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Applying Reflection and Self-Assessment Practices to Integrative STEM Lessons: A Design-Based Research Study to Develop an Instrument for Elementary Practitioners

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APPLYING REFLECTION AND SELF-ASSESSMENT PRACTICES TO INTEGRATIVE STEM LESSONS: A DESIGN-BASED RESEARCH STUDY TO DEVELOP AN INSTRUMENT FOR ELEMENTARY PRACTITIONERS

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ABSTRACT

APPLYING REFLECTION AND SELF-ASSESSMENT PRACTICES TO INTEGRATIVE STEM LESSONS: A DESIGN-BASED RESEARCH STUDY TO DEVELOP AN INSTRUMENT FOR ELEMENTARY PRACTITIONERS

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This study utilized design-based research (DBR) to develop an empirically substantiated local instruction theory about the use of self-assessment and reflection in creating and assessing integrative STEM lessons. The research goals that guided this study are:

1. Determine the initial STEM self-efficacy level for the study's participants.
2. Utilize theories of reflection and self-assessment to create an instrument for preparing and assessing an integrative STEM lesson.
3. Refine the instrument through two Design-Based Research macro cycles to ensure appropriate content and applicability for use in a K-2 elementary classroom.

A conjectured local instruction theory was developed through the study's literature review. A reflective and self-assessment practice instrument that embodied this local instruction theory was then created. It was conjectured that teachers who undergo self-assessment and reflection are better able to create and assess their integrative STEM lessons. Therefore, the study's instrument was used to guide teachers through self-assessment and reflection of their integrative STEM lessons during their initial planning, active teaching, and post teaching times.

DBR relies on an iterative process where participants of a study assist in the identification of relevant contextual factors while aiding and enriching the researchers' understanding of the intervention itself through continuous cycles of design, enactment, analysis and redesign (Cobb, 2001; Design-Based Research Collective, 2003). This process contributes to how teachers can utilize self-assessment and reflection in creating and assessing integrative STEM lessons. The study's instrument was implemented at the same elementary school for the duration of the study.

Findings indicate that the use of self-assessment and reflection helped study participants create, assess, and even improve their integrative STEM lessons. In addition, study findings appear to indicate improved teacher self-efficacy beliefs upon implementing the study's instrument. A revised local instruction theory is presented as result of the findings from this study in Chapter 4.

Keywords: Reflection, Self-Assessment, Integrative STEM Education, Integrative STEM Lesson Planning, Teacher-Self-Efficacy, Reflection and Self-Assessment Instrument, Design-Based Research, Creating and Assessing Integrative STEM Lessons

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This dissertation is dedicated to my family. Without your love and support, I could not be who I am today. To Tia, who did not live to see the completion of this dissertation, I know you are with me in spirit everyday.

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INTRODUCTION AND LITERATURE REVIEW

Introduction

Today's elementary school classroom is becoming increasingly complex. In conjunction to laying a foundation in traditional academic coursework, elementary teachers are being tasked with building stronger science, technology, engineering, and mathematics foundations and concepts in their students (Nadelson, Callahan, Pyke, Hay, Dance, & Pfiester, 2013). In addition, they contend with increasing pressure to prepare learners with 21st century social and technical skills such as collaboration; communication; information and communication technology (ICT) skills; technological and engineering literacy; social and cultural competency awareness; creativity, critical thinking; and problem-solving abilities (Partnership for 21st Century Skills (P21), n.d; Sanders, 2009; Strimel, 2014; Voogt & Roblin-Pareja, 2010). To ensure they themselves are qualified and prepared to address these growing complexities, teachers will need to develop skills in determining and addressing their own content and instructional needs (McCombs, 1997). Two skills elementary teachers can utilize as a means to this end are reflection and self-assessment.

The greatest benefit of practicing reflection and self-assessment in teaching is that teachers can take personal responsibility for their own professional development and growth process (McCombs, 1997). Reflective practices allow a teacher to observe their instruction through a wider lens, thus allowing him or her to question the quality and effectiveness of their craft. Self-assessment practices allow a teacher to self-diagnose his or her pedagogical and content needs in order to improve these identified areas. When teachers actively engage in these practices, they can better serve their students' learning because teachers are utilizing information gathered from self-monitoring and critical thought to improve or address their own particular content or instructional needs. This is important as research (Stinson, Harkness, Meyer, & Satllworth, 2009; Stohlmann, Roehrig, & Moore, 2012) has shown teachers need to develop knowledge and comfort of their content and pedagogical skills in order to engage in integrative STEM education.

Integrative STEM education can be characterized as an instructional practice, curriculum, or learning theory that purposefully and naturally integrates the disciplines of science, technology, engineering, and mathematics through technological or engineering design problems (Bybee, 2009; Sanders, 2009). Teachers that utilize integrative STEM instruction can provide students with an opportunity to learn through a trans-disciplinary and problem-based learning approach through the application of science, technology, engineering, and mathematics concepts in real-world contexts. This then allows teachers the ability to apply academic rigor in order to bridge classroom learning with global 21^{st} century skills (Laboy-Rush, 2011; Lantz, 2009; Strimel, 2014; Tsupros, Kohler, & Hallinen, 2009). Integrative STEM instruction also provides a teacher the ability to construct a complete, multifaceted experience for student learning by bridging the greater complexities of the STEM disciplines through an integrative method of understanding and application (Lantz, 2009). Therefore, interest in teachers engaging in integrative STEM education at an elementary school level has grown (Epstein & Miller, 2011) because students are provided an opportunity to connect, reinforce, and apply their science, technology, engineering, and mathematics concepts (Rogers & Portsmore, 2004).

Another student advantage is that they are given an opportunity to engage a real-world problem in order to explore its various solutions, hence students can develop an understanding of 21st century problems (Laboy-Rush, 2011; P21, n.d.). Furthermore, students can see their learning as relevant and applicable to the real world (Roberts & Cantu, 2012). In addition, Morrison (2006) found students who learned through this approach are more apt to invent, become more self-reliant, become better problem-solvers, utilize and apply innovation, utilize logical thinking, and they could increase their technological literacy. Therefore, an integrative STEM education classroom can foster the preferred 21st century skills needed in tomorrow's global economy.

