated that he spent over 35 hours reading science education literature within the past three years, and helped facilitate professional development or in-service trainings about technology education and teaching science within technology education. He frequently engaged in collaborative networks with other science and technology education teachers and recently attended a national technology education conference. Once a month Teacher 1 reported collaborating with the physics and mathematics teachers in his school. *School and Learners:* The school where Teacher 1 worked was constructed within the past five years. He had a classroom with rows of rectangular tables where students can sit and face the SMART Board and document camera at the front of the room. Adjacent to his room was a laboratory with traditional woodworking and metalworking equipment. Within the laboratory there were five wooden workbenches, a chalkboard, and a LCD projector. The diverse group of students in the observed class was comprised of three African American females, one Hispanic female, two Caucasian females, six African American males, one Hispanic male, and four Caucasian male students. *Lesson and Activity:* This instructor was observed during the second to last period of the school day. He had a good rapport with the students and his

(continued)

Table 38 Continued

Participant	Unique Preparation Experiences
Teacher 1	class was very energetic due to his witty sense of humor during the lesson. The students participated in class discussions related to the first lesson of Unit 3 within the FoT curriculum that investigated forms and conversion of energy.
Teacher 2	*Background:* Was a male teacher in the intermediate category in their late 40s that has taught for 10 years. Within those 10 years he has taught FoT for eight, business education and computer science for two, and science for one. He grew up in a suburban area and has taught in an urban school his entire career where he currently serves as department chair. His father was a civil engineer and he grew up making things such as soapbox derby cars, sheds, and other items. He was teaching business and his school system needed more FoT teachers, so he volunteered to teach FoT because of his comfort and enjoyment of tinkering with things during his childhood. He possesses a bachelor's degree in business education and a graduate certificate in technology education, and is certified to teach in both areas. This teacher reported high self-efficacy and expected outcome scores among others classified in the intermediate category. *Coursework:* Attended a one-week training session to learn how to teach FoT. His undergraduate coursework included some science education methods courses in addition to many physics, space science, and technology education classes. In graduate school he completed two courses each in physics, biology, and chemistry as well as coursework about integrating science concepts within technology education. *Additional Experiences:* Teacher 2 has recently helped students participate in Vex robotics and statewide engineering design competitions. Over the past three years he has participated in six or more higher education courses, workshops or in-service trainings, summer institutes, and conferences focused on teaching technology education and the teaching of science within technology education. Additionally this teacher has served on numerous committees regarding science and technology education, as well as spent many hours mentoring other teachers, participating in collaborative networks, and consulting with curriculum specialists in both science and T&E education. Within the past three years he has attended a state T&E education conference and a national science education conference. Once a semester he collaborated with the mathematics, chemistry, and family and consumer science teachers in his school. *School and Learners:* This teacher taught at an alternative school for students experiencing behavioral and emotional difficulty within a traditional high school setting. His school was located in an urban setting with 64% of their students receiving free and reduced meals. The class was taught in a newer career and technical education academy and included three Caucasian female students. The classroom itself was very

(continued)

Table 38 Continued

Participant	Unique Preparation Experiences
Teacher 2	small with tables in the middle facing a white board, and about a dozen computers located around the outskirts of the room. There were some glass windows along one wall that looked into a tiny fabrication laboratory. This space had a small traditional woodworking equipment and a workbench. *Lesson and Activity:* This educator had a very relaxed teaching style that relied on a lot of discussion and participation due to the size and nature of the class. Since students were in this setting for disciplinary reasons, he taught both STEM concepts and life skills. His school system was also in an area heavily focused on technical skills to help students pursue careers in local industries. The teacher presented the Unit 4 FoT PowerPoint presentations on various electronic circuit parts and had students complete a circuit activity that included soldering.
Teacher 3	*Background:* This instructor was a female novice teacher in her mid 20s and was in her second year of teaching, of which she has taught FoT both years. She taught in a rural school similar to the setting in which she grew up. Teacher 3 entered T&E education due to the influence of her middle school T&E teacher and her passion for secondary level T&E education classes. This teacher possesses a B.S. degree in technology education. She recorded low self-efficacy and expected outcome scores compared to other novice teachers. *Coursework:* Teacher 3 attended training for one-week on how to teach FoT. She did not take any biology, chemistry, physics, or earth science classes in high school, however she did take a lot of technology education classes. For her undergraduate preparation she completed two biology, two space science, three electronics, two biotechnology, and two technology education teaching methods courses. This teacher shared that she graduated from an undergraduate teacher preparation program which focused on teaching many of the traditional manufacturing and fabrication skills. She had not taken any graduate courses at the time of the observation. *Additional Experiences:* Within the past three years she helped with TSA and visited another technology education facility for an observation. As an undergraduate student she attended a state technology education conference. She did not engage in any readings or professional development regarding the teaching of science in T&E education, but did spend about six hours interacting with other teachers in an online T&E education collaborative network. On a daily basis this participant reports collaborating with many teachers at her school, including the biology, physics, chemistry, earth science, space science, math, business, and family and consumer science teachers. *School and Learners:* The class was taught in a large CADD laboratory of a

(continued)

Table 38 Continued

Participant	Unique Preparation Experiences
Teacher 3	newer school building located in a rural area. There were 15 Caucasian female, two African American male, and 11 Caucasian male students in the class. Rows of rectangular tables with a computer for every student faced a white board and projector at the front of the room. The only fabrication tools seen were hot glue guns and rulers. *Lesson and Activity:* This instructor seemed overwhelmed with the stresses of being a newer teacher. She presented the first lesson of Unit 3 regarding energy forms and conversion. Her lesson did not vary much from the slides provided by the FoT curriculum and consisted mostly of her lecturing at the front of the room asking for very little student input.
Teacher 4	*Background:* A male licensed technology education teacher in the intermediate category who was in his late 40s. In his 13 years of teaching he has taught FoT for five years and science for two years. This teacher grew up and taught in a suburban setting. He had a bachelor's degree in industrial engineering and owned his own pre-fabricated concrete business prior to entering teaching. Teacher 4 stated that he gained interest in T&E education when he was helping mentor technology education students at a local school through his business. This prompted him to take some teaching courses and pursue provisional licensure. He did not student teach, but did long term sub for a person that mentored him because they were not healthy enough to teach a full day. *Coursework:* Attended a half-day training on how to teach FoT. Completed graduate level courses in career and technology education, including methods courses, to obtain provisional licensure. In high school he completed many biology and chemistry courses. His undergraduate preparation included four physics, two biology, and one space science courses. Additionally, he took many mathematics courses in pre calculus, calculus, and statistics. *Additional Experiences:* Has participated in the EbD assessment writing summer workshops. Over the past three years he has not helped with any clubs but has spent a significant amount of time reading literature, participating in higher education courses, in-service workshops, and summer institutes about teaching science in technology education. Recently he completed a high amount of graduate level technology education courses, has served on school committees, and delivered workshops related to both science education and technology education. This participant spends a substantial amount of time mentoring and observing, participating in collaborative networks, and consulting with curriculum specialists in both science education and technology education. Within the past three years he has not attended a conference, but when he does he attends a mix of science and T&E sessions. Once a semester he collaborates with the physics teacher at his school, while once a month he

(continued)

Table 38 Continued

Participant	Unique Preparation Experiences
Teacher 4	works with the mathematics teacher. *School and Learners:* The class was in a small room at the end of an older school building. Upon walking into the classroom it was evident that there was some form of science and T&E integration occurring. There were a series of tables in rows facing the front of the classroom. In the middle of the classroom were two science lab tables with pulleys, incline planes, and Newton scales attached to them for lab activities. On the board at the front were science vocabulary terms listed such as mass, BTU, mechanical wave, elasticity, and gravitational. In the room next to this classroom was a laboratory with large woodworking and metalworking equipment. The class consisted of 11 Caucasian females, one African American male, and 11 Caucasian males. *Lesson and Activity:* This observation occurred during the last period of the day. The teacher focused on discussing energy consumption that is part of Unit 3, but also making students critical consumers of energy sources. The lesson took on a life of its own as students asked intriguing questions and the teacher took the time to thoroughly answer them. Students participated in a lab activity by troubleshooting an electronic circuit to make a buzzer work with a potentiometer. The teacher provided many applicable examples during the class discussion.
Teacher 5	*Background:* This was a male veteran teacher in his mid 50s with a wealth of formal and informal experiences over his 33 years as an educator, four of which he has recently spent teaching FoT. He grew up in a suburban setting, and previously taught in a suburban setting for 10 years, before teaching in an urban setting for the past 23 years. Within that time he taught technology education at the middle school level for 19 years, high school career education for four years, and high school technology education for the past 14 years. He had a strong interest for industrial arts classes growing up and credits his high school industrial arts teacher as the reason he became a T&E educator. In fact, his high school teacher convinced him to attend the same teacher preparation program as he did. The participant went to that traditional industrial arts teacher preparation program for three years and then transferred to a research/theory focused industrial arts program where he received his bachelor’s degree. He later earned a master’s in technology education and has his Arts and Sciences I and II licensure. Teacher 5 is certified to teach both technology education and elementary education. *Coursework:* To learn about FoT he attended a half-day training session. In his high school and undergraduate coursework he completed a high amount of physics courses. Specifically within undergraduate technology education courses, he completed three in electronics, three in manufacturing, two in robotics, and two in construction. Additionally, he

(continued)

Table 38 Continued

Participant	Unique Preparation Experiences
Teacher 5	took a high amount of algebra and industrial arts methods courses in his undergraduate career. In graduate school he reported taking a number of space science, robotics, and methods of teaching technology education courses. *Additional Experiences:* In addition to the coursework, he has participated in the Teacher in Space program and served on the original Center to Advance the Teaching of Technology and Science (CATTS) professional development team, which provided national training when the STLs were released. He has held supervisory roles at the county and state levels, and served as ITEEA president. He helped write a state curriculum project, the STLs, and served as one of the original test sites to pilot the STLs. From these experiences he gained extensive knowledge of the STL indicators and the ITEEA courses. He reported not helping with any clubs, but has delivered workshops related to both science and T&E education. Additionally, he has spent a lot time serving on science and T&E committees, mentoring T&E teachers, and consulting with a science curriculum specialist about teaching T&E education. To further enhance his science knowledge he spends an ample amount of time reading science education literature and attended a national science education association conference within the past three years. Teacher 5 also went to an Advanced Placement (AP) College Board conference and reports attending a mix of science and T&E sessions. Not only does this participant attend state T&E conferences, but he also presents there quite often. Lastly, this participant reported collaborating with physics and biology teachers once a year, earth and space science teachers once a month, and mathematics teachers every two weeks. *School and Learners:* This teacher taught at an older school within an urban city. Their classroom was near the front office and was a rectangular space with three rows of science lab tables facing the front. In the back of the room were a bunch of cabinets and some small fabricating equipment (e.g., drill press, band saw). Around the room were student made posters displaying idea webs of what they thought each component of STEM was, the core technologies, and the systems model. This class was very diverse with six African American females, four Hispanic females, two Caucasian females, seven African American males, eight Hispanic males, one Asian male, and one Caucasian male student. *Lesson and Activity:* This teacher led a brief review of electricity flow and electronic circuits related to Unit 4, then moved about the room as a facilitator for the majority of the class to help students troubleshoot various breadboard circuit designs. He was well respected and every student was engaged while also making progress toward meeting the objectives and completing the required number of circuit designs.

(continued)

Table 38 Continued

Participant	Unique Preparation Experiences
Teacher 6	*Background:* A male veteran teacher in his early 60s who taught for 28 years, of which the past ten were spent teaching FoT. He grew up in a suburban area and has taught in a similar setting for the past 14 years. Teacher 6 has a master's degree in theology and an educational specialist degree in technology education. During the summers he has done soil and concrete testing for a geotechnology engineering firm. Currently he has earned 30 credits beyond his master's degree. He taught U.S. and European history in a private high school for eight years before pursuing a career in home remodeling for a few years, then reentered teaching as a carpentry instructor due to his love for teaching and doing home improvements. Eventually the curriculum transitioned to a technology education focus, which prompted him to teach FoT for the past 10 years. He is certified to teach carpentry and technology education, and is also national board certified in CTE. *Coursework:* Attended FoT training for one week, and took no technology education, physics, or earth science classes in high school. In his undergraduate studies he did not complete any electronics or power, energy, and transportation (PET) courses, nor did he complete any science courses. He did take one biology, one industrial arts methods, and two technology education methods courses during his graduate studies. *Additional Experiences:* The teacher helped with FIRST robotics and reported spending many hours reading science literature. Within the past three years he has observed at another school's science facility, participated in in-service trainings, and a completed a summer institute regarding the teaching of science within T&E education. He also partakes in T&E in-service and annually attends the state T&E conference. When attending this conference he predominantly attends T&E education sessions. For six hours or more he has participated in science discussion groups, teacher collaborative networks, and consulted with a science curriculum specialist. Furthermore, he has spent numerous hours mentoring a T&E education class, participating in T&E educator collaborative networks, and consulted with a science curriculum specialist about how to teach T&E. Most of his time was spent in a T&E teacher collaborative network (16-35 hours) and mentoring a T&E teacher (6-15 hours). Throughout the year he reported collaborating with a variety of teachers but he most frequently (once a month) worked with the physics, business, and family and consumer science teachers at his school. *School and Learners:* This instructor taught in a large, older modular classroom that had been converted to meet the needs of the FoT curriculum. There were rows of tables facing the front and on one wall there were modular stations that housed computers for research and design. On the opposite wall there were small fabrication tools and

(continued)

Table 38 Continued

Participant	Unique Preparation Experiences
Teacher 6	machines (e.g., drill press, band saw, scroll saw, miter saw, belt/disc sander) within the modular stations. There was no dust collection system connected to these machines. The class was made up of nine Caucasian females, one African American male, one Asian male, and 14 Caucasian male students. *Lesson and Activity:* Teacher 6 lectured on the Unit 3 PowerPoint regarding energy forms and conversion. He allowed minimal student input and little variation from the slides. This lesson included no demonstrations, hands-on, or laboratory component related to the content. At the end of the lesson students continued finishing up their Unit 2 projects.
Teacher 7	*Background:* Was a male veteran teacher in his late 50s who taught FoT for the past six years of his 21-year career. Teacher 7 grew up in a suburban setting and has taught technology education in the same setting his entire career. Out of high school he wanted to become a shop teacher so he enrolled in an industrial arts teacher preparation program, but as he got further into the program he realized he was not ready to be in a classroom. At that point he switched his major to psychology so he could stay on track for graduation, after which he went to work in heating, ventilation, and air conditioning (HVAC). After seven years of working in that field he entered into technology education because he felt at that point he was ready to be in the classroom. This participant holds bachelor's degrees in psychology and technology education. *Coursework:* Completed one week of FoT training when it was the CATTS curriculum. For his undergraduate studies he took one space science, one technology education methods, and three statistics courses; however, he did not complete any physics courses. He had not completed any graduate level coursework, nor had he taken any courses on how to integrate science within T&E education. *Additional Experiences:* Within the past three years he has not helped with any after school clubs or activities related to science or T&E education. He reported that he does not read science education readings but does read T&E readings regularly. This teacher has attended and helped deliver six or more workshops regarding T&E education and how to integrate science concepts within T&E education. Despite not serving on any science or T&E education committees, he has spent 6-15 hours over the past three years engaging in science discussion groups. This participant expressed a strong understanding and belief in the curriculum because of his involvement in delivering the weeklong FoT training for EbD over the past three summers. Annually he goes to state science and T&E education association conferences, and while there he attends mostly T&E education sessions. Two to three times per week he collaborates with T&E education teachers, but did not disclose working with any other teachers.

(continued)

Table 38 Continued

Participant	Unique Preparation Experiences
Teacher 7	*School and Learners:* Teacher 7's classroom was an older drafting/CADD lab that was used for teaching communication technology as well as FoT courses. Tables with a computer for every student lined the sides of the room to create an aisle in the middle, which is where the teacher presented. There were no fabrication tools or machines seen other than hot glue guns, but there were numerous student projects displayed (e.g., hydraulic robotic stacker). This class had approximately one African American female, 10 Caucasian females, and 13 Caucasian male students. In addition, there was one student at the front of the room that was wheelchair bound with an assistive talking device and an aide. *Lesson and Activity:* This teacher used a lot of videos to supplement the FoT Unit 3 PowerPoint. The lesson focused around the core content of energy forms and conversion, but the supplemental videos helped tie in math and science concepts that were not explicitly stated in the PowerPoint. Student feedback was welcomed but the lesson was mostly teacher driven with no physical demonstrations or laboratory activities to reinforce the content.
Teacher 8	*Background:* This teacher was a male novice teacher in his mid 20s and in his third year of teaching, all of which he has taught FoT. He grew up in a suburban setting and has taught in an urban setting all three years. Teacher 8 completed a traditional teacher preparation program to earn a bachelor's degree and certification in physical and health education. He also earned a graduate certificate in technology education but was not certified to teach in that area. They student taught at the school they currently worked for and were hired full time after the completion of their internship. The school had difficulty finding a technology education teacher and asked if this individual would be interested in teaching FoT. This instructor liked technology education courses in high school and enjoyed the hands-on learning aspect of FoT, so he agreed to teach it. *Coursework:* Attended a one-week training to learn about teaching FoT. In high school he completed two technology education courses, and an average amount of math and science courses. The participant reported completing a biology, chemistry, electronics, and algebra course in his undergraduate studies. He did not take any teaching methods courses in his preparation program, and at the time of the observation he had not taken any graduate courses. *Additional Experiences:* As a newer teacher with many other responsibilities, including coaching one of the school's athletic teams, he had not helped with any after school clubs or activities related to science or technology education. He reported spending less than 15 hours in the past three years reading technology and science education literature. However, he did spend 6-15 hours engaged in a workshop about teaching science in T&E

(continued)

Table 38 Continued

Participant	Unique Preparation Experiences
Teacher 8	education, and observing another school's science and T&E education facilities. He has also served on three task force committees, and spent over 35 hours peer coaching, completing in-service training, and participating in collaborative networks regarding T&E education. Conversely, he spent less than six hours observing a class, in a discussion group, in a teacher collaborative network, and consulting with a science curriculum specialist regarding the teaching of science. For 6-15 hours the past three years he has observed a T&E education class and consulted with a science curriculum specialist about how to teach science within T&E education. Also within the past three years he has attended a mix of science and T&E sessions at a state T&E education association conference. Overall, he collaborates with a variety educators once a year, including the science, T&E, business, and family and consumer science teachers at his school. *School and Learners:* This teacher taught in a newer school building within an urban setting where technical skills were a large focus to pursue careers at local businesses. Their large rectangular room looked like a former science classroom with lab tables in rows facing the front, and computers on the outskirts. Student projects (e.g., hydraulic robotic stackers) were displayed around the room and core technology posters hung from the walls. There were no fabrication tools or equipment seen in the room. The diverse class was comprised of four African American females, one Hispanic female, four Caucasian females, four African American males, and one Hispanic male. *Lesson and Activity:* This teacher was well liked and respected by the students. The class reviewed the first lesson of Unit 3 on energy forms, and then worked in pairs during a teacher led activity where they had to wire a light switch, outlet, and light socket within a miniature 2x4 wall section. As evidenced by the motivational quote of the day he presented at the end of class, he was interested in providing students knowledge they could apply to their everyday lives.