To instruct through an integrative STEM educational approach, elementary teachers will need to become skilled in using various instructional approaches while learning to draw from a variety of subjects to address distinct learner needs (Nadleson et al., 2013; Miller & Stewart, 2013, Young, Grant, Montbriand, & Therriault, 2001). They will also need to further develop or improve their integrative STEM lesson planning. Thoughtful and effective lesson plans link classroom activities with desired objectives and discipline standards (Artz et al., 2008). Effective lesson plans also promote purposeful instruction, teacher effectiveness, and allow for students to increase their own learning as lessons are usually developed using logical and sequential events (Artz et al., 2008). Integrative STEM lesson planning requires an elementary teacher to carefully consider integrative instructional approaches; science, technology, engineering, and mathematics content; 21st century skills; and other foundational elementary concepts. Hence, it becomes necessary for elementary teachers to have reflection and self-assessment skills in order to question their own degree of content knowledge and instructional skills (Artz et al., 2008; Boud, 2003; Ross & Bruce, 2007a; Valli 1992) as they will impact learners in the classroom, especially when engaging in integrative STEM practices. Therefore, this study will build upon effective integrative STEM practice by developing a reflective and self-assessment tool elementary teachers can utilize in preparing and assessing integrative STEM lesson materials and instruction.

Literature Review

Overview

The problems facing the 21st century are considered multidisciplinary in nature (Roehrig, Moore, Wang, & Park, 2012). In order to engage these multidisciplinary problems and propose their possible solutions, the integration and application of STEM concepts will be required (Roehrig et al., 2012). Therefore, students should be prepared during their K-12 coursework with integrative STEM concepts. This is particularly important during elementary grades as these STEM foundations are essential in latter grades (Nadelson et al., 2013). Because there are several definitions of STEM education (Breiner, Harkness, & Johnson, 2013; Ostler, 2012; Sanders, 2009) and various approaches to its implementation (Dugger, 2010; Honey, Pearson, & Schweingruber, 2014; Johnson, 2013), the review will begin with a proposed definition of integrative STEM education and integrative STEM instruction.

The next section will explore STEM content and teacher standards. STEM concepts are governed by standards and frameworks that are developed and maintained by various professional organizations such as the National Council of Teachers of Mathematics (NCTM), National Research Council (NRC), National Science Teacher's Association (NSTA), International Technology and Engineering Educators Association

(ITEEA), International Society for Technology in Education (ISTE), and the National Governors Association (NGA) (Barton, 2009). An overview of how STEM content standards evolved and how they relate to integrative STEM education will be provided. Thereafter, a review of the *Interstate Teacher Assessment and Support Consortium's (InTASC) Model Core Teaching Standards* (Chief Council for School Officers, 2013) will show how these teacher standards support integration and 21st century skill development.

The review will then address elementary teacher preparation and teacher self-efficacy. Researchers (Epstein & Miller, 2011; Murphy & Mancini-Samuelson, 2012; Nadelson et al. 2013) assert elementary teachers may have limited background knowledge, efficacy, and confidence for teaching integrative STEM concepts, which can impact student learning. Hence, teacher self-efficacy, elementary teacher preparation, and pedagogical content knowledge (PCK) will also be explored as these factors can contribute to the development of effective STEM lessons and instruction.

The review will conclude with a detailed explanation of lesson planning, reflection, and self-assessment practices. Thoughtful and effective lesson planning is considered a critical component of STEM instruction (Artz et al., 2008). Therefore, benefits and factors to consider while planning thoughtful and effective lessons will be explored. Likewise, teachers often require support or tools to build their teaching capabilities (McCombs, 1997), particularly during integrative STEM instruction (Murphy et al., 2012; Nadleson et al., 2013; Stohlman et al., 2012). Thus, reflection and self-assessment practices will be described. These practices are considered tools that can support teachers in building their instructional and content capacity (Artz et al., 2008; Boud, 2008; McCombs, 1997; Ross & Bruce, 2007a; Zeichner & Liston, 1996).

Integrative STEM Education

The STEM education movement can be attributed to the "Space Age" brought on by the launch of the Russian satellite Sputnik in 1957 (Jolly, 2009; Sanders, 2009). As a result, the nation was inspired to pursue STEM fields of study during the 1950's, 60's, and 70's in order to challenge and surpass Russia's space feats. However, interest has since dwindled as currently, the United States is struggling to garner enough student attention in STEM fields to ensure its ability to meet workforce and economic demands (Honey et al., 2014; NGA, 2011; NRC, 2007; U.S.D.O.E., 1983). Hence, significant attention is being placed on STEM education as a means to prepare 21^{st} century students for a highly competitive global market (Dugger, 2010; Honey et al., 2014; Morrison & Bartlett, 2009).

As a result of this movement, hundreds of STEM-focused schools and thousands of STEM programs have emerged throughout the nation. These schools and programs have uniquely implemented STEM education as they deemed fit since a single unified definition of STEM education has yet to be adopted (Johnson, 2013; Ostler, 2012). Morrison and Bartlett (2006) have defined STEM education as a curricular approach or "meta-discipline" that could mean a "realm of knowledge that speaks to the presentation of technical subjects as they exist in the natural world, part and parcel of each other" (p. 2). Other definitions offer similar notions, yet they extend beyond curriculum. These definitions imply more of a pedagogical approach to learning that can be utilized in the classroom to unify STEM disciplines with instruction (Honey et al., 2014; Laboy-Rush, 2010; Lantz, 2009; Tsupros, Kohler, & Hallinen, 2009).

Integrative STEM education, as an instructional approach, purposefully and naturally integrates the disciplines of science, technology, engineering, and mathematics through student application of technological or engineering design problems (Sanders, 2009; Strimel, 2014). Teachers that utilize an integrative STEM instructional approach have the ability to construct a complete, multifaceted experience in learning by bridging the greater complexities of the STEM disciplines through an integrative method of understanding and application (Lantz, 2009). They can provide students trans-disciplinary learning opportunities through the application of science, technology, engineering, and mathematics concepts while embedding them in real-world contexts. Teachers can then apply academic rigor and discipline standards while promoting student-driven learning in order to connect classroom learning with global 21st century skills (Honey et al., 2014; Laboy-Rush, 2010; Lantz, 2009; Tsupros et al., 2009). Furthermore, the purpose of integrative STEM instruction is to encourage students to think collectively and apply knowledge and skills in a multitude of areas (Roberts, 2013). Hence, for study purposes, integrative STEM education will be defined as an instructional approach that allows teachers the ability to construct a complete, multifaceted experience in learning by naturally and purposefully integrating STEM disciplines through student application of technological or engineering design problems (Lantz, 2009; Sanders, 2009; Strimel, 2014).

Further support for integrative STEM instruction has come from the *Committee on Integrated STEM Education,* formed in 2012, by the National Research Council and National Academy of Engineering (Honey et al., 2014). This committee undertook a charge to determine the best approaches and conditions for STEM education to positively impact K-12 learners. The committee found that an integrative approach that is explicit; provides support for student knowledge in STEM disciplines; and utilizes a measured, strategic approach to implementation of integrated STEM education should be used in the design of integrated STEM education initiatives (Honey et al., 2014). Moreover, the committee provided its endorsement of integrative instruction, as they believed it could influence the natural connections between and among the STEM subjects from which students and teachers could stand to benefit.

Positive outcomes can result from engaging in this type of learning and instruction. For example, positive student outcomes can include improved learning and achievement; 21st century competency gains; interest in STEM course-taking, educational persistence, and improved graduation rates; STEM-related employment; STEM interest, development of STEM identity; and the ability to transfer understanding across STEM disciplines (Honey et al., 2014; Morrison, 2006). Positive teacher outcomes include ease in modifying teaching practices; increased STEM content and pedagogical content knowledge, and improved teacher confidence (Honey et al., 2014, p. 39; Stohlman et al., 2012). Thus an elementary teacher must consider STEM disciplines, their standards, and in-service teacher guidelines that will play a definitive role in integrative STEM lesson planning and instruction.

The Standards Movement

In the late 20th century, standards arose as a means to reform education in the United States. One of the first calls for reform came in 1983 when the United States Department of Education (U.S.D.O.E.) (1983) released *A Nation at Risk: The Imperative for Educational Reform.* It stated, "Our nation is at risk...the educational foundations of our society are presently being eroded by a rising tide of mediocrity that threatens our very future as a Nation and a people" (U.S.D.O.E., 1983, p. 9). The report claimed the United States was losing its "preeminence in commerce, industry, science, and technological innovation" (U.S.D.O.E., 1983, p. 9). The report sent ripples through the U.S. educational system as it raised concerns the United States was not doing enough to promote interest in STEM fields of study. It further urged policymakers to undertake prompt educational reform.

Concurrently, the scientific community authored a report of their own. The *American Association for Advancement of Science* (AAAS) program, or *Project 2061,* sought to identify knowledge and skills were most essential for the next generation of learners to know and be able to do in science, mathematics, and technology (AAAS, 1990). The report called for increased attention and further development of student scientific literacy. The AAAS (1990) described scientific literacy as a necessary development of scientific habits of mind that utilize scientific, technological, and mathematical skills in order to help people deal with global problems and situations. Furthermore, the report also endorsed educational reform as the AAAS (1990) felt there was a strong connection between the health of the United States' economic standing and that of a high quality and well distributed educational system.

These reports, coupled with only modest gains in National Assessment of Educational Progress student assessments (Alvarado, 1994), drew additional attention to the United States' ailing educational system. Consequently, many professional teacher and discipline organizations began to question how they could improve educational efforts in their fields (Barton, 2009). These organizations turned to the development of content standards as they believed standards could promote rigor, relevance, and interest in the fields such as science, technology, engineering, and mathematics. Furthermore, educational legislation appeared and fueled support for content standards and standardized testing. Examples of this legislation include President Clinton's *Goal 2000* in 1994 which proposed the creation of voluntary national tests in fourth-grade reading and eighth-grade mathematics, the amendments to the *Elementary and Secondary Education Act* in 1994 that required states to establish content standard tests, and *No Child Left Behind* in 2001 which took previous legislation further and demanded "proficiency" among students for teacher accountability (Barton, 2009). Organizations such as the National Council of Teachers of Mathematics (NCTM, 2000), National Science Teacher's Association (NGSS Lead States, 2013), International Technology Education Association (ITEA, 2000), and the International Society for Technology in Education (ISTE) (2012) began to heed the call and began to determine what was most critical for students to learn in their particular discipline (Barton, 2009).

The nation began to embrace these new emerging standards and frameworks. However, there was concern individual states were forming their own interpretation of these content standards (NGA, 2011), thus yielding an uneven learning field for students across the nation. This concern led the National Governors Association (NGA) and the Council of Chief State Officers (CCSO) to propose a common set of standards (Common Core, 2014). In 2010, the *Common Core Standards* in English Language Arts and Mathematics were released and signaled a national push toward unified standardization of learning. To date, all but five states have joined the *Common Core Standards* movement (Common Core, 2014).

These various organizations believed standards would create in-depth and meaningful learning of their respective disciplines (NCTM, 2000). Furthermore, standards documents and frameworks were seen to provide teachers with the necessary guidance to incorporate the desired content knowledge and skills needed in their K-12 classrooms (Barton, 2009). Table 1 provides a chronological overview of STEM and Common Core documents, standards, and release dates.

Table 1.

Chronological STEM Standard Documents, Frameworks, and Release Dates

	Professional Organization, Release Date, & Document Title	STEM Education Highlights
Mathematics	National Council of Teacher's of Mathematics (NCTM) released: • 1989, *Curriculum and Evaluation Standards for School Mathematics* • 1991, *Professional Teaching Standards for School Mathematics,* • 1995, *Assessment Standards* • 2000, *Principals and Standards for School Mathematics* • 2007, *Mathematics Teaching Today* (Source: NCTM, 2014)	"The underpinnings of everyday life are increasingly mathematical and technological" and "although all careers require a foundation of mathematical knowledge, some are mathematics intensive. More students must pursue an educational path that will prepare them for lifelong work as mathematicians, statisticians, engineers, and scientists" (NCTM, 2000, p. 3)
Science	National Science Teacher's Association (NSTA) released: • 1992, *Content Core/Scope, Sequence, and Coordination of National Science Education Content Standards,* American Association for the Advancement of Science (AAAS) released: • 1993, *Benchmarks for Scientific Literacy* National Research Council (NRC) released: • 1996, *National Science Education Science Standards* • 2000, *National Science Education Science Standards* NGSS Lead States released: • 2013, *Next Generation Science Standards* (Source: NGSS Lead States, 2013)	"The world has changed dramatically in the 15 years since state science education standards' guiding documents were developed. Since that time, many advances have occurred in the fields of science and science education, as well as in the innovation-driven economy. The U.S. has a leaky K–12 science, technology, engineering and mathematics (STEM) talent pipeline, with too few students entering STEM majors and careers at every level—from those with relevant postsecondary certificates to PhD's. We need new science standards that stimulate and build interest in STEM" (NGSS Lead States, 2013, p. 11).

Table 1 (Continued).