APPENDIX J

Modified Section 4 of the RTOP Instrument

Propositional Knowledge – Science Content

6.	The lesson involved detailed explanations and examples about the fundamental science content identified in the EbD lesson plan.	0 1 2 3 4
7.	The lesson promoted strongly coherent conceptual understanding of science content.	0 1 2 3 4
8.	The teacher had a solid grasp of the science content presented in the lesson.	0 1 2 3 4
9.	Elements of scientific abstraction (e.g.,, symbolic representations, theory building) were encouraged when it was important to do so.	0 1 2 3 4
10.	Connections with science content to other content disciplines and/or real world phenomena were explored and valued.	0 1 2 3 4

Propositional Knowledge – T&E Content

11.	The lesson involved detailed explanations and examples about the fundamental T&E content identified in the EbD lesson plan.	0 1 2 3 4
12.	The lesson promoted strongly coherent conceptual understanding of T&E content.	0 1 2 3 4
13.	The teacher had a solid grasp of T&E content presented in the lesson.	0 1 2 3 4
14.	Elements of T&E abstraction (e.g.,, symbolic representations, theory building) were encouraged when it was important to do so.	0 1 2 3 4
15.	Connections with T&E content to other content disciplines and/or real world phenomena were explored and valued.	0 1 2 3 4

Procedural Knowledge – Science Practices

16.	Students used a variety of means (simulations, drawings, graphs, concrete materials, manipulatives, etc.) to represent science phenomena.	0 1 2 3 4
17.	Students made predictions, estimations and/or hypotheses about the conversion of energy, and devised means for testing them.	0 1 2 3 4
18.	Students were actively engaged in thought-provoking activity that often involved the critical assessment of procedures to convert and measure energy.	0 1 2 3 4
19.	Students were reflective about their science learning.	0 1 2 3 4
20.	Intellectual rigor, constructive criticism, and the challenging of scientific content were valued.	0 1 2 3 4

Procedural Knowledge – T&E Practices

21.	Students used a variety of means (models, prototypes, drawings, graphs, concrete materials, manipulatives, etc.) to represent T&E phenomena.	0 1 2 3 4
22.	Students made predictions, estimations and/or hypotheses about the how to harness forms of energy, and devised means for testing them.	0 1 2 3 4
23.	Students were actively engaged in thought-provoking activity that often involved the critical assessment of energy collection procedures.	0 1 2 3 4
24.	Students were reflective about their T&E learning.	0 1 2 3 4
25.	Intellectual rigor, constructive criticism, and the challenging of T&E content were valued.	0 1 2 3 4

APPENDIX K

Operationalized RTOP Criteria Rubric

RTOP Section IV Operationalized Content Criterion

Ques. #	0	1	2	3	4
6 & 11 *Detailed explanations and examples*	Targeted fundamental content was **never** mentioned.	Targeted fundamental content **was rarely** mentioned and was **not a focal point** of the lesson.	The lesson had **very little** focus on targeted fundamental content.	The lesson was focused **to some extent** on targeted fundamental content.	The lesson was focused **entirely** around targeted fundamental content.
7 & 12 *Coherent conceptual understanding*	Targeted content was **not** inter-related with any other concepts.	Targeted content was **vaguely** inter-related with other concepts to **rarely** increase its meaning.	Targeted content was **vaguely** inter-related with other concepts to **sometimes** increase its meaning.	Targeted content was **vaguely** inter-related with other concepts to **moderately** increase its meaning.	Targeted content was **strongly** inter-related with other concepts to **greatly** increase its meaning.
8 & 13 *Solid grasp of content*	**No evidence** that the teacher has a solid grasp of the content in the information presented to the class.	Teacher **rarely** illustrates a solid grasp of the content in the information presented to the class.	Teacher **sometimes** illustrates a solid grasp of the content in the information presented to the class.	Teacher **frequently** illustrates a solid grasp of the content in the information presented to the class.	Teacher **regularly** illustrates a solid grasp of the content in the information presented to the class.
9 & 14 *Elements of abstraction*	Relationships were **never** represented in abstract and/or symbolic ways when it was important to do so.	Relationships were **rarely** represented in abstract and/or symbolic ways when it was important to do so.	Relationships were **sometimes** represented in abstract and/or symbolic ways when it was important to do so.	Relationships were **often** represented in abstract and/or symbolic ways when it was important to do so.	Relationships were **regularly** represented in abstract and/or symbolic ways when it was important to do so.
10 & 15 *Connections to other disciplines/ real world*	Targeted content was **never** connected with content across disciplines or with a real world application example.	Targeted content was **rarely** connected with content across disciplines **or** a real world application example.	Targeted content was **sometimes** connected with content across disciplines or included **an example** of a real world application.	Targeted content was **often** connected with content across disciplines or included **2 examples** of real world applications.	Targeted content was **regularly** connected with content across disciplines and included **more than 2** examples of real world applications.

RTOP Section IV Operationalized Practices Criterion

Ques. #	0	1	2	3	4
16 & 21 *Means to represent phenomena*	Students **never** used a variety of practices (models, drawings, graphs, concrete materials, manipulatives, etc.) to represent targeted science phenomena.	Students **incompletely** used a variety of practices (models, drawings, graphs, concrete materials, manipulatives, etc.) to represent targeted science phenomena.	Students **sometimes (once or twice)** used a **complete** practice (models, drawings, graphs, concrete materials, manipulatives, etc.) to represent targeted science phenomena.	Students **often (three)** used a variety of **complete** practices (models, drawings, graphs, concrete materials, manipulatives, etc.) to represent targeted science phenomena.	Students **consistently (four or more)** used a variety of **complete** practices (models, drawings, graphs, concrete materials, manipulatives, etc.) to represent targeted science phenomena.
17 & 22 *Made Predictions/ Estimations/ Hypotheses*	Students were **not** led to state predictions, estimations, and/or hypotheses associated with the targeted content, and **did not** have to devise ways to test it.	Students were **vaguely** led to state predictions, estimations, and/or hypotheses associated with the targeted content, and **did not** have to devise ways to test them.	Students were **clearly** led to state predictions, estimations, and/or hypotheses associated with the targeted content, and **did not** have to devise ways to test them.	Students were **explicitly** led to state predictions, estimations, and/or hypotheses associated with the targeted content, and **devised** ways to test each.	Students were **explicitly** led to state predictions, estimations, and/or hypotheses associated with the targeted content, and **devised several** ways to test each.
18 & 23 *Actively engaged in thought-provoking activity and critical assessment*	Students were **never** involved with the investigation, **nor** engaged in thought-provoking activity leading to critical assessment of procedures.	Students **were** involved with the investigation, but **rarely** engaged in thought-provoking activity leading to critical assessment of procedures.	Students **were** involved with the investigation, and **sometimes** engaged in thought-provoking activity leading to critical assessment of procedures.	Students **were** involved with the investigation, and **often** engaged in thought-provoking activity leading to critical assessment of procedures.	Students **were** involved with the investigation, and **regularly** engaged in thought-provoking activity leading to critical assessment of procedures.

(continued)

RTOP Section IV Operationalized Practices Criterion Continued

Ques. #	0	1	2	3	4
19 & 24 *Reflective*	Students were **never** reflective about their learning on the targeted content or concepts in tasks.	Students were **vaguely** reflective about their learning on the targeted content or concepts in tasks with a **vague** prompt and **inappropriate** time allowed.	Students were **minimally** reflective about their learning on the targeted content or concepts in tasks with a **minimal** prompt and **minimal** time allowed.	Students were **clearly** reflective about their learning on the targeted content or concepts in tasks with a **clear** prompt and **adequate** time allowed.	Students were reflective on **multiple occasions** about their learning on the targeted content or concepts in tasks with **clear** prompts and **ample** times.
20 & 25 *Intellectual rigor/criticism /challenging*	Teacher **never** allows ideas to be presented, challenged, or negotiated by students on the targeted content.	Teacher **rarely** allows ideas to be presented, challenged, or negotiated by the students on the targeted content, but **without** evidence.	Teacher **sometimes** allows **some** ideas to be presented, challenged, or negotiated by the students on the targeted content with **very little** accurate evidence.	Teacher **often** allows a **variety** of ideas to be presented, challenged, or negotiated by the students on the targeted content with **some** accurate evidence.	Teacher **always** allows a **variety** of ideas to be presented, challenged, or negotiated by the students on the targeted content **with** adequate and accurate evidence.

APPENDIX L

RTOP Interrater Reliability

	Pilot Video 2 Scores			Arbitrated Score	Rater Agreement			Total Agreement by Round
	Rater 1	Rater 2	Rater 3		Rater 1	Rater 2	Rater 3	
Lesson D&I								
1	1	1	0	1	1	1	0	2
2	1	1	1	1	1	1	1	3
3	0	0	0	0	1	1	1	3
4	0	0	0	0	1	1	1	3
5	0	0	1	0	1	1	0	2
Sci Content								
6	1	2	1	1	1	0	1	2
7	1	1	1	1	1	1	1	3
8	1	1	1	1	1	1	1	3
9	0	1	1	1	0	1	1	2
10	2	2	2	2	1	1	1	3
T&E Content								
11	1	1	3	1	1	1	0	2
12	1	1	3	1	1	1	0	2
13	2	2	2		1	1	1	3
14	0	1	1	1	0	1	1	2
15	2	2	4	2	1	1	0	2
Sci Practices								
16	0	0	0	0	1	1	1	3
17	0	0	0	0	1	1	1	3
18	0	0	0	0	1	1	1	3
19	0	0	1	0	1	1	0	2
20	0	0	0	1	1	1	1	3
T&E Practices								
21	0	1	0	0	1	0	1	2
22	0	0	0	0	1	1	1	3
23	0	0	0	0	1	1	1	3
24	0	0	2	0	1	1	0	2
25	0	1	1	1	0	1	1	2
Comm. Inter								
26	0	1	0	0	1	0	1	2
27	1	1	1	1	1	1	1	3
28	1	1	0	1	1	1	0	2
29	0	1	0	0	1	0	1	2
30	1	1	1	1	1	1	1	3
S/T Relation								
31	1	1	0	1	1	1	0	2
32	0	1	0	0	1	0	1	2
33	1	2	1	1	1	0	1	2
34	0	0	0	0	1	1	1	3
35	1	1	0	1	1	1	0	2
Agreement 1st 10%					100%	57%	57%	**71%**
Agreement 2nd 10%					100%	86%	86%	**90%**
Agreement Remaining 80%					86%	90%	71%	**83%**

APPENDIX M

Interview Questions Corroborated with Research Questions

Questions adapted from Park, Jang, Chen, & Jung, 2011

Question	Key Point	RQ
***Questions Prior to the Lesson* (Teacher fills out and submits to researcher)**		
1. When you were planning today's lesson, were there specific things you had to take into consideration? Were there any concepts or ideas you were unsure of? How did you prepare to teach them?	1. Planning, CK, experience, collaborative efforts	RQ1 & RQ2
2. Do you think there are any concepts students will struggle with today?	2. Prior experience, PCK	RQ1
Questions After the Lesson **Questions About the Lesson**		
3. How do you feel the lesson went today and why?	3. Reflection, recognition of student responses	RQ1 & RQ2
4. Did you teach this class different than in other class periods? Why?	4. PCK, modifications	RQ2
Teaching Strategies		
5. What key concepts do you want your students to take away at the end of this lesson? Why?	5. Curricular knowledge	RQ1
a. What about (pick science concepts from list which were very rarely mentioned in lesson)? Do you believe that is an important take away? Why or why not?	a. Curricular knowledge, Preparation	RQ1
6. Tell me a little bit about why you needed to take more time to cover (name concepts from lesson plan that were frequently mentioned during the lesson).	6. Knowledge of students, Curricular knowledge, PCK	RQ1
a. Do you believe your preparation experiences influence your teaching of these concepts? What specific experiences? Why?	a. Preparation, CK, PK	RQ1 & RQ2
7. Tell me a little bit about why you spent less time to cover (name concepts from lesson plan rarely mentioned during the lesson).	7. Preparation, Curricular knowledge, CK, PK	RQ1
a. Do you believe your preparation experiences influence your teaching of these concepts? What specific experiences? Why?	a. Preparation	RQ1 & RQ2

(continued)

Questions adapted from Park, Jang, Chen, & Jung, 2011 Continued

Question	Key Point	RQ
Background Questions		
8. Tell me a little bit about how you got into teaching technology and engineering (T&E) education?	8. Background, Informal experiences	RQ1 & RQ2
a. What about your teacher preparation experiences? How do you believe your T&E education courses and labs inform your teaching of the FoT curriculum?	a. Formal T&E preparation, CK, PK, practices	RQ1: SQ2 RQ2: SQ2
b. How about any science courses and labs you had, how do you believe those inform your teaching of the FoT curriculum?	b. Formal science preparation, CK, PK, practices	RQ1: SQ1 RQ2: SQ1
c. What about any work or home (informal) related experiences? Can you tell me a little about any of those informal T&E experiences which you believe inform your teaching of FoT. Any informal science experiences?	c. Informal T&E and science preparation, CK, practices	RQ1 & RQ2
9. Describe for me how you feel about your preparation to teach the T&E content in this lesson? How prepared are you to model this content through demonstrations and labs?	9. T&E preparation, self efficacy, CK, PK, practices, Curricular knowledge	RQ2:SQ2
10. What about your preparation to teach the science content in this lesson? How prepared are you to model this content through demonstrations and labs?	10. Science preparation, self efficacy, CK, PK, practices, Curricular knowledge	RQ2: SQ1
11. To enhance your preparation, what pre-service resources or experiences (content, labs, methods) would help you teach science concepts embedded within T&E? How about in-service resources or experiences (PD, summer institutes, conferences)?	11. Reveal gaps, content, practices, make Implications/ Recommendations	RQ1 & RQ2

APPENDIX N

Full TEES-PCK Survey Results

Table 39

General Demographic Data for Participants

	Demographic Data						
	Gender						
	Male	Female					
n (%)	40(73)	15(27)					
	Ethnicity						
	Caucasian	African American	Latin American	Asian	Ugandan-American	African American/Caucasian	Middle Eastern
n (%)	51(93)	1(2)	0	1(2)	1(2)	1(2)	0
	Age						
	21-30	31-50	51+	Total Mean			
n (%)	12(22)	28(51)	15(27)	43			
	Years Teaching						
	1-5 Years	6-19 Years	20+ Years	Total Mean			
n (%)	14(26)	28(51)	13(24)	13			
	Years Teaching FoT						
	1-3 Years	4-9 Years	10+ Years	Total Mean			
n (%)	23(42)	23(42)	9(16)	5			
	Highest Degree Earned						
	B.S.	Master's	Master's +30	Master's +60	Ed.S.	Ed.D./Ph.D.	
n (%)	14(26)	24(44)	10(18)	5(9)	0(0)	2(4)	
	Setting Currently Teaching In						
	Urban	Suburban	Rural				
n (%)	13(24)	30(55)	12(22)				

(continued)

Table 39 Continued

	Years Teaching Technology Education at the following level						
	Elementary	Middle School	High School				
Mean Years	0	1	9				
	Subject Areas Certified to Teach						
	Tech Ed	Math	Biology	Chemistry	Earth Science	Business Ed	Other
n (%)	46(84)	4(7)	0	0	1(2)	10(18)	29(53)
	Length of Training/Professional Development Attended for FoT						
	No Training	Half Day	Full Day	2-3 Days	1 week	Other	
n (%)	14(26)	6(11)	4(7)	3(6)	18(33)	10(18)	

Table 40

STEBI Data for Participants

	STEBI Scales					
	Self-Efficacy			Expected Outcomes		
	0-21	22-43	44-65	0-20	21-40	41-60
n (%)	24(44)	31(56)	0(0)	0(0)	52(95)	3(6)

Table 41

Formal Preparation Data for Participants

	Preparation Data			
	Path into Teaching			
	Teacher Education Program	Career Changer	No Formal Teaching Training	Other
n (%)	40(73)	9(17)	3(6)	3(6)

Table 42

Degree Data for Participants

	Degree Held n(%)					
				Degree		
	Asso-ciates	B.S.	Grad Certificate	Master's	Ed.S.	Ed.D/Ph.D.
Industrial Arts	1(2)	6(11)	6(11)	3(6)	0(0)	0(0)
Technology Education	0(0)	21(40)	0(0)	15(28)	2(4)	0(0)
Business Education	2(4)	5(9)	1(2)	0(0)	0(0)	0(0)
Mathematics Education	0(0)	1(2)	0(0)	1(2)	0(0)	0(0)
Curriculum & Instruction	0(0)	2(4)	0(0)	5(9)	0(0)	0(0)
Administration	0(0)	0(0)	3(6)	7(13)	0(0)	1(2)
Engineering	0(0)	1(2)	0(0)	1(2)	0(0)	0(0)
Industrial Technology	0(0)	1(2)	0(0)	0(0)	0(0)	0(0)
Elementary Ed	0(0)	1(2)	0(0)	0(0)	0(0)	0(0)
Kinesiology	0(0)	1(2)	0(0)	0(0)	0(0)	0(0)
Physical/Health Education	0(0)	4(8)	0(0)	0(0)	0(0)	0(0)
Horticulture	0(0)	1(2)	0(0)	0(0)	0(0)	0(0)
Counseling	0(0)	0(0)	0(0)	0(0)	0(0)	1(2)
Other	4(8)	21(38)	0(0)	10(19)	0(0)	0(0)