Chronological STEM Standard Documents, Frameworks, and Release Dates

	Professional Organization, Release Date, & Document Title	STEM Education Highlights
Technology	International Technology Educators Association (now known as the International Technology and Engineering Educators Association (ITEEA)): • 1996, *Technology for All Americans* • 2000, *Standards for Technological Literacy* (Source: ITEA, 1996, 2000) International Society for Technology in Education (ISTE): • 1998, *National Educational Standards* (NETS) • 2007, *ISTE Standards for Students (Formerly NETS)* • 2000, 2008, *Technology Standards for All Teachers (NETS for Teachers)* (Source ISTE, 2012)	"When taught effectively, technology is not simply one more field of study seeking admission to an already crowded curriculum, pushing others out of the way. Instead, it reinforces and complements the material that students learn in other classes" (ITEA, 2000, p.6)
Engineering	Although standards have been discussed for engineering education, no standards have been written to date (National Academy of Engineering, 2010; Honey et al., 2014).	
Common Core	Chief Council of School Officers and National Governors Association: • 2010, *Common Core State Standards (Mathematics and English Language Arts)* (Source, Common Core, 2014)	"For years, the academic progress of our nation's students has been stagnant, and we have lost ground to our international peers. Particularly in subjects such as math, college remediation rates have been high. One root cause has been an uneven patchwork of academic standards that vary from state to state and do not agree on what students should know and be able to do at each grade level" (Common Core, 2014).

Note: The above table depicts a content standard release dates (in chronological order) of STEM disciplines and Common Core standards. In addition, the table describes how these disciplines are addressing integration and student learning.

In-Service Practitioner Guidelines: The Interstate Teacher Assessment and Support Consortium (inTASC) Model Core Teaching Standards

The release of content standards drew increased attention to teacher classroom practices. Hence, the Council of Chief State School Officers, or CCSO (2013), began to question what they could do to help reform teaching practices. They worked under the premise that an effective teacher should be able understand students' strengths and weaknesses while integrating content knowledge to meet their specific needs (CCSO, 2013). This belief led to the creation of the *Interstate Teacher Assessment and Support Consortium* (InTASC) whose goal would be to help transform and improve teacher preparation, licensing, and teacher professional development.

The CCSO and InTASC authored a set of practitioner standards entitled *Interstate Teacher Assessment and Support Consortium's (InTASC) Model Core Teaching Standards: A Resource for State Dialogue* in 2011 (CCSO, 2013). According to InTASC, these standards "outline what teachers should know and be able to do to ensure every PK-12 student reaches the goal of being ready to enter college or the workforce in today's world" (CCSO, 2013, p. 3). They are divided into four distinct categories: The Learner and Learning, Content, Instructional Practice, and Professional Responsibility (CCSO, 2013). The standards are written in a three-level progression (novice to mastery) that allows teachers the ability to grow and develop in their craft. They are further detailed in Table 2.

These standards call for teachers to develop and promote several qualities in their instruction that also aligns with the development of 21st century skills and integrative STEM instruction. For example, Standards 3, 4, 5, 6, and 7 detail 21st century characteristics such as collaboration, problem-solving, and social and cultural awareness contexts. Standard 8 promotes integrative instructional practices in which teachers utilize cross-curricular approaches to develop students' deep understanding of content areas and their connections (CCSO, 2013). Table 3 provides a side-by-side comparison of InTASC (2013) standards that align with STEM education and 21st century skills.

Table 2.

Interstate Teacher Assessment and Support Consortium's Model Core Teaching Standards

Standard		Description
Learner and Learning	1	*Learner Development*: The teacher understands how learners grow and develop, recognizing that patterns of learning and development vary individually within and across the cognitive, linguistic, social, emotional, and physical areas, and designs and implements developmentally appropriate and challenging learning experiences.
	2	*Learning Differences*: The teacher uses understanding of individual differences and diverse cultures and communities to ensure inclusive learning environments that enable each learner to meet high standards.
	3	*Learning Environments*: The teacher works with others to create environments that support individual and collaborative learning, and that encourage positive social interaction, active engagement in learning, and self-motivation.
Content	4	*Content Knowledge*: The teacher understands the central concepts, tools of inquiry, and structures of the discipline(s) he or she teaches and creates learning experiences that make the discipline accessible and meaningful for learners to assure mastery of the content.
	5	*Application of Content*: The teacher understands how to connect concepts and use differing perspectives to engage learners in critical thinking, creativity, and collaborative problem solving related to authentic local and global issues.
Instructional Practice	6	*Assessment*: The teacher understands and uses multiple methods of assessment to engage learners in their own growth, to monitor learner progress, and to guide the teacher's and learner's decision making.
	7	*Planning for Instruction*: The teacher plans instruction that supports every student in meeting rigorous learning goals by drawing upon knowledge of content areas, curriculum, cross-disciplinary skills, and pedagogy, as well as knowledge of learners and the community context.
	8	*Instructional Strategies*: The teacher understands and uses a variety of instructional strategies to encourage learners to develop deep understanding of content areas and their connections, and to build skills to apply knowledge in meaningful ways
Professional Responsibility	9	*Professional Learning and Ethical Practice*: The teacher engages in ongoing professional learning and uses evidence to continually evaluate his/her practice, particularly the effects of his/her choices and actions on others (learners, families, other professionals, and the community), and adapts practice to meet the needs of each learner.
	10	*Leadership and Collaboration*: The teacher seeks appropriate leadership roles and opportunities to take responsibility for student learning, to collaborate with learners, families, colleagues, other school professionals, and community members to ensure learner growth, and to advance the profession.

Note: Adopted from the *Interstate Teacher Assessment and Support Consortium's (InTASC) Model Core Teaching Standards: A Resource for State Dialogue* (CCSO, 2013, p. 8-9).

Table 3.

STEM Education Characteristics and InTASC Standards Alignment

STEM & 21st Century Characteristics	**InTASC Standard (CCSO, 2013)**
Creates and promotes a collaborative learning environment (Roberts 2013). Students are self-motivated to solve real-world problems (Johnson, 2013).	*Standard 3 - Learning Environments*: The teacher works with others to create environments that support individual and collaborative learning, and that encourage positive social interaction, active engagement in learning, and self-motivation.
Teachers are able to apply academic rigor in order to bridge classroom learning with global 21st century skills while fostering creativity, innovation, and problem-solving skills context (Lantz, 2009; Strimel, 2014; Tsupros et al., 2009; Partnership for 21st Century Skills, n.d.).	*Standard 4 - Content Knowledge*: The teacher understands the central concepts, tools of inquiry, and structures of the discipline(s) he or she teaches and creates learning experiences that make the discipline accessible and meaningful for learners to assure mastery of the content. *Standard 5 - Application of Content*: The teacher understands how to connect concepts and use differing perspectives to engage learners in critical thinking, creativity, and collaborative problem solving related to authentic local and global issues. *Standard 6 - Assessment*: The teacher understands and uses multiple methods of assessment to engage learners in their own growth, to monitor learner progress, and to guide the teachers and learner's decision making.
Students are encouraged to engage a problem in order to find its solution through a real-world context (Lantz, 2009; Sanders, 2009; Strimel, 2014; Tsupros et al., 2009 Partnership for 21st Century Skills, n.d.).	*Standard 7 - Planning for Instruction*: The teacher plans instruction that supports every student in meeting rigorous learning goals by drawing upon knowledge of content areas, curriculum, cross-disciplinary skills, and pedagogy, as well as knowledge of learners and the community context.
Promotes integrative application of STEM disciplines (Lantz, 2009; Sanders, 2009; Strimel, 2014; Tsupros et al., 2009)	*Standard 8 - Instructional Strategies*: The teacher understands and uses a variety of instructional strategies to encourage learners to develop deep understanding of content areas and their connections, and to build skills to apply knowledge in meaningful ways

Note: This table illustrates integrative STEM education and 21st century skills that align *InTASC's Model Core Teaching Standards: A Resource for State Dialogue* (2013) practitioner requirements.

The CCSO (2013) promotes the teaching of 21st century skills in order to ensure students are properly prepared to face a global workforce and for learning beyond K-12 education. Accordingly, they emphasize the need for a practitioner to learn how to properly instruct 21st century skills in order to create a successful 21st century learning environment for students.

Balancing STEM Standards in the Classroom

Content STEM standards, such as the *Common Core State Standards* (Common Core, 2013), *Next Generation Science Standards* (NGSS Lead States, 2013), *Standards for Technological Literacy* (ITEA, 2000), and *Principles and Standards for School Mathematics* (NCTM, 2000), have been written with interdisciplinary intentions (Johnson, 2013). Yet, there are concerns some teachers may still find it difficult to align and create interdisciplinary lessons such as those required in an integrative STEM approach (Bybee, 2010; Johnson, 2013; Williams, 2011),

This is evident when we observe the current level of technology and engineering instruction (Bybee, 2009). Bybee claims K-12 technology and engineering instruction is low, which could be a challenge to advancing integrative STEM education. Williams (2011) supports this assertion and states when STEM subjects are integrated, particularly at an elementary level, technology and engineering instruction is less prevalent than science and mathematics instruction.

Another concern is whether a teacher has developed or mastered the skills necessary to teach through an integrative STEM approach (Johnson, 2013). An integrative STEM approach requires a teacher to understand and implement integrative instructional practices and STEM content (Johnson, 2013; Stohlman et al., 2012). Hence, teachers will need to develop an understanding of how to properly align and integrate STEM standards while balancing integrative pedagogy (Becker & Park, 2013). Other factors that contribute to a teacher's ability to create quality integrative lessons and instruction include teacher self-efficacy and pedagogical content knowledge (Becker & Park, 2013).

Teacher Self-Efficacy

Teacher self-efficacy is a critical factor to the success of integrating STEM education in a classroom (Stohlmann et al., 2012). Teacher self-efficacy is defined as a teacher's beliefs regarding their capability to produce desired student learning outcomes (Goddard, Hoy, & Woolfolk-Hoy, 2000; Ross & Bruce, 2007a; Stohlmann et al., 2012). It is specific to particular subjects, students, and contexts (Goddard et al., 2000; Ross & Bruce, 2007a).

Teacher self-efficacy can be traced back to the work of Dewey, Rotter, and studies conducted by the RAND Corporation in the 1950's (Goddard et al., 2000; Ross & Bruce, 2007a). In 1977, Albert Bandura further added to the theory. Bandura (1977) believed teacher self-efficacy is an extension of self-efficacy; it is a cognitive process in which people are either positively or negatively affected by their perception of their ability to perform on a certain task. Bandura further postulated teachers' self-beliefs are affected by factors such as resilience, persistence, and personal response to stress in certain situations.

In a randomized field trial to determine the effects of professional development on teacher self-efficacy of 106 grade six teachers, Ross and Bruce (2007b) found teacher self-efficacy can be positively affected. They state, "teachers who believe they will be successful set higher goals for themselves and their students, try harder to achieve those goals, and persist through obstacles. Individuals who believe they will fail avoid expending effort because failure after trying hard threatens self-esteem" (p. 3). Another key finding of the study redefined teacher conceptions of success, "emphasizing that student knowledge construction is the prime criterion for appraising teacher success" (p.18). Therefore, teachers with high self-efficacy are more likely to undertake teaching innovations despite challenges that may arise in the classroom, use classroom management skills that encourage autonomous learning, differentiate instruction for diverse student needs, manage classroom problems as they arise, and keep students on task (Caprara et al., 2006; Ross & Bruce, 2007a).

Teacher self-efficacy can directly impact student learning (Caprara, Barbaranelli, Steca, & Malone, 2006) and is linked to the development of student self-efficacy (Ross & Bruce, 2007b; Ross, McKeiver, and Hogaboam-Gray, 1997). Ross, McKeiver, and Hogaboam-Gray (1997) showed the negative effects of low teacher self-efficacy on students. The researchers followed four exemplary mathematics teachers over a year as they implemented a district-required initiative. The teachers initially felt confident in their ability to teach mathematic concepts to students who were segregated by mathematics ability. However, when ability groups were mixed, teacher self-efficacy declined and student learning was hindered.

As teachers modify their behavior based on their own self-efficacy, a student's perception about his or her ability can change (Ross & Bruce, 2007b). Therefore, a teacher with high self-efficacy has the ability to foster a student with high self-efficacy of his or her own. These students are enthusiastic learners and are more willing to work with the teacher as they feel confident about their learning, which are processes that can positively impact their achievement (Ross & Bruce, 2007b).

Pedagogical Content Knowledge

Content and pedagogical knowledge is also linked to teacher self-efficacy (Hill, Rowan, Ball, 2005; Lamberg, 2009, Stohlmann et al., 2012). Shulman first introduced

Pedagogical Content Knowledge, or *PCK,* in 1986. Shulman believed that traditional teacher education either emphasized pedagogical skills or content knowledge. In his 1986 article, *Those Who Understand, Knowledge Growth in Teaching*, Shulman presented the idea that teachers should be balanced in their pedagogy and content knowledge. In addition, Shulman wanted to explore how knowledge grows in a teacher's mind. He proposed three categories of knowledge: subject matter content knowledge, pedagogical knowledge, and curricular knowledge. Figure 1 illustrates Shulman's vision of PCK.