Table 43

Undergraduate Preparation Data for Participants

Undergraduate Coursework Completed n(%)					
	Frequency of Science Courses Taken				
	0	1	2	3	4+
Physics	26(47)	14(26)	12(22)	0(0)	3(6)
Biology	19(35)	21(38)	11(20)	2(4)	2(4)
Chemistry	25(46)	22(40)	6(11)	1(2)	1(2)
Earth Science	28(51)	23(42)	3(6)	0(0)	1(2)
Space Science	45(82)	7(13)	0(0)	0(0)	3(6)
Other	47(86)	5(9)	2(4)	0(0)	3(6)
	Frequency of T&E Courses Taken				
	0	1	2	3	4+
Electronics	26(47)	12(22)	14(26)	0(0)	3(6)
Electrical Engineering	41(75)	10(18)	2(4)	0(0)	2(4)
Power/Energy & Transportation	28(51)	17(31)	5(9)	3(6)	2(4)
Biotechnology	45(82)	8(15)	0(0)	1(2)	1(2)
Robotics	38(69)	14(26)	1(2)	1(2)	1(2)
Drafting/CADD	0(0)	0(0)	1(2)	3(6)	1(2)
Materials/ Manufacturing	0(0)	4(8)	5(9)	2(4)	3(2)
Other	53(96)	0(0)	0(0)	1(2)	1(2)
	Frequency of Math Courses Taken				
	0	1	2	3	4+
Algebra	14(26)	28(51)	11(20)	0(0)	2(4)
Geometry	27(49)	23(42)	3(6)	1(2)	1(2)

(continued)

Table 43 Continued

	Frequency of Math Courses Taken				
	0	1	2	3	4+
Pre Calculus	38(69)	14(26)	1(2)	1(2)	1(2)
Calculus	38(69)	10(18)	2(4)	2(4)	3(6)
Statistics	18(33)	29(53)	5(9)	2(4)	1(2)
Other	51(93)	2(4)	2(4)	0(0)	0(0)
	Frequency of Education Courses Taken				
	0	1	2	3	4+
Methods for Teaching IA	40(73)	10(18)	2(4)	2(4)	1(2)
Methods for Teaching T&E	26(47)	17(31)	8(15)	2(4)	2(4)
Methods for Teaching Science	47(86)	7(13)	0(0)	0(0)	1(2)
Methods for Teaching Math	47(86)	6(11)	0(0)	0(0)	2(4)
Other Methods	46(84)	8(15)	1(2)	1(2)	3(6)

Table 44

Graduate Preparation Data for Participants

Graduate Coursework Completed n(%)					
	Frequency of Science Courses Taken				
	0	1	2	3	4+
Physics	52(95)	2(4)	0(0)	0(0)	1(2)
Biology	51(93)	3(6)	0(0)	0(0)	1(2)
Chemistry	52(95)	2(4)	0(0)	0(0)	1(2)
Earth Science	53(97)	1(2)	0(0)	0(0)	1(2)
Space Science	52(95)	2(4)	0(0)	0(0)	1(2)

(continued)

Table 44 Continued

	Frequency of Science Courses Taken				
	0	1	2	3	4+
Kinesiology	54(98)	0(0)	1(2)	0(0)	0(0)
Other	51(93)	2(4)	1(2)	0(0)	1(2)
	Frequency of T&E Courses Taken				
	0	1	2	3	4+
Electronics	47(86)	7(13)	0(0)	0(0)	1(2)
Electrical Engineering	51(93)	2(4)	0(0)	0(0)	2(4)
Power/Energy & Transportation	47(86)	6(11)	1(2)	0(0)	1(2)
Biotechnology	52(95)	2(4)	0(0)	0(0)	1(2)
Robotics	51(93)	2(4)	1(2)	0(0)	1(2)
Other	48(87)	5(9)	2(4)	0(0)	2(4)
	Frequency of Math Courses Taken				
	0	1	2	3	4+
Algebra	52(95)	2(4)	0(0)	0(0)	1(2)
Geometry	52(95)	2(4)	0(0)	0(0)	1(2)
Pre Calculus	52(95)	2(4)	0(0)	0(0)	1(2)
Calculus	53(96)	1(2)	0(0)	0(0)	1(2)
Statistics	39(71)	14(26)	1(2)	0(0)	1(2)
Other?	52(95)	1(2)	1(2)	0(0)	0(0)
	Frequency of Education Courses Taken				
	0	1	2	3	4+
Methods for Teaching IA	43(78)	7(13)	4(7)	0(0)	1(2)
Methods for Teaching T&E	30(55)	11(20)	8(15)	1(2)	5(9)
Methods for Teaching Science	51(93)	2(4)	0(0)	0(0)	1(2)

(continued)

Table 44 Continued

	Frequency of Education Courses Taken				
	0	1	2	3	4+
Methods for Teaching Math	51(93)	2(4)	0(0)	0(0)	2(4)
Other Methods	49(89)	3(6)	3(6)	2(4)	1(2)

Completed Undergraduate or Graduate Coursework Discussing Methods for Integrating Science within T&E

	Completed Coursework	
	Yes	No
n (%)	16(29)	39(71)

Table 45

Informal Non-Collaborative Preparation Data for Participants

High School Coursework Completed n(%)

	Frequency of Courses Taken				
	0	1	2	3	4+
Industrial Arts	18(33)	11(20)	7(13)	2(4)	16(29)
Technology Education	31(56)	6(11)	4(7)	4(7)	10(18)
Biology	1(2)	39(71)	10(18)	2(4)	3(6)
Chemistry	8(15)	37(67)	9(16)	0(0)	1(2)
Physics	20(36)	28(51)	5(9)	1(2)	1(2)
Earth Science	15(27)	34(62)	4(7)	1(2)	1(2)

Clubs/Activities Facilitated within the Past Three Years

Club	n(%)
TSA	7(13)
First Robotics	5(9)
Vex Robotics	8(15)
Other Robotics	1(2)
Lego League	2(4)

(continued)

Table 45 Continued

Clubs/Activities Facilitated within the Past Three Years	
Club	n(%)
Engineering Challenges	3(6)
MESA	2(4)
Odyssey of the Mind	1(2)
Skills USA	1(2)
None	32(58)

	Hours Spent Engaged in Independent Readings Over the Past Three Years				
Field	Hours				
	0	>6	6-15	16-35	35+
Science Education	24(44)	12(22)	6(11)	1(2)	12(22)
T&E Education	6(11)	10(18)	10(18)	7(13)	22(40)

	Professional Development Participated in Related to Teaching Science within T&E within the Past Three Years						
	Frequency of Participation						
	0	1	2	3	4	5	6+
College Courses	45(82)	2(4)	3(6)	1(2)	1(2)	0(0)	3(6)
Workshop or In-service Training	19(35)	10(18)	10(18)	6(11)	1(2)	0(0)	9(16)
Summer Institute	36(66)	8(15)	5(9)	3(6)	0(0)	1(2)	2(4)
Professional Association/ Conference	39(71)	7(13)	5(9)	2(4)	0(0)	0(0)	2(4)
Observation/Visit to another STEM facility	39(71)	8(15)	6(11)	1(2)	0(0)	0(0)	1(2)

	Professional Development Participated in Related to Teaching of T&E within the Past Three Years						
	Frequency of Participation						
	0	1	2	3	4	5	6+
College Courses	43(78)	2(4)	4(7)	1(2)	2(4)	0(0)	3(6)

(continued)

Table 45 Continued

	Frequency of Participation						
	0	1	2	3	4	5	6+
Workshop or In-service Training	14(26)	9(16)	8(15)	8(15)	3(6)	1(2)	12(22)
Summer Institute	31(56)	9(16)	10(18)	3(6)	0(0)	0(0)	2(4)
Professional Association/ Conference	37(67)	6(11)	5(9)	5(9)	0(0)	0(0)	2(4)
Observation/Visit to another STEM facility	38(69)	8(15)	5(9)	2(4)	1(2)	0(0)	1(2)

Table 46

Informal Collaborative Preparation Data for Participants

Activities in Science or T&E Participated in within the past Three Years n(%)		
Activity	Field	
	Science Education	T&E Education
District/School Committee	2(4)	26(47)
Teaching Coach or Mentor	1(2)	29(53)
Delivered in-service workshop	2(4)	23(42)
Did not participate	37(67)	19(35)

Committees or Task Forces Participated in Within the Past Three Years Related to Science or T&E Education							
Field	Frequency of Committees or Task Forces						
	0	1	2	3	4	5	6+
Science Education	33(60)	6(11)	2(4)	0(0)	1(2)	0(0	1(2)
T&E Education	24(44)	10(18)	7(13)	5(9)	0(0)	0(0)	3(6)

(continued)

Table 46 Continued

	Hours of Professional Development Participated in Related to Teaching of Science within T&E Over the Past Three Years				
PD Activity	Hours				
	0	>6	6-15	16-35	35+
Mentor/Observe Science class/lab	33(60)	5(9)	1(2)	1(2)	2(4)
Discussion or Study Group	38(69)	8(15)	6(11)	0(0)	3(6)
Teacher Collaborative Network	33(60)	13(24)	5(9)	1(2)	3(6)
Consultation with Science Curriculum Specialist	39(71)	12(22)	3(6)	0(0)	1(2)

	Hours of Professional Development Participated in Related to Teaching of T&E Education Over the Past Three Years				
PD Activity	Hours				
	0	>6	6-15	16-35	35+
Mentor/Observe T&E class/lab	17(31)	17(31)	8(15)	4(7)	9(16)
Discussion or Study Group	22(40)	16(29)	5(9)	3(6)	9(16)
Teacher Collaborative Network	15(27)	18(33)	7(13)	3(6)	12(22)
Consultation with Science Curriculum Specialist	37(67)	15(27)	1(2)	0(0)	2(4)
Consultation with T&E Curriculum Specialist	18(33)	23(42)	8(15)	2(4)	4(7)

(continued)

Table 46 Continued

	Conferences Attended in the Past Three Years
Conference	n(%)
State Science Association	2(4)
State T&E Association	15(27)
National Science Association	3(5)
National T&E Association	5(9)
Other?	4(7)
Have not attended	35(64)

	Conference Sessions Attended in the Past Three Years
Session	n(%)
Mostly T&E	19(35)
Mostly Science	0(0)
Mix of STE	10(18)
Other?	1(2)
Unsure	25(46)

	Teachers With Whom Participants Collaborate or Network							
Field	Frequency							
	Daily	2-3 times/ week	Once a week	Every 2 weeks	Once a month	Once a semester	Once a year	Never
Tech Ed	20(36)	17(31)	5(9)	5(9)	3(6)	1(2)	0(0)	2(4)
Physics	1(2)	1(2)	2(4)	2(4)	6(11)	8(15)	5(9)	28(51)
Biology	1(2)	1(2)	1(2)	1(2)	4(7)	3(6)	6(11)	36(66)
Chemistry	1(2)	0(0)	1(2)	1(2)	4(7)	4(7)	4(7)	38(69)

(continued)

Table 46 Continued

Field	Frequency							
	Daily	2-3 times/ week	Once a week	Every 2 weeks	Once a month	Once a semester	Once a year	Never
Earth Science	1(2)	0(0)	1(2)	1(2)	5(9)	7(13)	3(6)	35(64)
Space Science	1(2)	0(0)	0(0)	1(2)	4(7)	4(7)	1(2)	42(76)
Business Ed	2(4)	5(9)	6(11)	1(2)	8(15)	4(7)	2(4)	25(46)
FACS	1(2)	1(2)	2(4)	2(4)	3(6)	1(2)	4(7)	39(71)
Math Ed	1(2)	1(2)	1(2)	5(9)	5(9)	10(18)	2(4)	28(51)
Other	4(7)	2(4)	0(0)	1(2)	2(4)	1(2)	0(0)	45(82)

APPENDIX O

Observed Teaching of Content and Practices

Teacher 1

From the interview they thought the lesson went well because he was informative and entertaining, but also because the students were cooperative. His big take away was making students better citizens by showing them how they consume energy and helping them realize that energy is involved in everything they do. He described that it took him longer than normal to plan the lesson because it was his first time teaching that specific FoT lesson. In planning the lesson he anticipated students would understand energy efficiency but would need help making the connection of how to become more efficient at using energy. He believed that thermodynamics was important for teaching them about energy loss in their home and the cost of electricity.

Teaching Strategies Observed

In the observed lesson, Teacher 1 taught the first lesson from Unit 3 about energy forms and conversion. He used a lecture format with opportunities for students to provide their input; however, he often cut their ideas short before they were allowed to fully develop. The instructor started the class by engaging students with a video from PBS regarding technological advancement and the purification of water. Following the video were a series of questions posed by the teacher about how the students used water on a daily basis, but the teacher heavily facilitated the discussion with little elaboration on student ideas. Transitioning into a review of the previous lesson, the teacher asked students what energy was by having them record their responses in their engineering journals. The lesson then led into a discussion about energy efficiency that allowed the teacher to provide examples to which the students related well. Considering a diagram of a house that was presented to them earlier, students were prompted to brainstorm how different types of renewable energy systems could be used to improve that residence. In the final minutes of the lesson, the instructor walked students through a pre-calculated example (provided by FoT) showing how to determine a home appliance's annual energy usage.

Overall this teacher's RTOP ratings were very low on the lesson design and implementation, communicative interactions, and student/teacher relationships sections. His low rating on the lesson design implementation section was due to the lack of students sharing ideas among the class, and seldom investigating, problem solving, or helping determine the direction of the lesson. Student ideas were often not allowed to fully develop since the instructor usually provided the answer or moved on to the next portion of the lesson. In the communications and interactions section the low score resulted from the instructor not encouraging discussion among students and the entire class, as well as limiting the influence that student questions and comments had on the focus of the lesson. The student/teacher relationship section also resulted in a low rating due to the teacher-centered focus of the lesson and not allowing students ample opportunities to design methods for investigating science or T&E phenomena. The sum of this instructor's total score for the RTOP was 23, which was well below the mean for all teachers (59.4). Teacher 1 also scored below the mean for his teaching of science and T&E content and practices which are described in the following sections in more detail.

Teaching of Science Content

This instructor received a score of six for teaching of science content. The only fundamental science content that was emphasized was work and efficiency, and it was vaguely interrelated with other concepts to increase its meaning (e.g., he only related types of energy to doing work). It could not be concluded that Teacher 1 had a solid grasp of the targeted content since he rarely described many of the other science concepts within the lesson. Abstract science content was only represented in a symbolic fashion with the use of the energy source to house diagram in which students were asked what type of energy they believed would be created:

> Teacher 1: Electrical energy will be created in the form of?
>
> Student A: AC. AC electricity will be made and converted to DC.
>
> Teacher 1: Alternating Current, hence the idea of transformers. They're going to send this electrical energy to my house and the community.

In this example, Student A proposed the idea of alternating current. The instructor did not elaborate on what AC is or how it is converted to DC, he simply stated that a transformer converted it to DC and provided electricity for the community to use technological devices. This was a great opportunity for the instructor to explain about the structure of atoms, movement of electrons, and how that movement creates energy flow otherwise known as current. He then could have expanded on the differences between AC and DC, and their applications.

Although Teacher 1 provided many examples and stories throughout the lesson, only sometimes did he connect science content with content from other disciplines. For example, to clarify energy efficiency the instructor wrote the definition on the board for students to copy into their engineering journals. Students were not asked to hypothesize the meaning of this term or express their prior knowledge about it. Furthermore, the instructor provided examples of appliances at his house to help students relate to the concept of energy efficiency, and later presented types of renewable energy systems. Despite presenting great examples and stories, in neither case did the teacher require students to brainstorm and provide evidence to help direct the focus of the lesson. Students were then prompted to review the house diagram and think about where the types of renewable energy systems he presented could be used. One form of energy the instructor prompted students to think about was biomass:

Teacher 1: What is biomass?

Student B: Biomass is like atomic atoms.

Teacher 1: Bio. Not nuclear now.

Student C: Living matter.

Teacher 1: Okay. How do we get energy out of living matter?

Student B: Burn it.

Teacher 1: Or? Let it decay.

The teacher continued on to describe how India is one of the leading users of biomass because of the amount of cow manure they have access to in their country. However as seen in the example above, Teacher 1 never went into great detail about the energy cycle that produces biomass (e.g., photosynthesis) or the release of carbon dioxide when burning living matter to create biomass. Students also proposed nuclear energy later in the lesson but the instructor did not explain the foundational concept of fission. In both cases he focused on the energy and environmental advantages and disadvantages. This showed the emphasis the lesson had on T&E content.

Teaching of Science Practices

For their teaching of science practices this instructor earned a score of one. Students were not encouraged to use any means to represent science content, the only practice displayed was copying and drawing the house diagram presented by the teacher, they were not led to state hypotheses associated with the targeted content or devise ways to test them, and they were also not involved in any thought-provoking activity to investigate or measure the conversion of energy. Furthermore, students were not led to be reflective about the fundamental science concepts they learned, and Teacher 1 rarely allowed students to challenge ideas by cutting them short or redirecting the conversation to continue with the planned lesson.

This entire lesson lacked science practices, which was evident from its teacher driven lecture focus. There were a few occasions where the teacher could have had students investigate science concepts. One example was when the class was unsure of what biomass was. The teacher could have conducted a small lab in which students investigated where in nature to obtain biomass and how combustible it is. In the interview Teacher 1 described a demonstration he did in the previous lesson which included bending paper clips to investigate variables that influence potential and kinetic energy when they are pushed down to spring up like a grasshopper. In the observed lesson there were no science practices witnessed, therefore the teacher could only be rated on what was seen. This teacher's lack of comfort with demonstrating science concepts from the lesson such as thermodynamics were corroborated in the interview, "With the thermodynamics, because this is the first time that I've done it, I really don't have anything demonstration wise that I could cook up real quick to show them that's as easy as the paper clip." Teacher 1 did a slightly better job addressing the T&E content and practices within the lesson as reported by his RTOP ratings.

Teaching of T&E Content and Practices

For teaching of T&E content this instructor received a score of seven, and for T&E practices he scored a one. In regards to T&E content, forms of energy were not the focus of the lesson as the teacher rarely mentioned them or provided examples that vaguely interrelated them to increase the meaning of the content. He also did not elaborate on many alternative energy sources, and aside from the house diagram, did not represent abstract T&E content in symbolic ways. This teacher did attempt to connect content about energy forms to other disciplines (e.g., the technological tools and processes needed to create energy from biomass). When viewing T&E practices this teacher failed to use a variety of practices to represent T&E phenomena, did not have students make predictions or test them, did not have students investigate or assess energy collection procedures, and did not have students reflect on their learning of the content. Additionally, Teacher 1 rarely allowed ideas to be presented or challenged, but without evidence.