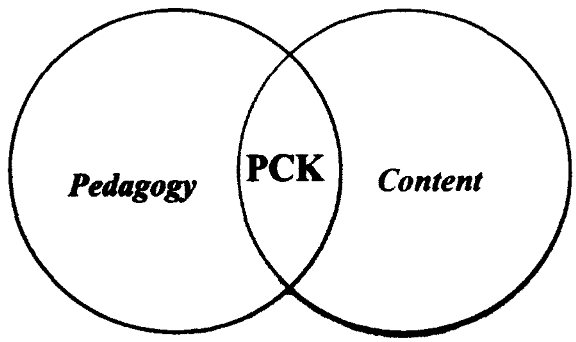

Figure 1. Pedagogical Content Knowledge. This figure illustrates pedagogical content knowledge, as theorized by Shulman in 1986. Ideally, a teacher should be balanced in their pedagogical and content knowledge.

The content knowledge domain is described as the amount and organization of knowledge within a teacher's mind. This requires a teacher to think beyond simple concepts and facts. It also requires an understanding of the actual structures of the particular subject matter. Ideally, a teacher would be able to define and move past "*accepted truths*" of a domain, which are those conjectures believed to be foundational in a content area. They should then be able to explain how a particular idea works in theory or practice. Shulman states, "the teacher must not only understand *that* something is so; the teacher must further understand *why* it is" (p. 9).

Pedagogical knowledge goes beyond simple subject knowledge. Shulman (1986) believed it encompassed subject matter *for* teaching. Thus, included in this domain are the classroom strategies or the ways a teacher represents and formulates the subject to make it comprehensible for students. It also includes understanding appropriate age-level development in order to ensure a student is learning the subject matter. Curricular knowledge is a domain Shulman (1986) believes is remiss from teacher education and is vital to pedagogical knowledge. This knowledge domain refers to a teacher's ability to relate the content of a subject simultaneously to other subjects. Thus, the teacher understands how to properly utilize the curriculum. Shulman (1986) believed a teacher should not only "be a master of procedure, but also of content and rationale, and capable of explaining why something is done" (p. 13).

Mishra and Koehler (2006) further expounded Shulman's PCK theory with a new knowledge domain: technological knowledge (TPACK). They believe various technological advancements have evolved the classroom and consequently, teachers are now required to use technology as part of their pedagogy and subject matter content. Furthermore, Harris, Mishra, and Koehler (2009) assert new activities and learning taxonomies should be utilized to address technological advancements as teachers will need to look at content and instruction in different ways. Thus, as technology and its products are integrated into classroom environments, technological knowledge will need to be developed (Crompton, 2011; Crompton, Goodhand, & Wells, 2011; Harris, Mishra, & Koehler, 2009; Manouchehri & Enderson, 2004). According to Voogt and Roblin-Pareja (2010), information and communication technology literacy is a desired 21st century skill. Hence, an integrative STEM educational approach should require students and teachers to utilize various instructional technologies to support research, delivery, application, projects, and lessons (Bybee, 2009). Figure 2 illustrates technology as the third domain in PCK.

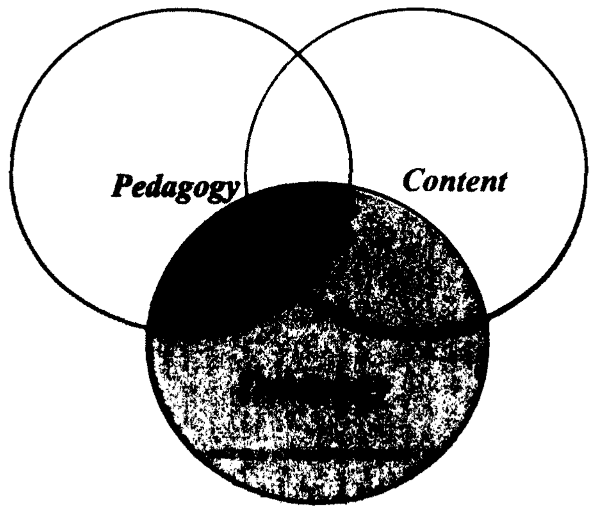

Figure 2. Technological, Pedagogical, and Content Knowledge (TPACK). This figure illustrates technological pedagogical content knowledge, as theorized by Mishra and Kohler in 2006.

According to Williams and Lockley (2012), considerations for the differences in the nature of each discipline are important. Furthermore, they posit that TPACK development is unique to each teacher and should be fostered throughout an individual's career (Williams & Lockley, 2012). As a result, TPACK will vary greatly from teacher to teacher. A thorough understanding of pedagogy, content, and technological knowledge coupled with an understanding of teacher self-efficacy is an important consideration for STEM education to achieve its full potential.

Elementary Teacher Preparation and STEM Education

STEM education is taking root in elementary school settings as a result of increased attention being drawn to acquiring necessary STEM knowledge and skills at an earlier age (Bybee & Fuchs, 2006; DeJarnette, 2012; Nadelson et al., 2012). Hence, elementary school administrators are emphasizing the need to utilize STEM educational initiatives to their teachers. In a mixed-methods study conducted by Cantu (2011) on elementary-level STEM perceptions, 73 elementary administrators were asked to what degree they supported STEM integration in their schools. The administrators responded that they highly support STEM integration and STEM-related training in their schools as they felt it was necessary to prepare students with the necessary 21st century skills. Yet, research has shown that elementary teachers often avoid teaching science (Bencze, 2010; Lee & Houseal, 2003), technology and engineering (Brophy, Klein, Portsmore, & Rogers 2008; Yaşar, Baker, Robinson-Kurpius, Krause, & Roberts, 2013), and mathematics (Ball, 1990; Hill, Rowan, & Ball, 2005; Ma, 1999). Some believe (viz., Epstein & Miller, 2012; Murphy, 2011; Nadelson et al., 2013) this is due to minimal pre-licensure STEM coursework requirements. Unlike middle and high school teachers who earn a degree in a specialization area such as science, technology, engineering, or mathematics education, elementary teachers often receive a bachelor's degree in education or interdisciplinary studies (Epstein & Miller, 2012; Murphy, 2011). This distinct type of training differentiation provides middle and high school teachers with deep, content-rich knowledge and leaves elementary teachers with a need to further develop their own STEM pedagogical content knowledge (Stinson et al., 2009; Stohlman et al., 2012).

Ongoing, professional development can be a way to increase a teacher's STEM pedagogical content knowledge. Nadleson et al. (2012) assert a "teachers' knowledge of STEM subject matter and their effectiveness in teaching STEM is justification for providing professional development designed to increase content knowledge of STEM" (p. 71). Yet, the National Science Foundation (2010) has provided evidence that participation in professional development by elementary school teachers in mathematics and science was not as common as participation by middle and high school teachers. Technology and engineering instruction and professional development is no different.