The low score for the practices component can be explained by the teacher-driven lecture format of the lesson which was discussed previously. Even with this format the teacher still could have included opportunities for the students to explore technological concepts with which they struggled. One example that afforded an opportunity to incorporate these practices was when the teacher showed his sketch of energy traveling from the power plant to his house. In the picture the teacher provided no explanation or investigation of how electricity travels. Students could have been prompted to experiment with various materials to see which makes a better conductor for energy to travel. Alternatively, the teacher could have presented a demonstration on energy flow using various materials (hose and water) and allowed students to manipulate them to restrict or promote water flow, simulating conductors, resistors, and electron flow. Furthermore, in the example where Student A mentioned the conversion of AC to DC, this again presented an opportunity in which students could have conducted a lab activity investigating the two types of currents. The instructor could have helped students make the connections between circuits and energy flow at the atomic level. Graphics depicting these concepts were provided in the Unit 4 PowerPoint from ITEEA but were not used by Teacher 1.

Summary

This instructor clearly emphasized the importance of T&E content as the focus of the lesson which was supported with what he wanted students to take away from the lesson:

> I wanted to get them to understand the idea that the ability to do work is the definition of energy. They were going to look at how they could be efficient with energy and to tie those two terms together. (personal communication, October 16, 2014)

There was very little focus on the science content embedded within the lesson, although it was vaguely highlighted in some portions. When presenting forms of alternative energy the instructor was very knowledgeable and provided examples to which the students could easily relate. Although the instructor provided some examples and explanations of forms of alternative energy, he very rarely represented the content in abstract or symbolic ways when it was important to do so.

The higher T&E content and practice scores were evident from the lesson's focus on renewable energy, efficiency, and sustainability as opposed to the conversion of energy. Despite the varied science and T&E experiences over this veteran teacher's 30-year career, he still missed opportunities to discuss and demonstrate targeted science content in depth. One reason for this may have been the fact that this was the first time he was presenting this lesson. Teacher 1 admitted that with more practice he could refine the lesson and which could help incorporate more science content and practices:

> Being comfortable with the material, this being the first time, so it took a lot longer than I anticipated but if I had to do this two more times today it would abbreviate itself and I would find those things in it that I wanted to stress or take out or how I would I handle it better. (personal communication, October 16, 2014)

This lesson provided a snapshot of the targeted science and T&E content and practices taught by a veteran teacher delivering a specific FoT lesson for the first time. The low ratings may have been a reflection of the teacher's inexperience with delivering this particular lesson; however, when key science topics arose it appeared he very rarely expanded on them by drawing from his broad array of preparation experiences. Recommendations for distinguishing between teachers' curricular knowledge and science PCK by using additional observations after more experience with the curriculum are presented in Chapter 5. Investigating the various pre- and in-service experiences that had a significant influence on participants' teaching of science content and practices are analyzed later in this chapter.

Teacher 2

He believed the lesson went well because students learned concepts that will stick with them beyond FoT. Examples he provided of these important concepts included names of important circuit components (e.g., capacitor), recognizing circuit symbols, understanding the flow of electrons and electricity, and learning how to solder. The key concept he wanted students to learn was as he perceived it presented by the FoT curriculum – what are specific circuit parts and what do they do? He also felt learning how to solder was an added take-away for the students. When planning the lesson he had to take into consideration that his school did not have the breadboards called for in the FoT curriculum, therefore he had to modify the lesson to do the soldering activity. In planning the lesson he anticipated students would struggle with applying Ohm's law to parallel circuits. Despite teaching science concepts that were called for in the curriculum, he viewed FoT was a foundational course that should serve as an advertisement to pursue STEM or CTE related careers. In regards to teaching of science content and practices within FoT he felt that the curriculum was becoming too closely intertwined with physics, which detracted from the emphasis on T&E education content and practices.

Teaching Strategies Observed

This teacher was observed teaching a modified version of the second lesson from Unit 4 regarding troubleshooting and electronic circuits. Due to the unique setting of this school, students were provided a meal prior to the start of class. While the students ate dinner the teacher played video clips of new technological innovations regarding maglev cars and artificial human limbs. The lesson began with the teacher asking students about their discussion from last class, to which he provided some interesting prompts and students had various responses:

Teacher 2: Who can tell me what we were talking about last class?

Student C: Circuit stuff. That's all I remember.

Student D: It was on circuits, current.

Teacher 2: Yeah.

Student D: Electrons, atoms, and chemistry stuff. Basically chemistry stuff.

Teacher 2: What makes the tight and loose insulators? One of those things that circle it.

Student D: I said electrons and atoms.

Teacher 2: Do you remember what the number was of the outer shell that made it.

Student D: 24?

Teacher 2: It comes in multiples of four so 24 is a multiple of 4.

This vignette showed that science content was a focus of the previous lesson and students were able to recall some of these concepts. The teacher then displayed the PowerPoint presentation on resistors provided by the FoT curriculum, which elicited a review on resistance and resistor colors. What followed was a presentation and discussion of the FoT PowerPoints on potentiometers, photocells, capacitors, and speakers. After the content from the FoT presentations were presented, the students then participated in a teacher-led lab that involved soldering electronic circuit components from a kit. The instructor gave a thorough demonstration of how to safely use soldering irons prior to the beginning of the activity. During this presentation the instructor related soldering to electron flow and conductivity. He then gave a demonstration of tinning and soldering a circuit component. Prior to every step of the activity the teacher demonstrated how to solder the component into a predetermined space before students were allowed to proceed. Following the completion of the activity students tested their circuits with a 9-volt battery and made any necessary adjustments with the instructor's guidance. Teacher 2 closed the lesson by reading the selected response assessment questions from the FoT curriculum to the students and calling on them for responses.

Overall the RTOP ratings regarding lesson design and implementation, communicative interactions, and student/teacher relationships were all above the mean among observed participants. Teacher 2 scored high on the lesson design and implementation section because students were engaged as members of a learning community, sharing ideas among each other and the entire class. The communicative interactions were above the mean due to a high proportion of student talk between and among students, and student questions helping determine the direction of classroom discourse. The student/teacher relationships category recorded high ratings for encouraging and valuing active participation while also being patient with students to let their input influence the direction of the class. This instructor had the third highest RTOP rating (78) as he received high scores in teaching of science and T&E practices, and moderate ratings for teaching of science and T&E content. The rationale for these scores is explained further in the subsequent sections.

Teaching of Science Content

This instructor received a score of nine for their teaching of science content. To some extent the lesson involved detailed explanations and examples of fundamental science content, of which the teacher sometimes illustrated a solid grasp. He explained a lot of what was provided in the PowerPoint but did not expand on many of the scientific principles. Science content was vaguely interrelated with other concepts which sometimes increased its meaning. The following vignette provides an example where the interrelation between electron flow (science content) and speakers (technological application) was mentioned but not explained in a manner to enhance the science content.

> Teacher 2: That is the symbol for a speaker. Look at that word.
>
> Student C: Electromagnetic.
>
> Teacher 2: The speaker has a coil of wires and when electrical current is applied to it creates an electromagnetic field. It sounds like a magnet is involved.

The teacher could have provided more explanation about how electromagnetic fields are created to reinforce this scientific concept. Furthermore, targeted content was sometimes connected with authentic applications like the example provided below:

> Teacher 2: So if I said I was increasing the resistance and your brother was spraying you with a water hose, would that mean he's getting more water or less water on you? If I started making more resistance?
>
> Student E: Less.
>
> Teacher 2: Yeah. So if we apply that electricity and a light bulb if we increase the resistance going to the light would it be brighter or dimmer?
>
> Student E: Dimmer.

Teacher 2: Correct.

This provided a realistic example to which students were easily able to relate. One item where Teacher 2 did not receive any points was representing abstract science content in symbolic ways. The teacher did not use any materials or simulations to show energy at the atomic level or the flow of electrons in circuits.

Teaching of Science Practices

This instructor received a score of six for the teaching of science practices for a number of reasons. Students only used one practice to represent science phenomena:

> Teacher 2: If you go across a bridge and see a construction crew with sparks coming off of it they are fixing the bridge, soldering or welding the steel for strength to build it. Heat smells.
>
> Student D: Yeah. Like burning.
>
> Teacher 2: Soldering is for conductivity and allows electrons to flow. You just told me that electricity is electrons flowing. When you take a piece of metal and hook it to another piece of metal it is really not touching all the time. So what you do is you fill that void with solder like that.

This teacher used the soldering activity to reinforce the concept of conductivity. Students were vaguely led to state predictions about what would happen if the solder touched, but did not have to devise ways to test it since the lab was teacher led. For this same reason the instructor received a low rating on RTOP item 18. Students were involved in the investigation of energy flow during the lab but were not engaged in thought-provoking assessment because the teacher provided step-by-step directions. Students were vaguely prompted to be reflective of their learning during the lab, most reflection occurred during the review at the beginning of class and the selected response assessment questions at the end. Sometimes the teacher allowed students to present ideas or challenge the concepts presented, but with very little evidence as seen in this example about resistor colors:

Student C: So I am guessing white is the main concept of stopping the flow.

Teacher 2: Yeah.

Student C: So if you wanted to stop it less, black is what you want to get.

Teacher 2: Alright.

Student C: The more levels you go it depends on what circuit you are using it for to resist.

Teacher 2: Yeah and the color determines how much the resistance is worth.

In that example the student intuitively predicted what the different colors represented, prompting her to ask the instructor for more information prior to any presentation.

Teaching of T&E Content and Practices

For the T&E content criteria Teacher 1 received a score of 17. He posted the highest possible score (4) for the lesson being focused entirely around fundamental T&E content identified in the EbD lesson plan, regularly illustrating a solid grasp of T&E content, and regularly connecting content across disciplines with numerous examples (e.g., he related potentiometers to a dimmer switch, photocells to solar panels, and capacitors to the Flux capacitor from the movie Back to the Future). He lost points for vaguely interrelating targeted content with other concepts to moderately increase their meaning and only sometimes representing abstract T&E concepts in symbolic ways (e.g., introducing soldering as a way to promote electron flow).

For T&E practices portion Teacher 1 earned a 12. The lower score for the practices component is due to the fact that students only used soldering to represent the T&E phenomena of electricity, they were clearly led to state predictions but did not have to devise ways to test them (e.g., he asked what each circuit part did, but then showed students how to connect them instead of test them). Students were involved in seeing the function of the circuit parts but were not involved in the assessment of procedures or design of the circuit. On various occasions the teacher used clear prompts to ask students about targeted content in the soldering activity and provided ample wait time. One student questioned what was inside a 9-volt battery, using an online video to support her idea:

> Student C: Did you know if you take apart a 9-volt battery there is actually six AAA batteries inside of it and the same thing with AA and AAA batteries. There are kind of little watch batteries inside of them.
>
> Teacher 2: I do not agree. There is a bunch of carbon in there. Maybe we will get a hammer out and prove you wrong when we finish the lab.
>
> Student C: You have to unwrap it.

The teacher allowed this to direct of the focus of the class and explore students' interest at the end of class by showing an online video of someone opening a 9-volt battery. Additionally, the teacher helped the student to unravel a 9-volt battery to investigate their hypothesis and found that the student was correct. This teacher allowed students to challenge and present ideas on a variety of other occasions and asked students for some form of evidence to support their claims.

Summary

This teacher used the FoT PowerPoints to present much of the science content, and to supplement the slides he provided some detailed explanations and authentic examples (e.g., electron flow and a water hose). The small class size allowed for increased participation between and among students. He vaguely interrelated the embedded science content with T&E concepts to sometimes increase its meaning (e.g. electron flow/resistance and a dimmer switch).

This teacher provided good examples for students to relate to the science content but did not demonstrate any of those scenarios (e.g., water flow from a hose, magnets inside of a speaker). During the lesson no resources were observed demonstrating science practices other than the soldering activity. Even in the soldering activity science practices were limited (e.g., solder creating a bridge for electrons to flow) because the activity involved following step-by-step instructions demonstrated by the teacher. In the interview, Teacher 2 expressed how difficult it was to do the soldering activity with a class of 30 students he teaches during another period. He also revealed that he wanted to do a more design-based lesson but could not because his school system did not have budget to purchase solderless breadboards and circuit components. They were still using soldering kits that they purchased before the activity in the curriculum transitioned to the current one. Allowing students to experiment with solderless breadboards and circuit components would have elicited more thought-provoking inquiry and experimentation.

This participant's concerns about the materials needed for the curriculum were also raised by other participants and are described in Chapter 5. Due to his teacher preparation coming from a field outside of science and T&E education, he attributed much of his science knowledge to his high school physics and chemistry classes. The influence that these courses had on participants' teaching of science content and practices is explored in more detail later in this chapter.

Teacher 3

This teacher believed the lesson went well because she was able to present all of the content she had planned, provided good explanations, and all students were well behaved, listened, and paid attention. The key concept she wanted students to learn from the lesson was energy transfer and seeing how energy is converted from one form to another, because this would play an important role in their end of unit windmill project. When planning the lesson she had to familiarize herself with the curriculum to better understand what concepts should be highlighted. She specifically cited thermodynamics as a topic she needed to review, which she did so by researching online. In planning the lesson she anticipated students would struggle with the concept of thermodynamics from a vocabulary perspective due to the high amount of English language learners (ELL) in her FoT courses. She believed that science concepts such as thermodynamics were important to teach in FoT, but did not make it a focal point of the lesson because she felt the curriculum does not focus on it beyond this unit.

Teaching Strategies Observed

Like Teacher 1, this instructor was also observed teaching the first lesson from Unit 3 which introduces energy forms and conversion. Upon entering the class students were prompted to take a pre-assessment quiz from the FoT curriculum on energy conversion. The teacher reviewed the pre-assessment by calling on students to share their responses and provided the correct answers without much elaboration. The quizzes were collected and then Teacher 3 began presenting the Unit 3 PowerPoint very closely to how FoT supplied it. The last portion of the class involved the instructor describing how to calculate energy consumption of home appliances using the example provided in the FoT worksheet. With a partner, students were instructed to list a dozen different appliances in their house and calculate the annual energy consumption for each. While students were completing this task the teacher navigated the room to answer questions, then returned to her desk to enter the pre-assessment quiz grades. The quizzes were returned to students with no further discussion before dismissal.

Overall the RTOP ratings for lesson design and implementation, communicative interactions, and student/teacher relationships were well below the mean among all those observed. Teacher 3's low rating on the lesson design and implementation section resulted from no observed student exploration or seeking of alternative problem solving modes, not allowing student ideas to determine the direction of the lesson, and very little inclusion of students as a learning community. Additionally, the teacher administered the pre-assessment quiz and only asked for answers, which did not allow students to explain their choices and inform the lesson. On the communicative interaction section the teacher scored low because most student communication occurred through a worksheet, there was a high proportion of talk between but not among students, and although the teacher respected student questions she did not use them to help direct classroom discourse. In regards to student/teacher relationships Teacher 3 received low ratings for rarely encouraging students to participate, and providing information (e.g., the equations for calculating energy consumption) without challenging students to first to generate alternative solution strategies to interpret this data. This teacher received the second lowest total RTOP rating (20), with very low scores in her teaching of science and T&E content and practices. The ratings for observed teaching of science and T&E content and practices are described below.

Teaching of Science Content

For the teaching of science content this instructor received a score of three because she did not provide many detailed explanations beyond what was provided on the FoT PowerPoint.

She earned a zero for grasp of science content, which was observed from her explanation of nuclear energy:

> Teacher 3: We also think of nuclear power as a nonrenewable resource. We use uranium which fulfills about 11% of the world's energy needs. Our heat is generated from fission so when the atoms split they are going to release that heat energy and it is going to produce the steam to turn the turbine. Kind of like coal except we are using atoms.

Other than comparing it to coal, the information she presents is almost verbatim from the FoT PowerPoint. Her lack of knowledge and experience with teaching science content was corroborated with her interview responses, which are presented later in the chapter. Teacher 3 did not provide any symbolic representations of abstract science content; however, she did rarely connect content to authentic applications and vaguely interrelated the content with other concepts to increase its meaning. One instance where she attempted to provide an example beyond what was embedded within the FoT PowerPoint to increase the content meaning was related to the law of conservation of energy:

> Teacher 3: Energy can neither be created nor destroyed, however the energy can flow from one form to another. If you think of energy as indestructible little blocks no matter what you do with the blocks, you separate them, you lose one you get it back, you are still going to have the same amount of blocks. Same thing with energy.

The instructor did attempt to make this concept more relatable for students but could have used a more appropriate example that was easier for students to understand. Some examples would include a cue ball striking another pool ball, a spring being released, a ball being dropped, or water being boiled into steam. All of these phenomena could have easily been demonstrated in class allowing students to predict and see how the energy was transformed.

Teaching of Science Practices

This instructor received a score of one for the teaching of science practices because there were no practices observed that represented targeted science phenomena. Students were not led to state predictions, estimations, or hypotheses as exemplified at the end of the lesson when they were tasked with calculating the amount of energy consumed annually in their household. Without predicting how to solve the problem or what they thought the result would be, they were shown an example from the worksheet and instructed to complete the assignment. From this portion of the lesson students were involved in the investigating of energy consumption in their home, but it was not thought-provoking since the formulas and procedures were provided for them. This teacher never prompted students to be reflective of their learning on targeted science content, and rarely if ever provided students the opportunity to present or challenge ideas. This was evident in the part of the lesson examining thermodynamics, in which Teacher 3 continued lecturing without pausing to ask for student feedback or allow them to challenge the laws of thermodynamics with their misconceptions. This would have been beneficial in helping students reflect on their learning and allowing the teacher to gauge where additional symbolic representations were needed to help students make the necessary connections.

Teaching of T&E Content and Practices

For the teaching of T&E content Teacher 3 received a score of seven. The lesson focused on the fundamental T&E content since the teacher did not stray from the FoT PowerPoint very much; however, it lacked strong examples of interrelated content to increase its meaning. Teacher 3 rarely illustrated a solid grasp of the T&E content presented since she stuck to the slides. One example of this was when she provided very little detail about the conversion of wind to mechanical to electrical energy:

> Teacher 3: We have our wind, our wind turbines being blown by the wind. It is going to be constantly flowing. That is renewable.

The teacher did not elaborate on how the energy transformed from wind to electric energy via a generator, she just stated that wind turbines are utilized. No relationships of T&E abstraction were shown beside the power plant slide provided in the presentation, and targeted content was rarely connected across disciplines with authentic applications as seen with the example she provided for the first law of thermodynamics:

> Teacher 3: Performing work is a form of energy transfer. So when a tool machine moves an object, the object is going to absorb the energy from the person. Some of that energy from the tool/machine to person, person to tool/machine. It is the flow of the energy back and forth.

This example could have been strengthened if she provided an example of a specific tool or action to which students could have easily related. For teaching of T&E practices she scored a one. The low score for the practices component can be explained by the fact that students never used a variety of practices to represent targeted content, no estimations or hypotheses were encouraged regarding ways to harness forms of energy, students were never involved in investigation or thought-provoking activity, and they were never asked to be reflective about their learning. Reviewing the pre-assessment quizzes at the end of class could have prompted student reflection, along with asking students what they learned from the home energy consumption calculation activity. The teacher did receive a point because on occasion she allowed ideas to be presented during the lecture (mostly during the pre-assessment), but without evidence.

Summary

This lesson was mainly focused on conversion of energy in preparation for the end of unit windmill activity. Teacher 3 focused on presenting what was provided to her by the FoT curriculum and rarely strayed from those materials or content. Although she delivered the targeted science content as it appeared in the PowerPoint slides, she rarely elaborated on these concepts to enhance their meaning. She did provide further detail about the law of conservation of energy, however the example she provided could have been grounded in science or T&E concepts to help students see the connection more easily.

During this lesson, science practices were almost non-existent as students were never engaged in thought-provoking exploration of science and T&E phenomena. Also, she did not demonstrate a strong grasp of T&E content nor did she utilize any practices to captivate students' interest. The students could have used the energy consumption assignment at the end of the lesson to predict and investigate their personal energy usage, but instead they were given all of the information with specific steps to follow. Even in terms of harnessing energy, students were told they would be designing windmills at the conclusion of the unit. That activity may immerse students in the critical assessment of energy collection, but for the observed lesson there were no opportunities like this for students to explore their ideas.

For the reasons mentioned above Teacher 3 scored very low in all categories, especially in teaching of science content and practices. Her observation ratings were corroborated by her interview responses expressing that she felt ill-prepared to teach science content and practices, and believed these were areas she needed to become more familiar with to improve her teaching of T&E education. This instructor was a novice teacher and did not have the same amount or quality of informal preparation experiences that some of the veteran teachers reported. This warranted the need for examining the strength of the relationship between participants' informal experiences and teaching of science content and practices.

Teacher 4

He thought the lesson went well despite its unorganized appearance. It is normal for him to deviate from the lesson plan because he values engaging questions from students, which he tries to answer to the best of his ability. The key concept he wanted students to learn from the lesson was how to be a critical consumer of energy sources. In addition, he wanted students to learn how to connect and manipulate science and technology to solve a problem. He gave an example of understanding wavelength spectrum to change the color of a light bulb and then applying that concept to solve design problems or investigate other variables that could be changed. When planning the lesson he had to take into consideration students' preconceptions about energy sources and he anticipated they would not be critical enough when researching energy sources. He did not think the FoT curriculum integrated enough science content nor did it in a manner that helped students make connections to the end of unit design challenge (a windmill). Teacher 4 believed the concept of thermodynamics should be emphasized in a more relevant context so students could explicitly see the connection between thermal reactions, heat loss, and heat waste to mechanical efficiency and home insulation. Even though he thought there should be more emphasis placed on science content, he believed it would be difficult to teach due to the various levels of students enrolled in an FoT class versus a physics class.

Teaching Strategies Observed

Teacher 4 was observed teaching a blend of content from the first lesson of Unit 3 on energy conversion, and a lab activity from Unit 4 on troubleshooting electronic circuits. The lesson started with a class discussion reviewing social, political, environmental, and economic effects of energy sources that students researched for homework. During this portion of the lesson the teacher emphasized being a critical consumer and the importance of analyzing research. This led into a discussion and questions about retrieving energy from nuclear power and fracking. Teacher 4 supported his focus about being a critical consumer by handing out an article regarding the benefits of nuclear energy and challenged students to raise concerns not mentioned in the article. The class compared advantages and disadvantages of nuclear energy to wind energy. This discussion on energy transitioned into questions about static energy and magnetic fields which the instructor answered with examples and demonstrations. The teacher then used the conversation regarding static electricity to segue into an electricity activity. He first demonstrated how to connect a buzzer to a breadboard and explained their challenge was to design a circuit in which they could control the sound of the buzzer using only the components in the provided kit. Students worked in pairs as the instructor walked around to scaffold them with questions until they discovered that a potentiometer and switch could be used to control the buzzer. They were then challenged to add a light to the circuit so that they could control both the light and the buzzer. Teacher 4 then refocused the class to ask what they found the parts did and how they think they worked to control the flow of electrons. Students asked the instructor about speakers and how they worked, which prompted him to discuss magnetism and magnetic fields. A more in depth conversation about nuclear energy followed with numerous questions about how it occurs. The teacher used this opportunity to relate fission to energy efficiency, which led to a demonstration of a hand crank generator to show how magnetism helped convert mechanical to electrical energy. This intrigued students and elicited many questions about electricity and harnessing energy from the sun via a parabolic dish, which the teacher took time to answer and provide relevant examples. Teacher 4 ended the lesson by connecting all of these concepts back to the conversation from the beginning of class about the importance of analyzing all advantages and disadvantages with energy sources, including efficiency.

Among all participants, Teacher 4 earned RTOP ratings that were among the highest across the board. His scores in lesson design and implementation, communicative interactions, and student/teacher relationships were all above the mean. His high rating in lesson design and implementation can be attributed to the amount of questioning he used to gauge students' prior knowledge and allowing the lesson to evolve from building upon student comments. For communicative interactions the teacher's questions often triggered divergent modes of thinking, used student questions and comments to direct classroom discourse (e.g., student questions about speakers and magnets), and he respected student comments as evidenced by the thorough answers he provided for any questions that arose. In the final section examining this instructor's student/teacher relationships he scored high for patiently scaffolding students to better understand the content, intently listening to their feedback to help answer questions, and encouraging them to generate alternative interpretations and solutions for energy sources. The total RTOP rating for Teacher 4 was 102 (second highest among all participants), resulting from high ratings in the previously mentioned criteria as well as in teaching of science and T&E content and practices. These ratings are explained further in the preceding sections.

Teaching of Science Content

This instructor received a score of 17 for their teaching of science content. The lesson was focused to some extent on targeted science content, of which the teacher frequently illustrated a solid grasp. He lost points because during parts of the lesson he failed to describe how nuclear energy is created at the atomic level. However, he did an exceptional job interrelating the targeted science content with other concepts to greatly increase its meaning, regularly connected content across disciplines with multiple examples to authentic applications, and regularly represented abstract science content in a symbolic way as portrayed in the following vignette:

Teacher 4: Remember when I showed you a power plant [referring to the graphic provided in the FoT PowerPoint slide]? What do most of them do?

Student F: Make steam.

Teacher 4: How do you make steam?

Student F: Heat up the water.

Teacher 4: Once you have the steam, it starts spinning the turbine. What form of energy did we just jump into?

Student G: Mechanical!

Teacher 4: Mechanical. So you now have rotary motion. It is going around and around and around. That rotary motion is hooked up to an electric generator which will create?

Student H: Electricity.

Teacher 4: How does it do that? [Teacher retrieves a hand crank generator from the closet that when spun fast enough, lights up a bulb. He has a student volunteer to come up to the front of the class and crank the generator.] By spinning this I am making the electricity. If you look at this what is in here?

Student I: A magnet.

Teacher 4: A magnet. That conversion from mechanical to electrical requires electromagnetic in the middle. You do not get there without the electromagnetic. What two things did I say were always tied together? As soon as you send current through a wire you get what?

Student I: Magnetic field.

The teacher then went to a computer and asked students what the big plastic part on the end of a USB cord was. He explained that magnets not only create electricity but can also dampen the flow of electrons to prevent surges of static electricity from ruining devices like computers. Teacher 4 continued on to give more applications of magnets such as credit card strips. These examples provided engaging authentic contexts to which students could relate. They also made connections between various forms of energy and scientific concepts. Another great example he provided dealt with static electricity and pumping gas:

Student J: How does the static work with gas pump explosions?

Teacher 4: The worst-case scenario is a pick-up truck. If the truck has a little bit of sand or dust in the back, as you are driving down the road that dust is swirling around building up a static charge. That is why they tell you if you are going to fill up a can of gas, take it out of the truck and put it on the ground before you fill it up to ground the charge. If you fill the can in the back of your truck with the pump nozzle, there is a good chance the spark discharge could ignite the gas from your pumping. Do not pump gas into a container into the back of your car. Also

> during winter do not begin pumping gas and get back into your car until it is finished. As you get back into your car and you are wearing your winter sweater and hat, you are building up a static charge. Then when you get back our of your car and go to grab the nozzle you could discharge that nozzle right there. Another good cause for an explosion at the gas pump.

Again the teacher exemplifies how to use student input to engage the class and determine the direction of the lesson while still covering targeted content.

Teaching of Science Practices

This instructor received a little bit lower score (10) for teaching of science practices than science content, but it was the second highest rating for this category among all teachers. He lost points because he did not require students to use a variety of practices to represent targeted science phenomena; rather, he only required students to represent practices with the electronic circuit activity. Students were clearly led to state predictions and hypotheses about energy consumption but they did not have to devise ways to test them. Furthermore, students were encouraged to investigate what was occurring with the circuit components during the lab, but they were not led to participate in thought-provoking critical assessment of the energy created. Teacher 4 scored highly for consistently asking students to reflect on their learning of targeted science content while providing adequate wait time. This was evident in the review of the lab activity:

Teacher 4: Which one is the transmitter?

Student K: The one with the thingy.

Teacher 4: The thingy?

Student K: Yeah.

Teacher 4: Which one?

Student L: The one with the black strip.

Teacher 4: This is the transmitter.

Student M: Is that where the sound is coming from?

Teacher 4: It makes the signal. It is producing a frequency. That frequency is then converted into light pulses, which are sent to the other side. Does anyone know what any of the parts are on this thing?

Student K: A battery, speaker.

Teacher 4: We know battery. Good. What else?

Student M: Lights. The blue thing with the circle on it.

Teacher 4: What do you think that blue thing with the circle on it is called?

Student M: The volume.

Teacher 4: It does adjust volume but what is it? [waits 7 seconds] What did we say the knob that controlled volume was called? If I tell you that what it does to make the volume go up and down is it opposes electricity. What was the measure for the opposition to electric flow?

Student L: Resistance.

Teacher 4: So it is a…?

Student K: Resistor.

Teacher 4: More specifically it is a variable resistor. Literally what you are doing with that dial is you are changing the overall resistance and saying I want to send more or less voltage and current to the speaker.

Teacher 4: How does the speaker work?

Student N: It moves in and out to make waves.

Teacher 4: What makes it move? All of this is going to tie back to our energy forms. Remember our energy forms? Which of these forms of energy has to do with the design of something as simple as a speaker?

Student N: Electric.

Teacher 4: Definitely electric. What else?

Student M: Mechanical.

Teacher 4: Not really.

Student L: Some speakers move.

Teacher 4: You might be able to get some mechanical in terms of the design as far shape and how well it moves, but traditionally that is not important in the design of the speaker. What is really important is…?

Student M: Magnetic.

The teacher continued on to talk in great detail about how magnetic energy is created within the speaker to generate sound waves and he ended this segment of the lesson by stating, "See the connection from one energy to another energy to another energy?" This vignette shows the teacher's patience in helping scaffold students to understand not just what the circuit parts are, but to make predictions and draw conclusions about how they work and for what other applications they could be used. Teacher 4 also received a high rating for RTOP item 20 because he often allowed a variety of ideas to be presented and challenged with some accurate evidence as seen in the previous vignette.

Teaching of T&E Content and Practices

For the T&E content criteria Teacher 4 was one of only two teachers who received a perfect 20. The lesson was entirely focused around the targeted T&E content, the meaning of the content was greatly increased through strong connections he provided to other concepts, he constantly demonstrated a solid grasp of the content, abstract relationships were regularly represented in symbolic ways, and he regularly connected the content to other disciplines using authentic examples. Examples of these characteristics were seen throughout the lesson as he continually prompted students with questions and demonstrations to explicitly show the connection from one energy form to another.

He did not receive a perfect score for T&E practices, but still scored highly with a rating of 16. The lower score for the practices component can be explained by only having students use the circuit activity to represent electricity and energy conversion, explicitly leading them to state predictions for their circuit but only devising one way to test it, and prompting students to be reflective on multiple occasions about energy types and circuits. Students were regularly engaged in the assessment of various energy forms and troubleshooting their circuit, and the teacher always allowed a variety of ideas to be presented or challenged if adequate or accurate evidence was provided (e.g., forms of energy utilized by speakers).

Summary

Teacher 4 did an exemplary job of intricately weaving together the science and T&E content and practices from this lesson to create a deeper learning experience for students. As demonstrated from the examples above, his lesson fueled off of student participation. This teacher displayed great patience, and also used student feedback to determine the direction of the lesson while still covering the fundamental science content from the unit. This method enhanced student engagement and exploration because the content was tailored to examples with which they could personally connect. Teacher 4 predominantly used a Socratic method of teaching, which one would expect to rate highly on the RTOP because it lends itself well to facilitate student inquiry and exploration.

Despite using a loosely structured Socratic pedagogical method, Teacher 4 still demonstrated proficient knowledge of science content and practices within FoT. He did such a great job connecting the science and T&E content together, that at some points it was difficult to tell if he was teaching an applied science or FoT course. Despite missing opportunities to describe nuclear energy in more detail, he illustrated a solid grasp and application of the science content. He also provided excellent examples that represented authentic applications of abstract science phenomena (e.g., static electricity, magnetic fields) and enhanced students' understanding of the content.

The reason that he scored lower on science practices was because his students only engaged in one practice (the circuit activity) to explore targeted science phenomena. That activity was thought-provoking in that it allowed students to make predictions and test them out. It also elicited more questions about science content, which contributed to the momentum of the lesson and engaging students. The instructor utilized student comments and the circuit activity to eloquently illustrate the conversion of energy across various forms. The broad array of preparation experiences reported by this instructor were later examined in more detail to gain a better understanding of the select experiences that contributed to high science content and practices ratings.

Teacher 5

This teacher believed the lesson went really well because students were not only on task but they were progressively moving through the lesson at their own pace. The key concepts he wanted his students to learn were understanding the importance of inventorying and organizing their work (electronic components) before they begin, and the systems and routines that would be in place for the unit. His emphasis on inventorying and organization was apparent in the beginning of the lesson when he informed students:

> Just like a good dentist, a good doctor, or a person who is working on your car, they organize their work before they begin a task. Then when they're done with the work they do a quick inventory to make sure they didn't leave a sponge inside a patient or their tools are clean and operable for the next person. Even though you may be thinking about school, it's a transition to the habits we take into the work place and into our daily lives that's really important. (Teacher 5, classroom observation, November 11, 2014)

When planning the lesson he had to take into consideration how to best review and bridge important knowledge from yesterday's lesson about reading a resistor. He believed that understanding specific circuit components, knowing how a solderless breadboard worked, and being able to read a schematic needed to precede electron flow theory for students to later experiment with circuitry design and better understand electricity. In planning the lesson he anticipated students would struggle with some of the technical vocabulary due to a high amount of ELL students in his class. He believed that electron flow was an important concept for students to learn because it contributed to the bigger picture of electricity. Yesterday he taught students about insulators and semiconductors, but helping them see how those could control electricity for technological lifesaving devices such as a pacemaker, really helped engage students in learning the embedded science content.

Teaching Strategies Observed

On the day the researcher visited, he witnessed the second lesson of Unit 4 addressing electronics and flow of energy. For one third of the class period the teacher used a document camera and various diagrams to lead a brief review on energy flow theory, how to read a resistor, how a solderless breadboard is laid out, and how to inventory all components in the electronics kits. He emphasized that for this unit it was essential for students stay at their tables and he would navigate around the room to help them. In the interview the teacher stated that he would provide more detail about the technical content in later lessons, but today he had to make sure students understood the procedures for how the unit would be taught. The other two thirds of the class period involved a series of self-paced electronic circuit labs in which students diligently worked in pairs. During the lab, the instructor weaved from one end of the room to the other, helping students troubleshoot their circuit and provide further explanation about what they were experiencing. He carried a 9-volt battery with him to test the circuits as opposed to providing batteries to every group. The class ran very smoothly and the teacher exemplified teaching as an art. Teacher 5 credited this to learning from his experience with teaching similar lessons over his 33-year career. He said it took him some time to develop this system, but found it to be the most fair and equitable for students. The students enjoyed the class as witnessed by their engagement in learning and practices during the entire circuit lab. Furthermore, at the end of the lesson they expressed how much fun they had troubleshooting the circuits and learning about electronic components used in their cell phones.

Teacher 5's scores in every RTOP category were the highest among all participants. The instructor's high rating for the lesson design and implementation section was evident during the circuit lab where student exploration preceded formal presentation, and students' prior knowledge and preconceptions were well respected. After groups completed each circuit design the teacher provided examples of authentic applications for the circuit component. When asked if students would have been able to determine the application of a potentiometer or capacitor without him explicitly telling them, he replied:

> No. They show a fuel gauge from a dashboard on final exam questions and I still have kids who are 15-21 years old who have never seen that. I can't take that for granted. If I say a dimmer switch they say 'Oh yeah' but if I say a potentiometer or a rheostat they have no idea. (Teacher 5, personal communication, November 11, 2014)

In addition to considering and understanding his students' preconceptions, Teacher 5 encouraged them to seek alternative modes for troubleshooting their circuits and welcomed questions within the groups. Communicative interactions scores were also excellent as this instructor encouraged learning through discussions between and among students, allowed student comments to determine the direction of the lesson unique to each group, and respected all student questions by listening and providing detailed answers with examples. Finally, in the student/teacher relationships section this instructor also scored extremely well. Students were actively engaged in generating alternative solutions for the circuits to function properly, and the teacher was an extremely patient listener who acted as a resource person to support and enhance student investigations like the example described earlier. Teacher 5 recognized his dynamic role in the classroom that contributed to his pedagogical success:

> Different units will lend themselves to be positioned in a different way. Sometimes I can be the guide on the side and sometimes I have to be the sage on the stage. Sometimes I just have to be the community resource broker and just let it happen. (personal communication, November 11, 2014)

This instructor earned the greatest total RTOP rating (118) with high scores regarding observed teaching of science and T&E content and practices. More detail about the rationale for these high ratings can be found in the next sections.