Findings of Yaşar et al.'s (2013) study revealed that in-service teachers believed to a strong degree that design, technology, and engineering (DET) should be implemented into the curriculum. These findings are noteworthy, particularly to this study, because teachers found value in what DET can offer K-12 students. Yet, Yaşar et also found in their study that most elementary teachers place little importance on instruction utilizing design, technology, and engineering concepts. Brophy et al. (2008) suggest this is because they lack the background and experience to converse with their students about engineering and technology concepts, and they cannot anticipate the difficulties learners will demonstrate during the design process.

The National Science Board (NSB) (2010b) recommends "support [for] rigorous, research-based STEM preparation for teachers, particularly general education teachers, who have the most contact with potential STEM innovators at young ages" (NSB, 2010b, p. 2). Furthermore, Johnson (2013) emphasizes that an integrative STEM approach will be necessary in today's multifaceted world and consequently, students will have to utilize multidisciplinary skills to solve societal problems. Therefore, an elementary teacher must be fully prepared to draw from STEM disciplines, their standards, and to utilize a STEM integrative approach if they are to enhance student learning outcomes in today's multifaceted world (Berry, Reed, Ritz, Lin, Hsuing, & Frasier, 2005; Johnson, 2013).

Other Factors to Consider in Creating a STEM Elementary Classroom

STEM education requires a particular type of classroom environment in order to establish effective integrative STEM learning (Berry et al., 2005). Integrative STEM lessons and activities endorse authentic student-driven, exploratory, and collaborative learning environments (Dugger, 2010; Sanders, 2009; Morrison & Bartlett, 2009). However, engaging in these types of learning environment may require additional time and consideration by an elementary teacher (Reeve, 2006; Kolodner, 2002).

Authentic learning approaches can be beneficial to student learning because they better align with the methods students' use to process information into useful, transferable knowledge (Lombardi, 2007, p.7). However, authentic learning environments can be difficult for some teachers to promote (Lombardi, 2007). This is because it may be customary for teachers to instruct the individual STEM subjects in silos through teacher-led instruction. Lombardi (2007) has found students prefer to *do* rather than just listen to teacher instruction. Consequently, Lombardi asserts students should be given ample opportunity to engage real-world problems in order to formulate solutions of their own as students stand to bridge their learning of classroom concepts to real-world applications.

Autonomous learning environments are another classroom characteristic to consider in the success of integrative STEM education. Students should be allowed to understand what it feels like to be a stakeholder beyond the classroom (Lombardi, 2007; Reeve, 2006). Hence, students must be given opportunities to drive their own learning as "the goal is to give learners the confidence that comes with being recognized as "legitimate peripheral participants" in a community of practice" (Lombardi, 2007, p. 10).

Successful autonomous student learning requires a teacher to actively encourage this particular type of learning in their classroom (Ames, 1992; Ames & Archer, 1988, Reeve, 2006). According to Reeve (2006), students who are nurtured and supported in an autonomous learning environment exhibit many positive learning educational outcomes. These outcomes are described in Table 4.

Table 4.

Positive Learning Outcomes of Engaging Students in Autonomous Learning Environments

Positive Learning Outcomes of Engaging Students in Autonomous Learning Environments			
1.	Increased perceived confidence	2.	Higher mastery motivation
3.	Enhanced creativity	4.	Preference for challenging tasks over easy success
5.	Increased conceptual understanding	6.	Active and deeper information processing
7.	Greater enjoyment	8.	Positive emotionality
9.	Higher intrinsic motivation	10.	Enhanced well-being
11.	Better academic performance	12.	Academic persistence

Note: According to Reeve (2006), students stand to benefit when a teacher creates an autonomous learning environment in their classroom.

An integrative STEM approach will also require a teacher to utilize exploratory and problem-based learning methodologies (Dugger, 2010; Sanders, 2009; Morrison & Bartlett, 2009). Problem-based and exploratory learning involve an iterative process in which students collaborate, research, and select their best approach to solving a proposed problem (Kolodner, 2002; Laboy-Rush 2011). The proposed solution will be unique to each student, hence it will require a teacher to leverage classroom resources such as time, organization, and collaboration opportunities for students to actively engage the problem (Lombardi, 2007). Nonetheless, this kind of learning may be in direct conflict with the teacher's classroom routine (Reeve, 2006). If these types of learning approaches buttress existing classroom rules and practices, it may impede students' active nature and autonomous attempts (Reeve, 2006).

Managing this kind of classroom may prove to be difficult if not properly established from the beginning. Kolodner (2002) suggests given foundational rules and guidelines for their classroom designs and projects; and if these rules are enforced and practiced; the students will begin to enforce these boundaries themselves and an environment is set for "sustaining a culture that values rigor" (para. 67). Nonetheless, a teacher can hinder learning if they ask students to adhere to a strict instructional agenda that alienates students from undergoing a student-driven problem-based and exploratory approach (Reeve, 2006).

An integrative STEM education classroom will require a teacher to consider authentic, student-driven, exploratory, and problem-based learning environments. Thus, elementary teachers will need skills they can utilize to carefully view their STEM lessons and instruction from a wider perspective. Reflection and self-assessment are examples of such skills, as they can provide teachers with a discerning lens to determine if they are creating a conducive, STEM education environment.

Importance of Lesson Planning

In practice, teaching is considered a two-fold process (Johnson, 2000). First, teachers must link curriculum with instruction. Second, they must know, plan, do, and reflect on the effectiveness of their instruction. Johnson (2000) suggests teaching is a linear process: *Teaching = Knowing + Planning + Doing + Reflecting* (para. 2). Yet, Hunt, Wiseman, and Touzel (2009) assert this equation is further complicated as teachers today face a formidable teaching task: they must take new and evolving curricula and transform it into effective and rigorous learning activities for their students. In addition, teachers must also consider a plethora of content standards, assessment requirements, learner groups, ability levels, and learning styles during their planning and instruction (Hunt et al., 2009). According to Johnson (2000), *knowing* and *planning* are two critical steps to achieving effective teaching.

The *knowing*, or PCK, is a vital component of teaching as practitioners are drawing from their own knowledge base for the purpose of educating their students (Artz et al., 2008; Shulman, 1986). A teacher's PCK is developed during their initial licensing coursework and continues to be developed during professional development endeavors (Nadleson et al., 2012; Stohlmann et al., 2012). *Planning* is a culmination of linking a teacher's PCK (or *knowing*) to the desired instructional activities (Artz et al., 2008) in order to address a set of required content standards and to promote the desired student objectives (Hunt et al., 2009). The artifact produced from linking *knowing* and *planning* is a lesson plan. Artz et al. (2008) describe a lesson plan as the "concrete embodiment of the teacher's thinking regarding the instructional activities to be enacted in the classroom" (p. 21). Hence, a thoughtful and well-designed lesson plan can translate into effective classroom instruction in which clarity and varied instruction meets learner needs (Borich, 2007).