Teaching of Science Content

This instructor received a score of 19 regarding their teaching of science content. He did an exemplary job interrelating targeted science content to greatly increase its meaning, representing abstract science concepts through symbolic ways (e.g. conductivity by displaying a picture of a solderless breadboard with lines drawn on it, resistance using a potentiometer in the circuit lab), and regularly connected targeted content across disciplines with authentic applications like this example of electron flow and the solderless breadboard:

> Teacher 5: We need to revisit the breadboard. There is a little bit of mystery here but as you look at the breadboard I reminded you to keep in mind that the outer two strips let us consider that to be roads, like this is first avenue and this is second avenue. Traffic is all going along this direction to hit that piece of foil you worked on with electricity last week. Then all the traffic in the blue lane is connected there where those two meet without some sort of work being involved here. If I just take one wire to another it is going to fry. There are two different lanes on that street and these are two different lanes on this street, and then all along the streets are houses and these houses have a family of five. If I'm going

> to work in that household I have to have at least two people working. So if you are doing the first circuit and you have a resistor coming in here or a lead come in here now all of a sudden you are wondering why it was not working. That is because power was coming in but it was going nowhere, or there was a house waiting for a power source but there was none coming. So keep in mind when you troubleshoot that these are all the addresses of house one, two, three, four and these are another set of houses on this street and if I happen to have households working together I have to jump the alley or I maybe even need to bridge over to another one. But how this looks underneath, again so that you can do the visualization, underneath each of those holes are foil or basically good conductive materials that do not touch. They are independent even though their rows or columns are all aligned so that you can work and get more from that. This is the visual that really begins to help you make sense. This is lane one of that street, lane two, all going in one direction. These are all the houses where everyone in that family is fed, and I cannot work with the other house unless I bridge it with a component or a wire.

In this example the instructor referenced a previous lesson activity in which students had to make a light bulb illuminate using only a piece of tin foil, a light bulb, and a battery. He believed that activity gave them the foundational knowledge needed to complete a circuit, and the example from the vignette helped them to see the how the back of a breadboard is connected so they could make that connection and successfully experiment with different circuit components. The instructor felt that by providing it in this context he made it relative to all students, especially the high population of ELL students. Later in the lesson Teacher 5 referred to this example to help students troubleshoot their circuits.

Although he regularly illustrated a solid grasp of the foundational science content, he lost a point because he did not provide more detail about electron flow in the beginning of the lesson. In the interview he said this was a concept he touched on briefly in the previous lesson, but today was focused on students experimenting with how to use circuit components to give them context for later discussions about applying these components to control electron flow. Despite what was presented last class the instructor could only be rated on what was observed.

Teaching of Science Practices

This instructor received the highest score (15) among any participants for the teaching of science practices. He displayed excellence at engaging students in the investigation and thought-provoking assessment of the science content associated with electricity (e.g., conductors, insulators, electron flow) throughout the lab. In this first example he helped students assess applications for a capacitor:

Teacher 5: This is a light emitting diode. Now if I take this away it stays on.

Student O: Whoa that is cool, do it again!

Teacher 5: That is cool. That is in your cell phone charging at night so it runs all day.

Also, in this next example he scaffolds a student to troubleshoot a photocell circuit using the house example he provided at the beginning of the lesson:

Teacher 5: Put your finger on the photocell. Wait, something is not correct. Are two people working at home? Or are there two people alone working in different houses? Make sure two people are working at home in the same family. Now put your finger on the photocell. Good. Nicely done.

In addition to the criteria above, this teacher earned high ratings for prompting students to be reflective about their learning of resistance and flow of electrons, which was witnessed while helping students troubleshoot their circuits. He demonstrated lower ratings for only using the circuit activity to represent the electron flow phenomenon. If he also had students draw a schematic of their circuits using arrows to show the flow of electrons, that would have been an additional practice to help students comprehend the content. Although students were encouraged to explore and test their ideas, they were not explicitly led to state their predictions before constructing their circuit as seen in the following potentiometer example:

Teacher 5: Hold it and turn it. See it work?

Student P: Whoa ok it did get brighter.

Teacher 5: That is the dimmer switch in your dinning room. Or a volume control on your stereo. That is all that is. Good job. Trust yourself.

The instructor may have done this due to students' lack of prior knowledge about circuit components as previously described in the fuel gauge example. Limited prior knowledge may have also played a role in the minimal evidence he required of students when asked where they had seen similar electronic circuit components.

Teaching of T&E Content and Practices

For the T&E content criteria, Teacher 5 was the only other participant besides Teacher 4 to score a perfect 20. He regularly demonstrated a solid grasp of the content from the adequate examples he provided, the lesson was entirely focused around the fundamental T&E content about electrical circuits, it was strongly interrelated with other concepts to greatly increase its meaning (e.g., capacitor in a cell phone, potentiometer in a stereo volume button), content was regularly connected across disciplines with various examples, and abstract T&E content was regularly represented in symbolic ways (e.g., breadboard and family analogy).

This participant received a 16 for his teaching of T&E practices. This lower score for the practices component was still among the highest in the study. Students were actively engaged in the thought-provoking investigation and assessment of troubleshooting their circuit, they were constantly reflecting on their learning due to the teacher visiting each group and providing clear prompts, and the instructor welcomed ideas to be presented or challenged with adequate and accurate evidence. If students did not provide evidence the instructor eloquently prompted them by asking where they had seen or heard that information. One area in teaching T&E practices where Teacher 5 scored below a four was a result of students only using the circuit activity to represent electrical energy phenomena. The other was because students were vaguely led to predict how the circuit would work and could rely on schematic diagrams from the book to help them in designing their circuits. Students were not prompted to draw schematics or use other means to represent electricity. The instructor said that in later lessons students would be challenged to design a circuit that can perform specific tasks without the help of a schematic, but during the observed lesson he wanted to introduce them to various components and give them an understanding for what they do.

Summary

Similar to Teacher 4, this instructor did an excellent job integrating science and T&E content and practices together. Teacher 5 did not score below a two on any item, which demonstrates at minimum, an above average understanding of the many components needed to successfully teach science and T&E content and practices. The lesson focused on allowing students to experiment with circuit components so they could gain a better understanding for how those components control current flow.   This teacher demonstrated a solid grasp of the targeted science content by providing numerous examples of connections across disciplines and abstract concepts (e.g., solderless breadboard compared to streets and houses). He helped facilitate thought-provoking investigation and assessment of science practices unique to each learner. His rating of science practices was impacted by the fact that he only had students partake in one practice (completing the circuits) and did not explicitly lead them to state predictions. Regardless of these minor flaws students were constantly engaged in learning and he received the highest score for teaching of science practices among any of the participants.

Watching this instructor teach was like watching a conductor orchestrate a symphony - everything happened in perfect harmony. There were numerous “ah ha” moments from students who were intrigued to find out how basic electronic components impact their everyday lives. In his interview he expressed pride in covering all of the ITEEA standards and indicators by the completion of the course. He was confident that his students could apply their knowledge from FoT to various technological contexts. This instructor had a plethora of unique in-service and informal preparation experiences in both T&E and science education over his 33-year teaching career. Some of these unique experiences were later examined in greater detail to determine the influence they had on T&E educators’ teaching of science content and practices.

Teacher 6

He believed that the lesson went pretty well but said the FoT PowerPoint presentation went longer than he wanted, which may have contributed to the lack of attention from some students. The key concepts he wanted students to learn from the lesson were how energy is transformed from one system to another, and that technology is intricately related to how much energy we have and use. When planning the lesson he was somewhat unsure about the zeroth law of thermodynamics, so he researched it using Wikipedia and university websites, then added to the FoT slides to make it more relevant for students. In planning the lesson he anticipated students would struggle with the laws of thermodynamics because he felt the lesson did not do a good job of making it practical for them, hence the added PowerPoint slide. He believed that describing the science behind nuclear energy (e.g., atomic structure and fission) in great detail was not important for this particular lesson because he would later revisit the topic and ask students to write an argumentative essay about the advantages and disadvantages of nuclear energy.

Teaching Strategies Observed

This instructor taught the introduction to energy forms and conversion of energy lesson from Unit 3. To start class he instructed students to complete the unit pre-assessment quiz provided by the FoT curriculum, which he later collected but did not discuss further with them. He then began to present the FoT Unit 3 PowerPoint while students took notes in their engineering journals. While doing this he very rarely deviated from the slides other than to offer a few examples, most of which were related to his experience in home remodeling. He did add one slide to the presentation explaining thermal equilibrium and thermodynamics because he believed students had difficulty relating to those concepts in the manner that FoT presented them. Very seldom did Teacher 6 ask for student responses, nor did students ask many questions during the lesson. This class period consisted mostly of the teacher talking about the FoT slides near the front of the room while the students took notes. At the conclusion of the PowerPoint the instructor handed out the FoT worksheet for calculating annual energy consumption of home appliances. The teacher explained how to calculate energy consumption by reviewing the example provided on the worksheet. During the final minutes of class, students were allowed to work on completing their hydraulic robotic stacker project from the previous unit.

Teacher 6 received the lowest ratings on most items of the RTOP when compared to his colleagues. His RTOP scores for lesson design and implementation, communicative interactions, and student/teacher relationships were below the mean among observed teachers. This instructor's low rating on the lesson design and implementation section was the result of a very teacher directed lesson with little to no student input, exploration, or problem solving observed. Like Teacher 3, the FoT unit pre-assessment quiz was administered, but this instructor did not review it after students were finished. He began teaching without using the quiz to help reveal concepts that may require more attention during the lesson. Communicative interactions ratings were also low for this participant due to not using student questions or comments to help determine the focus of classroom discourse, no sharing of student ideas, and no talk between or among students. Also, ratings for the student/teacher relationships section were well below the mean because no form of active participation was encouraged or valued, students were never prompted to generate alternative solution strategies or interpret evidence since everything was presented directly from the PowerPoint, and although the teacher provided adequate wait times he did not allow the opportunity for questions or responses to fully develop. Ideas were often cut short to progress with the next part of the lesson. Teacher 6 recorded the lowest total RTOP score (18), demonstrating extremely low ratings in his teaching of science and T&E content and practices. Observations and examples as to why he received these ratings are provided below.

Teaching of Science Content

This instructor earned a score of three for their teaching of science content. He did not show any evidence that he had a solid grasp of the targeted fundamental science content, and he rarely mentioned it. The science content was not the focal point of the lesson, which was evident when he mentioned atomic bonds and fission only because they were in the FoT PowerPoint. He did not provide further explanations about those concepts:

> Teacher 6: Chemical energy which is stored in coal, natural gas, biomass, petroleum. Has a chemical energy that is stored up and when we heat it breaks the bonds and you get energy that you can use. Then finally we get nuclear energy and the nuclear energy we use at this point is the energy stored in atoms but we use it by breaking atoms apart. So it is fission, F-I-S-S-I-O-N.

Later in the lesson the topic of nuclear energy emerged again as the instructor provided this explanation:

> Teacher 6: If you take uranium as a non-renewable resource, and that is what we are using for nuclear power that is true. Then the question becomes, can we use other types of nuclear power that do not use uranium. Well yeah we could do that too. That would be much different for example if we used fusion instead of fission than we could use water. Lots of water out there.

Although the instructor enhances the science content by mentioning fusion, he does not explain what fusion is or why water would be needed. If he explained that the hydrogen isotope from water is used to create energy during fusion it could have helped students see connections between science and T&E.

The targeted science content was vaguely interrelated with other concepts, rarely increasing its meaning. Additionally, science content was rarely connected with content across disciplines or presented using examples of authentic applications. On one occasion the instructor related thermodynamics and heat loss to vents in a house.

Teacher 6: This has to do with the fact that molecules move. As I heat it up, internal and potential energy increases and I get those molecules moving faster. Part of that energy transfer is the flow of energy. Energy flows from hot to cold. Often times we have to kind of help it flow. So if you think about your house, take your bedroom for example, in most cases most of you have a register or something where the hot air is coming out. If you do not have a cold air register, one that is going to let the cold air flow out of the room, it is very difficult for hot air and cold air to pass each other. So one of the reasons you get cold spots in a house is because you do not have a return, a place for the cold air to go when the hot air is being pushed in. It always flows from hot to cold, like your air conditioner and refrigerator are pulling heat out, not cooling things.

This example corroborates the instructor's interview response attributing much of his knowledge and examples to his prior work experience in home remodeling. He did a good in the above example describing flow of energy in a context that students could easily relate. However, no abstract science content was represented in symbolic ways during the lesson. The instructor attempted to do this by adding a slide to better demonstrate the zeroth law of thermodynamics but it did not appear to convey the content in a manner that students could comprehend better. He provided Figure 6 on the added slide and gave the following explanation about it:

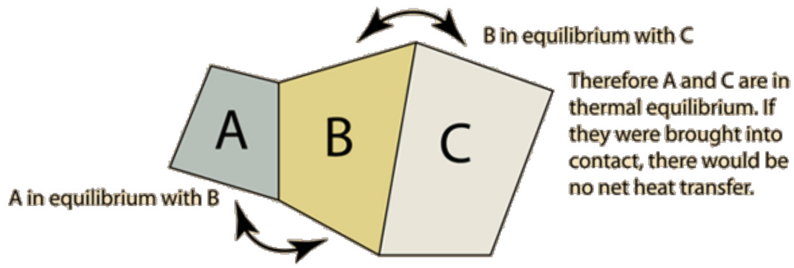

Figure 6. Zeroth law of thermodynamics. Reproduced from "Zeroth Law of Thermodynamics," by C. R. Nave, 2014. Retrieved from http://hyperphysics.phy-astr.gsu.edu/hbase/hph.html. Copyright 2014 by Georgia State University.

> Teacher 6: If A is two and B is two and C is two, then they're all equal. This is how that actually works. I found this graphic here to explain a little better how this works, and what it deals with in particular for us is heat. What you're looking at is the idea that if A is the same temperature as B because they are in contact with each other, and C is the same temperature as B, then all three of them will eventually be the same temperature just by shear contact. So the question becomes then how does heat and cold transfer? So I have gas in this one, and this one, and this one. Each one starts out at different temperatures. Even though they are separate containers since they are touching they will all end up at equal temperatures and be the same temperature eventually. The question is how does that take place? Does it take place from movement? Well they touch each other. So that is what they are talking about with the zeroth law, that they will equal out.

Even though the teacher attempted to use this example to clarify the zeroth law of thermodynamics for students, they still appeared confused. He did not explain that the gases need to be isolated from all forms of energy exchange and left alone for a long time to obtain thermal equilibrium. A more appropriate example could have been used for early high school students. The vignette provided above is a good example of how teacher dominated the lesson was. Prior to the lesson the instructor identified thermodynamics as a topic he expected students to struggle with, but during this portion of the lesson he never asked for student input or posed review questions to gauge their understanding of the content. Doing this could have allowed him to provide a better explanation of the zeroth law of thermodynamics.

Teaching of Science Practices

Many of this instructor's low ratings in teaching of science practices can be attributed to the lecture format of the class and not supplementing it with any practices. He received a rating of one for this section, with his only point coming from the time he allowed students to share ideas and challenge science concepts such as solar energy:

> Student Q: Is renewable considered immediately renewable that we use over and over again without a time loss?
>
> Teacher 6: Uh, yes and it is also renewable over time.
>
> Student Q: Are fossil fuels not somewhat renewable over time?
>
> Teacher 6: Technically yes but it will take millions of years. Eventually if we all die and get down into the ground and turned into mush then year we could pump ourselves out as oil.

As demonstrated, the teacher was unsure about this topic and did not require the student to provide evidence for his statement. Furthermore, students never utilized practices to represent energy phenomena, were never expected to make predictions or test them, were never involved in the investigation or thought-provoking assessment of procedures to convert energy, and were never prompted to be reflective about their science learning. This was witnessed when the unit pre-assessment quiz was administered and never discussed. Additionally, there was no review questions posed during the lecture to check for student comprehension.

Teaching of T&E Content and Practices

For the T&E content criteria Teacher 6 received a score of nine because the lesson was focused to some extent on thermodynamics and energy conversion, the meaning of targeted content was rarely increased due to vaguely interrelating it with other concepts, he rarely illustrated a solid grasp of the content (e.g., renewable energy), abstract T&E content was rarely represented in symbolic ways, and connections with other content or authentic applications were rare. The authentic application examples he did provide were based heavily on his background in home remodeling and working on cars, but no connections were observed across disciplines.

For T&E practices he scored a two. The low score for the practices component can be attributed to students not using any practices to represent T&E phenomena, never being involved in thought-provoking activity to examine or assess energy conversion, and never prompted to be reflective about their learning of T&E concepts. Rather, students were provided all information via a PowerPoint and lecture with no exploration or practices required. They were vaguely led to make predictions about the content during the lecture, but did not have to devise ways to test their predictions. Additionally, on a few occasions the teacher allowed students to present ideas or challenge those presented in the PowerPoint, but they were not asked to provide evidence for their claims.

Summary

Similar to Teacher 3, this instructor relied heavily on the FoT PowerPoint slides and the lesson was centered around energy transfer. He did not go into much more detail about targeted science and T&E content than what was presented on the slides. He mentioned key terms like nuclear energy, fission, fusion, and thermodynamics; but failed to provide adequate examples or demonstrations of these phenomena to help students make connections to T&E content. Because of this he did not display that he had a solid grasp of the science content and practices embedded within FoT. He also showed confusion in relation to some of the content, such as renewable energy and thermodynamics. Only one time did he attempt to enhance what was provided by FoT, and did so by adding an extra slide with a graphic depicting the zeroth law of thermodynamics. However, the graphic and explanation he provided did not clarify the topic at a level his students could easily comprehend.

The class was predominantly a teacher led lecture with almost no practices observed. Teacher 6 rarely allowed students to make predictions and share ideas, but they were never involved in testing or thought-provoking assessment procedures to collect and convert energy. This instructor did provide some good examples related to houses, which he attributed to his previous career in home remodeling. In addition, he had a wealth of teaching experiences over the past 28 years that he believed contributed to his teaching of FoT. Analyses of select in-service and informal preparation experiences that influenced participants teaching of science content and practices were reported in the later portions of Chapter 4.

Teacher 7

He thought the lesson went relatively well based on his observations that students acted more interested and were better behaved than normal. The key concepts he wanted students to learn from the lesson were that energy control deals with the conversion of energy from one form to another, and the more efficient we can make that conversion, the less energy we use. He was very familiar with the content and curriculum due to his experience delivering the FoT teacher training. His only preparation for the lesson was making sure he knew the exact location of the video clips he showed to supplement the FoT PowerPoint. In preparing for the lesson he anticipated students would struggle with the laws of thermodynamics because he felt the curriculum did not do an adequate job connecting this theory to energy conservation at a level that most high school students could comprehend. He believed that fusion was an important concept to discuss in the unit and FoT should emphasize it more; however, he did not go into great detail about it because he did not want students to confuse it with fission. He did not believe most FoT students could distinguish the difference between the two. Additionally, he thought the laws of thermodynamics were better suited for an advanced T&E course, "I introduced the laws of thermodynamics because they're in the curriculum, that's the only reason I mentioned the laws of thermodynamics quite honestly. I think it's probably a better next course level topic."

Teaching Strategies Observed

In the lesson that Teacher 7 was observed, he taught the first part of Unit 3 which examined types of energy and how it is converted. This instructor started by engaging students with a warm-up question about electricity, which they recorded in their engineering journals. To help refresh their memory this teacher showed a video clip about electric current and magnets, pausing the video to ask students questions and provide further explanations. The FoT PowerPoint was displayed and the teacher talked about thermodynamics in much more detail than was presented on the slide. Then he covered potential and kinetic energy, relating it to the oscillation of atoms to create energy. In the next section of the lesson he spent a significant amount of time discussing energy sources and how they convert energy. To enrich this portion of the lesson he played a video about a nuclear power plant, pausing to ask students what types of energy conversion they noticed, and the last video clip showed applications for wind and solar energy. In the final portion of the lesson, Teacher 7 explained how to read Sankey and energy flow diagrams. He added additional examples of these diagrams that were much easier for students at that level to understand in comparison to those provided by FoT. Before dismissing the students, Teacher 7 mentioned what they would be doing next class and how the observed lesson would contribute toward the rest of the unit. He closed by showing a video clip from Discovery explaining electromagnetism and energy. Despite the introduction of content being very teacher driven, he did encourage students to ask questions and present their ideas on numerous occasions. In addition, this instructor used the PowerPoint provided by FoT, but added many video clips to enrich the content. He believed the clips showed the targeted content applied in authentic contexts that he was unable to do because of various constraints (e.g., no field trips permitted, lack of equipment/space).

From a holistic view, Teacher 7's RTOP ratings regarding lesson design and implementation, and student/teacher relationships were slightly below the mean, while his communicative interactions scores were above the mean among observed participants. His moderate ratings on the lesson design and implementation section was a result of needing more student input to engage them in a learning community. The video provided a good introduction but it failed to precede student exploration, and ideas originating from students never directed the focus of the lesson. This instructor's ratings on the communicative interactions section were above average due to his questions sometimes triggering divergent modes of thinking, continual encouragement for students to share ideas among the class, and using student responses to maintain the momentum of the lesson. Lower ratings in the student/teacher relationships section were attributed to very little active participation aside from questions following the video clips, and no student investigation since the lesson was heavily teacher driven. This instructor did score well in this section in regards to providing ample time for student responses, allowing their responses to develop, and helping clarify or explain concepts based on what students shared.

Teacher 7 earned a total score of 69, which was above the overall mean (59.4). He received high scores for teaching of science and T&E content, and moderate scores for teaching of science and T&E practices. What follows are descriptions and examples from the observed teaching of these content and practices.

Teaching of Science Content

This instructor received a score of 14 for their teaching of science content. His lesson was focused to some extent on the targeted science content, and he frequently illustrated a solid grasp of it except for instances where science concepts were mentioned in the video clips (e.g., oxidation, subatomic particles, fission) and he did not provide further explanations about these concepts. One example occurred when presenting the six forms of energy:

> Teacher 7: Thermal heat. Literally the vibration of movement of atoms within a system. The atom molecules sit there and oscillate with energy. That oscillation, that bumping into one another, that vibration is what transfers the energy from one form to another. Radiant is the electromagnetic energy that travels in transverse waves. That is an interesting phenomenon we will talk about again. Typically a wave has a medium. Electromagnetic radiation creates its own medium here.

He did not provide details about why the atoms oscillate or demonstrate what this looked like. Furthermore, he mentioned transverse waves and having a medium but did not provide more information on this new concept. Rather he left it to be explained in a later unit. When the form of nuclear energy came up the instructor also provided a very brief explanation:

> Teacher 7: Nuclear energy. Energy stored in the nucleus of an atom. That's literally the energy that binds atoms together and their subatomic parts as well.

Additionally, one video clip was cut off as it said, "the most futuristic of technologies is fusion" because the teacher did not believe students had the background knowledge to distinguish between fission and fusion and he did not want to confuse them. However, nuclear energy was brought up in a later portion of the lesson at which point the instructor described it in more detail:

> Teacher 7: It works through the heat generated from fission. When the atom splits it reduces tons of heat, as the uranium turns into two smaller atoms the steam from that heat turns the turbine. Very similar to a coal plant but uses the nuclear reaction.

In the interview the teacher revealed that he did not go into detail on some of the science content because it was not a key focus later in the curriculum and he did not want to confuse students by adding more content that would simply become vocabulary terms to memorize:

> There was a slide in what I presented last class that mentions nuclear power and the splitting of the atom but nothing quite in depth. Nothing that I'm really going to expect the students to take away. It's difficult to apply so it's just more words that are easily forgotten at this level. (personal communication, December 1, 2014)

Having knowledge of science practices or design-based lab activities to demonstrate nuclear energy may have encouraged this instructor to place more emphasis on the topic. Teacher 7 provided many adequate examples of the targeted science content, but they were vaguely interrelated to other concepts for increased meaning. He only supplemented some abstract science content in the lesson through video clips and diagrams. Lastly, targeted content was often connected across disciplines with examples of authentic applications such as the concept of work:

Teacher 7: Work is equal to the force you exert times the distance an object moves. We talked about this in relationship to mechanical advantage in levers. I showed you books. If I moved 10 books five feet, 10 times five is 50 foot pounds. If I moved half of that weight, maybe five of those books at a time and I go twice as far but use half the force, I end up doing the same amount of work.

Enhancing the teaching of these science concepts through practices were examined in the next section.

Teaching of Science Practices

This instructor received a score of seven for the teaching of science practices. He received low ratings for not having students use any practices to represent targeted science phenomena, and vaguely leading students to make predictions without testing them. Students were engaged in thought-provoking investigation of energy collection and transfer, but did not have to assess practices to do this. Practices to assess energy collection may come up in the end of the unit activity when the teacher will have students design windmills and analyze their collection of energy, but it was not demonstrated in the observed lesson. One area where this teacher rated well in teaching of science practices was providing clear prompts for students to review and reflect on what they learned from video clips that emphasized targeted content such as magnetism and current:

Teacher 7: Induction has two parts. What is the second thing mentioned in the video?

Student R: Movement back and forth.

Teacher 7: A little bit more. What is the other thing he showed?

Student R: Moving a magnet in and out of a wire creates current.

Teacher 7: So if you take a magnet and you move it in and out or by or near a conductor or electrical wire you can produce an electric current.

The instructor also included a video clip on thermodynamics because he anticipated students would struggle with that concept in the theoretical manner which FoT presented it. Teacher 7 sometimes asked for student input, but aside from the video clips the lesson was still very teacher dominated. When the teacher did ask for input not many students volunteered, prompting the teacher to call on them. In the interview the teacher revealed that the observed class was a group of students who were not very interested in the FoT course, making it difficult to have classroom discussions that cultivate richer learning experiences.

Teaching of T&E Content and Practices

For the T&E content criteria Teacher 7 received a score of 19 since he regularly demonstrated a solid grasp of the content, the lesson focused entirely around the targeted content, it was strongly related with other concepts to greatly increase its meaning (e.g., how an electric generator converts energy), the videos represented abstract T&E concepts in symbolic ways, and the content was often connected across disciplines with multiple examples such as the following:

Teacher 7: In a typical power plant coal is the source of our power. It is an example of potential and chemical energy. We burn the coal, that is a chemical reaction creating fire, rapid oxidation basically which releases energy in the form of heat, the heat boils the water which turns the turbine creating mechanical energy, which is converted to electrical energy by pushing a magnet past wire. Remember the video with Faraday and his magnet passing inside a coil of wire, basically the turbine turns magnets past coils of wire.

The above example mentions some science content such as oxidation and magnetic fields but only goes into detail about creating a magnetic field. The instructor also connects this back to the video viewed in the beginning of class. The main focus still remains on the conversion of energy from one form to another as oxidation is not explained and the opportunity to reinforce it through T&E content is not used to its full potential.

For T&E practices Teacher 7 scored a six. The low score for the practices component can be explained by students not using any practices to represent T&E phenomena, vaguely leading them to state predictions during the lecture and not having to test them, rarely involving them in thought-provoking practices that led to critical assessment of energy sources, only requiring them to be minimally reflective about their learning of T&E content, and rarely providing the opportunity for them to present or challenge ideas. The theoretical investigation of content was thought-provoking during the lecture and videos, but students were not led to explore these theories or test them out.

Summary

Teacher 7 focused on presenting many of the targeted science concepts through the lens of energy conversion. His main goal was to help students become more technologically literate through making informed decisions about energy sources. He illustrated a solid grasp of the science content with the exception of a few targeted concepts that he did not explain in detail. This instructor also missed a few opportunities to describe important science content that emerged during class discussions (e.g., oxidation) to enhance the lesson and provide a richer Integrative STEM Education learning experience. On a positive note, this teacher was one of the only instructors to talk about energy at the molecular level as he described how atoms oscillate.

Although his lesson consisted mostly of a teacher led lecture, he supplemented it with many excellent video clips to demonstrate abstract science concepts (e.g., magnetic fields). Additionally he provided some authentic examples for students to see the applications of targeted science content. In regards to practices Teacher 7 lost points because students were vaguely led to make predictions but did not test or explore them. Most of the practices from this lesson involved viewing video clips and reviewing of content through class discussion.

It emerged during the interview that Teacher 7 contributed much of his knowledge about teaching FoT to his experience as an FoT teacher trainer in the summers. During the observation it was apparent that he had an increased comfort level with the curriculum and was able to enhance the lesson by including additional explanations and examples. He appeared unsure of a few science concepts that he did not go into great detail about which was confirmed in his interview. This information led the researcher to question whether there was a relationship between deliverance of professional development (specifically FoT teacher training) and teaching of science content and practices. This was examined in the mixed analyses presented later in this chapter using Spearman's rho tests.

Teacher 8

This teacher believed the lesson went well because students were able to apply the content through a hands-on activity and it was something to which they could easily relate. The key concept he wanted students to learn from the lesson was how electricity is created (e.g., from coal to their house), and what are some of the environmental impacts. Since he decided to modify the activity for this unit, his preparation included reviewing the content from the FoT PowerPoint slides and omitting those that did not correspond with the activity. When he had questions about planning the lesson he consulted the other T&E teachers in his school. He did not think there were any concepts students would struggle with because he believed they were exposed to renewable and nonrenewable energy in elementary school, and they learned about kinetic and potential energy in science class. Furthermore, he believed that atoms and electron flow was important but not something that could be covered in great detail within FoT since it was an introductory level course. He was often faced with the decision of which concepts to teach and which to omit since he only has nine weeks to cover the entire FoT curriculum. When tasked with this decision he normally resorted to skipping content that did not directly apply to the end of unit activities.

Teaching Strategies Observed

Teacher 8 was observed teaching energy conversion content from Unit 3 blended with a modified lab activity related to Unit 4 and troubleshooting circuits. Immediately upon entering the classroom, each student logged onto a computer to answer warm-up questions provided by the instructor. When finished, the students took a seat at their lab table to participate in a teacher led review of Unit 3 vocabulary terms. The teacher asked for student input while also providing further explanations and examples of the terms. Teacher 8 then asked more questions to review energy sources that were presented in the previous class. This led the instructor to display and discuss the FoT PowerPoint slide showing energy being converted from a coal plant to a house. Following this presentation of content, pairs of students were instructed to go retrieve a miniature 2x4 wall frame for their lab. In a prior class students had learned how to strip 14-gauge wire and nailed their electrical boxes to the studs. The teacher went around to make sure all students had their wires stripped properly, then demonstrated how to install all three wires in an electrical outlet and pull them through the outlet box. Students replicated this action while the teacher circulated the room providing assistance. Students were then shown how to remove their light switch and connect the wires just as they did for the electrical outlet. When a student asked why they needed to do the activity, the teacher's response was that it was a skill they could use to save money by fixing their parent's house or their future house. As the period came to a close students were prompted to clean up their materials and return all tools and wall sections. Teacher 8 briefly described what was planned for the next day and asked if students had any questions about the observed lesson. This teacher had a great rapport with the students and seemed well liked.

Overall, Teacher 8 scored low on the RTOP lesson design and implementation, and student/teacher relationships sections; however, he scored slightly above average on the communicative interactions section. His low rating on the lesson design and implementation section resulted from students following a very prescribed set of steps with no exploration or sharing of ideas among students during the lab. Teacher 8 did use student feedback at the beginning of class to gauge prior knowledge from the previous lesson and provide further explanations where needed. He earned above average ratings in communicative interactions for allowing student input to develop the focus and direction of the beginning portion of the lesson. The lab portion prevented Teacher 8 from receiving higher ratings in this section since students depended on his step-by-step instructions. Low ratings for the last section pertaining to student/teacher relationships were a result of the instructor doing most of the talking as opposed to letting students share their ideas, the teacher serving as a demonstrator of directions rather than a resource that enhances student investigations, and a lack of value placed on generating alternative solutions. This instructor received a total RTOP rating of 47, which was below the mean for all participants (59.4). Specifically in the teaching of science and T&E content and practices, he scored low on science content but was just below the means for science practices and T&E content and practices which is illustrated in the following sections.

Teaching of Science Content

This instructor received a score of six on their science content. The fundamental science content was not the focal point of the lesson, and was briefly mentioned in the review at the beginning of class. He rarely illustrated a solid grasp of science content as he did not discuss many of the targeted concepts nor did he go into detail about them. Teacher 8 confirmed this observation in the interview by describing his discomfort with teaching these science concepts because of his teacher preparation experience outside of T&E education. He did interrelate some targeted content with other concepts to increase its meaning, as seen in his review of the FoT power plant energy conversion slide:

Teacher 8: When we burn coal it creates what kind of energy?

Student S: Heat.

Teacher 8: Heat and what? Coal itself is what kind of energy? Same thing as natural gas.

Student T: Chemical energy?

Teacher 8: It is chemical energy right? When you part it, it gives off what?

Student U: Heat

Teacher 8: Heat energy or thermal energy. Very good. When we burn it what are we heating up?

Student S: Water.

Teacher 8: Water very good. When you heat up water what do you get?

Student T: Steam.

Teacher 8: Steam does what?

Student S: Rises.

Teacher 8: Steam rises to the top and turns the turbines, what energy is that?

Student U: Mechanical energy.

Teacher 8: So the turbines turn and do what?

Student S: Create electricity.

Teacher 8: Very good. So in a nutshell that is how it is done.

Despite presenting some targeted science concepts in that example, he does not use those examples to enrich the science content. He mentions chemical energy and water turning to steam which rises, but he quickly moves on. Discussing how or why these things happen could have interrelated the science and T&E content better and enhanced the meaning of the concepts.

Representing scientific abstractions was rarely encouraged when needed (e.g., transformation of energy, short circuits) and targeted content was rarely supported with authentic applications. The only example of this that was observed during the beginning of class review through a demonstration of potential and kinetic energy using a meter stick:

Teacher 8: So if I take the meter stick back like this what kind of energy is that?

Student V: Kinetic.

Teacher 8: Kinetic energy, but if I stop it what do I have?

Student W: Potential. If I come back down across here what does it have?

Student X: Kinetic.

Teacher 8: Kinetic right because I moved my hand. So when something is sitting it has potential to start moving. It has potential energy.

When asked if he learned this demonstration from his preparation experiences he said, “I probably just came up with that example last year. It's like I said, anything you can do to engage the kids.”

Teaching of Science Practices

This instructor received a score of five for the teaching of science practices. Students only used the wiring activity to represent flow of electrons. The instructor could have used this lab to demonstrate more science practices, such as how to control the resistance by adding a dimmer switch to the circuit. In the lab students were vaguely led to hypothesis what would happen with different variations in the circuit, but they did not have the opportunity to test them. This activity vaguely allowed them to investigate the conversion of chemical energy from a battery to electrical energy in a light; however, there was no thought-provoking assessment of the procedures since they were given detailed instruction on how to wire the components. Students were never reflective in their science practices, which was evident from the conversations the teacher had with them when troubleshooting their circuits. He did not pose any questions that prompted them to think about the science they were practicing. Finally, Teacher 8 sometimes allowed ideas to be presented or challenged but required students to present very little evidence supporting their claims as demonstrated during the circuit activity:

Student Y: How do you spell electrocute?

Teacher 8: Electrocute? Nobody is going to get electrocuted from this.

This presented an opportunity for the instructor to discuss electrocution, why it occurs, and what are some good conductors and insulators of electricity. Additionally he could have explained why humans are good conductors of electricity since they are comprised of mostly water. Conversely, he could have provided an authentic example such a defibrillator to give this concept more meaning. These opportunities provided a chance to enrich the science in the lesson but were overlooked to focus on the wiring of the circuit.

Teaching of T&E Content and Practices

For the T&E content criteria Teacher 8 received a score of 10, and for T&E practices he earned a seven. In regards to content, the lesson had very little focus on targeted T&E fundamental content, with most occurring during the brief energy conversion review at the beginning of class. This instructor sometimes illustrated a solid grasp of the content, more frequently in the technical skills of wiring than in the theory behind electronics. Also, the lesson only vaguely interrelated targeted content with other concepts to sometimes increase its meaning. Abstract T&E content were only sometimes represented in symbolic ways, but did not include any problem solving or design component (e.g., discussed the conversion of coal to electric PowerPoint slide, used a teacher led wiring activity to show electricity). Lastly, only the content about energy sources was connected to authentic applications. No such connections were made with the content from the wiring activity.

The low score for the T&E practices section was due to the fact that the lesson was mainly teacher driven with no design and testing component during the lab, and was a very prescribed activity that did not completely represent T&E phenomena (e.g., manipulating electricity) . Students were vaguely led to state predictions of what would happen with energy sources and their circuits, but did not have to test or troubleshoot these predictions. An example of this occurred during the lab when the instructor gave directions for how to wire a light switch but did not elaborate on the importance of the wire placements:

Teacher 8: Your ground wire is your bare wire with no casing. On the same side as that ground wire is where your white wire is going to go. On the side that is all by itself is where the black wire is going to go.

The teacher did not capitalize on the opportunity to reinforce T&E and science content in this activity. He could have explained that the white and black wires hold a different charge and then elaborated on the reason they should not touch. He could have also explained the importance of the ground wire to discharge extra electrical build up like static electricity. Instead students were left predicting what would happen with no safe means of testing it.

Furthermore, students were engaged in the conversion of energy discussion and wiring activity, but it was not thought-provoking since it only explored electrical circuitry through following step-by-step directions. During the lab the teacher did come around and provide a few prompts to help students minimally reflect on their T&E learning. There were very few instances during the lesson where the teacher allowed the students to present or challenge ideas, and they were never expected to provide evidence.

Summary

This lesson mainly focused on the T&E concepts behind energy transformation and electrical wiring. This was apparent from the focus of the review at the beginning of the class, which included a detailed explanation regarding energy conversion from coal to electricity. There was some disconnect of science content and practices throughout the lesson as shown in the examples. This teacher mentioned some of the targeted science concepts, but did not go into great detail and missed opportunities to explicitly show where they applied during the wiring activity. He attempted to enrich the targeted science content as exemplified with his demonstration and explanation of potential and kinetic energy. The lab was very teacher driven and did not allow opportunities for students to investigate and test science phenomena. This lesson could have been enhanced if it utilized more design-based pedagogical methods to help students explore some of the fundamental science practices through technological applications.

As corroborated in his interview, this instructor demonstrated some uncertainty about teaching science content and practices due to his teacher preparation experience outside of a T&E related field. Despite his discomfort with teaching these concepts he did do an adequate job keeping students engaged during the lesson. One of the challenges this teacher faced was modifying the curriculum to meet his school system's initiative to teach technical skills in T&E education. This teacher posted moderate scores among participants for the teaching of science and T&E content and practices despite graduating from a teacher preparation program outside of these fields. Therefore, analyzing the types of informal and in-service preparation experiences that informed the teaching of science content and practices was needed and tested in the succeeding sections.

APPENDIX P

Full RTOP Classroom Observation Results

Purposeful Sampling Classification	Teacher 3	Teacher 8	Teacher 2	Teacher 4	Teacher 7	Teacher 1	Teacher 6	Teacher 5		
	Novice Low	Novice High	Int. High	Int. High	Vet. Low	Vet. Med	Vet. High	Vet. High		
Question #				***Lesson D&I***					***Avg.***	***Mode***
1	1	2	3	3	2	1	0	3	**1.9**	**3**
2	1	1	4	2	1	1	0	2	**1.5**	**1**
3	0	1	2	2	2	0	0	4	**1.4**	**0**
4	0	0	1	2	1	0	0	3	**0.9**	**0**
5	0	0	2	3	0	0	0	3	**1.0**	**0**
Section Total	**2**	**4**	**12**	**12**	**6**	**2**	**0**	**15**	**6.6**	**2**
Question #				***Sci Content***					***Avg.***	***Mode***
6	1	1	3	3	3	1	1	3	**2.0**	**1**
7	1	2	2	4	3	1	1	4	**2.3**	**1**
8	0	1	2	3	3	1	0	4	**1.8**	**0**
9	0	1	0	3	2	1	0	4	**1.4**	**0**
10	1	1	2	4	3	2	1	4	**2.3**	**1**
Section Total	**3**	**6**	**9**	**17**	**14**	**6**	**3**	**19**	**9.6**	**3**
Question #				***T&E Content***					***Avg.***	***Mode***
11	3	2	4	4	4	1	3	4	**3.1**	**4**
12	1	2	3	4	4	1	2	4	**2.6**	**4**
13	1	2	4	4	4	2	1	4	**2.8**	**4**
14	1	2	2	4	4	1	1	4	**2.4**	**1**
15	1	2	4	4	3	2	2	4	**2.8**	**2**
Section Total	**7**	**10**	**17**	**20**	**19**	**7**	**9**	**20**	**13.6**	**7**
Question #				***Sci Practices***					***Avg.***	***Mode***
16	0	1	0	0	0	0	0	2	**0.4**	**0**
17	0	1	1	2	1	0	0	2	**0.9**	**0**
18	1	1	1	2	1	0	0	4	**1.3**	**1**
19	0	0	2	3	3	0	0	4	**1.5**	**0**
20	0	2	2	3	2	1	1	3	**1.8**	**2**
Section Total	**1**	**5**	**6**	**10**	**7**	**1**	**1**	**15**	**5.8**	**1**
Question #				***T&E Practices***					***Avg.***	***Mode***
21	0	2	2	2	0	0	0	2	**1.0**	**0**
22	0	1	2	3	1	0	1	2	**1.3**	**1**
23	0	1	1	4	1	0	0	4	**1.4**	**0**
24	0	2	4	3	2	0	0	4	**1.9**	**0**
25	1	1	3	4	2	1	1	4	**2.1**	**1**
Section Total	**1**	**7**	**12**	**16**	**6**	**1**	**2**	**16**	**7.6**	**1**
Question #				***Comunicative Interactions***					***Avg.***	***Mode***
26	0	0	1	1	0	0	0	2	**0.5**	**0**
27	0	2	2	3	1	1	0	2	**1.4**	**2**
28	1	2	3	1	1	1	0	4	**1.6**	**1**
29	0	2	3	4	1	0	0	3	**1.6**	**0**
30	2	3	3	4	4	1	1	4	**2.8**	**4**
Section Total	**3**	**9**	**12**	**13**	**7**	**3**	**1**	**15**	**7.9**	**3**
Question #				***Sudent/Teacher Relationship***					***Avg.***	***Mode***
31	1	1	3	2	1	1	0	3	**1.5**	**1**
32	0	0	0	2	1	0	0	3	**0.8**	**0**
33	1	2	3	4	4	1	1	4	**2.5**	**1**
34	0	2	2	3	1	0	0	4	**1.5**	**0**
35	1	1	2	3	3	1	1	4	**2.0**	**1**
Section Total	**3**	**6**	**10**	**14**	**10**	**3**	**2**	**18**	**8.3**	**3**
				Total Score					***Avg.***	***Mode***
	20	**47**	**78**	**102**	**69**	**23**	**18**	**118**	**59.38**	**#N/A**
÷ by max (140)	14%	34%	56%	73%	49%	16%	13%	84%	42%	

APPENDIX Q

Full Spearman's rho Tests Results

Research Question 1

Table 47

Spearman's rho Correlation Table of Demographic Characteristics and Teaching of Science Content

Demographic	r_s	p value
Age	.182	.667
Gender	-.501	.206
Total Years Teaching	.410	.313
Years Teaching FoT	.145	.731
Years Teaching Science	.410	.313
STEBI Self-Efficacy	-.473	.237
STEBI Expected Outcome	-.103	.808
STEBI Total Score	-.370	.367
Path Into Teaching	.083	.845
Current Education Level	-.064	.881
Length of FoT Training	-.668	.070

Research Question 1, Sub Question 1

Table 48

Spearman's rho Correlation Table of Formal Science Preparation Experiences and Teaching of Science Content

Formal Experiences		
High School Course	r_s	p value
Biology	.607	.110
Chemistry	.598	.117
Physics	.798	.018
Earth Science	.317	.445
Total Science Courses	.777	.023
Undergraduate Course	r_s	p value
Physics	.773	.024
Biology	.397	.331
Chemistry	.640	.087
Earth Science	.718	.045
Space Science	-.077	.857
Total Science Courses	.677	.065
Science Methods	.083	.844
Graduate Course	r_s	p value
Physics	.083	.844
Biology	-.319	.442
Chemistry	.083	.844
Earth Science	0	0
Space Science	.584	.128

(continued)

Table 48 Continued

Graduate Course	r_s	p value
Total Science Courses	.118	.780
Science Methods	0	0
Integrating Science in T&E	-.387	.344

Research Question 1, Sub-Question 1

Table 49

Spearman's rho Correlation Table of Informal Science Preparation Experiences and Teaching of Science Content

Informal Experiences		
After School Clubs	r_s	p value
Helped with MESA	0	0
Helped with Odyssey of the Mind	-.167	.693
Helped with None	.718	.045
Professional Development (PD)	r_s	p value
Science Education Readings	-.172	.684
Teach PD Science Course	.347	.400
Science Workshop	.269	.520
Science Summer Institute	.097	.820
Science Conference	.237	.573
Observe Science Ed. Facility	-.473	.236
Serve on Science Committee	.383	.350
Mentor Science Teacher	0	0
Deliver Science In-service	.765	.027
Total Science PD	.301	.468
No Science PD	-.798	.018
Committees and Groups	r_s	p value
Number of Science Committees	.704	.051
Hours Observing Science Ed. Lab	.334	.419
Hours Science Discussion Group	.319	.442
Hours Science Collab. Network	-.185	.661
Hours Meet with Science Ed. Spec.	-.066	.877
Total Hours of Collaborative Science Activity	.530	.176
Conferences	r_s	p value
Science Conference	.510	.197
Mixed Conference Sessions	.570	.140
Teacher Collaborations	r_s	p value
With Physics Teacher	.604	.113
With Chemistry Teacher	.679	.064
With Biology Teacher	.482	.227
With Earth Science Teacher	.330	.425

(continued)

Table 49 Continued

Teacher Collaborations	r_s	p value
With Space Science Teacher	.110	.795
Total Science Teacher Collab.	.333	.420

Research Question 1, Sub-Question 2

Table 50

Spearman's rho Correlation Table of Formal T&E Preparation Experiences and Teaching of Science Content

Formal Experiences		
High School Course	r_s	p value
Industrial Arts	.394	.334
Technology Education	-.397	.331
Degree Type	r_s	p value
B.S. in Industrial Arts	0	0
M.A. in Industrial Arts	.584	.128
Any Type of Degree in IA	.607	.110
B.S. in Technology Education	-.285	.494
M.A. in Technology Education	.584	.128
Any Type of Degree in TE	-.228	.587
Undergraduate Course	r_s	p value
Electronics	.389	.341
Electrical Engineering	-.064	.881
Power, Energy, & Transportation	.110	.795
Biotechnology	-.501	.206
Robotics	.741	.035
Total Elec/Eng/PET Class	.258	.538
Industrial Arts Methods	.654	.079
Technology Education Methods	0	0
Graduate Course	r_s	p value
Electronics	0	0
Electrical Engineering	0	0
Power, Energy, & Transportation	.083	.844
Biotechnology	0	0
Robotics	.584	.128
Total Elec/Eng/PET Class	.083	.844
Industrial Arts Methods	.438	.277
Technology Education Methods	.332	.422

Research Question 1, Sub-Question 2

Table 51

Spearman's rho Correlation Table of Informal T&E Preparation Experiences and Teaching of Science Content

Informal Experiences		
After School Clubs	r_s	p value
Helped with TSA	-.510	.197
Helped with First Robotics	-.501	.206
Helped with Vex Robotics	.083	.844
Helped with Other Robotics	0	0
Helped with Lego League	0	0
Helped with State Engineering Challenges	.083	.844
Helped with Skills USA	0	0
Helped with None	.718	.045
Professional Development (PD)	r_s	p value
T&E Education Readings	-.058	.891
Teach PD T&E Ed. Course	-.104	.806
T&E Education Workshop	-.110	.796
T&E Ed. Summer Institute	.083	.844
T&E Education Conference	-.218	.604
Observe T&E Ed. Facility	-.473	.236
Serve on T&E Ed. Committee	.285	.494
Mentor T&E Ed. Teacher	.765	.027
Deliver T&E Ed. In-service	.883	.004
Total T&E Education PD	-.085	.842
No T&E Education PD	-.501	.206
Committees and Groups	r_s	p value
Number of T&E Ed. Committees	.354	.389
Hours Observing T&E Ed. Lab	.263	.529
Hours T&E Discussion Group	.517	.190
Hours T&E Collab. Network	-.301	.469
Hours Meet with T&E Ed. Spec.	-.165	.469
Total Hours of Collaborative T&E Activity	.084	.843
Conferences	r_s	p value
T&E Conference	-.342	.407
T&E Conference Sessions	-.570	.140
Teacher Collaborations	r_s	p value
With T&E Education Teacher	.633	.092

Research Question 2

Table 52

Spearman's rho Correlation Table of Demographic Characteristics and Teaching of Science Practices

Demographic	r_s	p value
Age	0	1
Gender	-.423	.297
Total Years Teaching	.268	.520
Years Teaching FoT	.245	.558
Years Teaching Science	.415	.306
STEBI Self-Efficacy	-.528	.179
STEBI Expected Outcome	-.270	.624
STEBI Total Score	-.479	.230
Path Into Teaching	.140	.741
Current Education Level	-.207	.624
Length of FoT Training	.803	.016

Research Question 2, Sub-Question 1

Table 53

Spearman's rho Correlation Table of Formal Science Preparation Experiences and Teaching of Science Practices

Formal Experiences		
High School Course	r_s	p value
Biology	.559	.150
Chemistry	.704	.051
Physics	.866	.005
Earth Science	.147	.728
Total Science Courses	.755	.030
Undergraduate Course	r_s	p value
Physics	.783	.022
Biology	.211	.615
Chemistry	.695	.056
Earth Science	.783	.022
Space Science	-.028	.947
Total Science Courses	.543	.164
Science Methods	.085	.842
Graduate Course	r_s	p value
Physics	.085	.842
Biology	-.258	.537
Chemistry	.085	.842
Earth Science	0	0
Space Science	.592	.122

(continued)

Table 53 Continued

Graduate Course	r_s	p value
Total Science Courses	.169	.689
Science Methods	0	0
Integrating Science in T&E	-.447	.267

Research Question 2, Sub-Question 1

Table 54

Spearman's rho Correlation Table of Informal Science Preparation Experiences and Teaching of Science Practices

Informal Experiences		
After School Clubs	r_s	p value
Helped with MESA	0	0
Helped with Odyssey of the Mind	-.423	.297
Helped with None	.783	.022
Professional Development (PD)	r_s	p value
Science Education Readings	-.284	.495
Teach PD Science Course	.351	.393
Science Workshop	.241	.566
Science Summer Institute	.140	.741
Science Conference	.240	.568
Observe Science Ed. Facility	-.351	.393
Serve on Science Committee	.387	.343
Mentor Science Teacher	0	0
Deliver Science In-service	.775	.024
Total Science PD	.268	.520
No Science PD	-.635	.091
Committees and Groups	r_s	p value
Number of Science Committees	.811	.015
Hours Observing Science Ed. Lab	.468	.242
Hours Science Discussion Group	.387	.343
Hours Science Collab. Network	-.323	.436
Hours Meet with Science Ed. Spec.	.027	.950
Total Hours of Collaborative Science Activity	.617	.103
Conferences	r_s	p value
Science Conference	.516	.190
Mixed Conference Sessions	.635	.091
Teacher Collaborations	r_s	p value
With Physics Teacher	.617	.103
With Chemistry Teacher	.537	.170
With Biology Teacher	.321	.439
With Earth Sci Teacher	.183	.664

(continued)

Table 54 Continued

Teacher Collaborations	r_s	p value
With Space Sci Teacher	0	1
Total Science Teacher Collab.	.221	.599

Research Question 2, Sub-Question 2

Table 55

Spearman's rho Correlation Table of Formal T&E Preparation Experiences and Teaching of Science Practices

Formal Experiences		
High School Course	r_s	p value
Industrial Arts	.392	.336
Technology Education	-.296	.477
Degree Type	r_s	p value
B.S. in Industrial Arts	0	0
M.A. in Industrial Arts	.592	.122
Any Type of Degree in IA	.671	.069
B.S. in Technology Education	-.404	.321
M.A. in Technology Education	.592	.122
Any Type of Degree in TE	-.289	.488
Undergraduate Course	r_s	p value
Electronics	.400	.326
Electrical Engineering	0	1
Power, Energy, & Transportation	0	1
Biotechnology	-.423	.297
Robotics	.751	.032
Total Elec/Eng/PET Class	.248	.553
Industrial Arts Methods	.662	.074
Technology Education Methods	-.224	.595
Graduate Course	r_s	p value
Electronics	0	0
Electrical Engineering	0	0
Power, Energy, & Transportation	.085	.842
Biotechnology	0	0
Robotics	.592	.122
Total Elec/Eng/PET Class	.085	.842
Industrial Arts Methods	.493	.214
Technology Education Methods	.310	.455

Research Question 2, Sub-Question 2

Table 56

Spearman's rho Correlation Table of Informal T&E Preparation Experiences and Teaching of Science Practices

Informal Experiences		
After School Clubs	r_s	p value
Helped with TSA	-.645	.084
Helped with First Robotics	-.423	.297
Helped with Vex Robotics	.085	.842
Helped with Other Robotics	0	0
Helped with Lego League	0	0
Helped with State Engineering Challenges	.085	.842
Helped with Skills USA	0	0
Helped with None	.783	.022
Professional Development (PD)	r_s	p value
T&E Education Readings	-.170	.687
Teach PD T&E Ed. Course	-.042	.921
T&E Education Workshop	-.209	.619
T&E Ed. Summer Institute	.085	.842
T&E Education Conference	-.143	.736
Observe T&E Ed. Facility	-.351	.393
Serve on T&E Ed. Committee	.173	.682
Mentor T&E Ed. Teacher	.645	.084
Deliver T&E Ed. In-service	.894	.003
Total T&E Education PD	-.147	.728
No T&E Education PD	-.423	.297
Committees and Groups	r_s	p value
Number of T&E Ed. Committees	.440	.275
Hours Observing T&E Ed. Lab	.234	.577
Hours T&E Discussion Group	.602	.114
Hours T&E Collab. Network	-.273	.513
Hours Meet with T&E Ed. Spec.	-.180	.671
Total Hours of Collaborative T&E Activity	.146	.729
Conferences	r_s	p value
T&E Conference	-.404	.321
T&E Conference Sessions	-.635	.091
Teacher Collaborations	r_s	p value
With T&E Education Teacher	.720	.044