Thoughtful lesson plans are beneficial to both teachers and students. They help to establish logical and sequential instruction (Artz et al., 2008; Brophy, 1986; Clark & Peterson, 1986; Freiberg & Driscol 1992) and thus, help students achieve the desired instructional objectives set by the teacher (Artz et al., 2008; Parker & Jarolimick, 1997). Furthermore, a teacher can undertake complex learning activities that appeal to a student's natural curiosity (Artz et al., 2008; Borich, 2007; Freiberg and Driscol, 1992; Johnson, 2000) if plans are well structured allowing them to feel more confident about their instruction (Clark & Dunn, 1991; Freiberg & Driscol 1992). Additional teacher and student benefits can be seen in Table 5.

Table 5

Benefits of Creating Effective Lesson Plans

Proposed Benefit	Sources
Allows for purposeful instruction	Freiberg and Driscol (1992)
Enhances teacher effectiveness	Artz et al. (2008); Freiberg and Driscol, (1992); Hunter et al., (2009); Parker and Jarolimick (1997)
Highlights content knowledge needed for development effective lessons	Artz et al. (2008); Clark and Dunn (1991)
Improves teacher confidence	Clark and Dunn (1991); Freiberg and Driscol (1992)
Encourages teachers to incorporate new instructional strategies	Artz et al. (2008)
Links classroom activities to desired instructional objectives	Artz et al. (2008); Parker and Jarolimick (1997)
Facilitates a logical sequence of learning events	Artz et al. (2008); Brophy (1986); Clark and Peterson (1986); Freiberg and Driscol (1992)
Utilizes more complex learning activities	Artz et al. (2008)
Enhances student learning	Artz et al. (2008); Johnson (2000)
Maximizes student involvement	Artz et al. (2008)
Students are better able to extend their own learning	Artz et al. (2008); Freiberg and Driscol (1992)

Note: This table describes benefits of developing an effective lesson plan for both a teacher and a student. Sources indicating these benefits are listed in the right-hand column.

Components to Consider in a STEM Lesson Plan

Lesson plan development is a complex activity that requires careful thought and organization in order to create effective learning experiences for students. When considering PCK, teacher self-efficacy, STEM education, STEM integration, and content standards, it becomes evident that a teacher needs to not take the process of creating thoughtful lesson plans lightly. This is particularly important during the creation of integrative STEM lesson plans, as teachers will need to properly identify and utilize various components (Honey et al., 2014).

Swift and Watkins (2004) proffer elementary STEM lessons should be designed to meet teacher expectations and learning characteristics of students. Furthermore, they assert lesson plans should be age-appropriate and cover the required learning objectives set forth by the STEM content being instructed. This in turn will provide for open-ended student experiences in order to promote creative thinking. Other components to consider in integrative STEM lessons are content standards in science, technology, engineering, and mathematics; integrative instructional approaches; environmental and instructional factors such as autonomous learning environments, problem-based and exploratory approaches, authentic learning, and 21st century skills; and assessment requirements (Becker & Park, 2011; Honey et al., 2014; Sanders, 2009). However, careful consideration should be given to the degree and type of STEM subject-matter integration chosen for instruction (Becker & Park, 2011).

Becker and Park (2011) conducted a meta-analysis of 28 different studies ranging from K-16 grade levels. The studies also ranged from two-subject STEM integration to four-subject STEM integration. Although findings showed some positive effects on student learning when only two subjects were integrated, the highest effect size resulted when all four subjects were fully integrated. Furthermore, Becker and Park found four-STEM subject integrative approaches at an elementary level had the highest effect size overall. Given these findings, an elementary integrative STEM lesson should always try to employ integrative instructional approaches that maximize the four-subject integration of STEM disciplines. However, if a four, STEM subject integration cannot be undertaken, a minimum of two-subject integration should be used in order to maximize student learning. Furthermore, teachers should consider utilizing varied instructional design strategies while planning their lessons (Roberts, 2013).

In a Delphi study conducted by Roberts (2013), an expert panel of 21 science, seven mathematics, and seven technology and engineering education experts recommended nine instructional strategies such as project-based and experiential learning approaches, utilizing the engineering design process to engage problems, and the employment of collaborative learning be utilized in teaching integrated STEM content. Further consideration should also be given to environmental and instructional factors such as autonomous learning environments, exploratory approaches, authentic learning, and 21st century skills.

Planned lessons should allow for proper assessment of student learning, be age-appropriate, cover the required and desired content standards, and allow for open-ended exploration. Furthermore, an integrative STEM lesson plan should challenge students to actively apply STEM subject knowledge in way that is applicable and relevant to their learning. Hence an elementary teacher may benefit from using reflection and self-assessment, which can assist them in properly creating the best learning experience for students as they can become aware of their own needs in order to create integrative STEM lessons (McCombs, 1997).

Reflection and Self-Assessment in Teacher Education

Reflection and self-assessment practices have been implemented into many teacher education programs as a means to prepare reflective practitioners for dynamic learning environments (Boud, 1999; Valli, 1992). However, this implementation has been inconsistent and thus, reflective practices are often misunderstood, improperly taught or practiced, or insufficient emphasis is placed on what it can do for a practicing teacher (Boud, 1999; Boud, 2003, Grant & Zeichner; 1984; Valli, 1992). McCombs (1997) posited that teachers "need reflection and self-assessment tools to help them assess fundamental beliefs and assumptions about learning, learners, and teaching, as well as differences between their perceptions of practice and those held by students in their classrooms" (p. 1).

There are those who believe (viz., Artz et al., 2008; Boud, 2003; Ross & Bruce, 2007a) a teacher who utilizes these practices can not only increase their teacher self-efficacy and improve their PCK, but they can also determine if they are delivering the required concepts and instruction needed by their learners to achieve mastery learning and understanding. The National Council for Accreditation of Teacher Education (NCATE) (2013) supports and advocates for the instruction of reflection and self-assessment in teacher education programs. NCATE's publication *Transforming Teacher Education Through Clinical Practice: A National Strategy To Prepare Effective Teachers* (2010) states,

> New teachers need more than technical skills; they need a repertoire of general and subject-specific practices and the understandings and judgment to engage all students in worthwhile learning. They need to have opportunities to reflect upon and think about what they do, how they make decisions, how they "theorize" their work, and how they integrate their content knowledge and pedagogical knowledge into what they do. (p. 9)

Further support for these practices comes from the CCSO (2013). Their framework, the *Interstate Teacher Assessment and Support Consortium's (InTASC)*

Model Core Teaching Standards: A Resource for State Dialogue (2013), endorses the use of teacher reflection and self-assessment by in-service practitioners. According to the CCSO, the InTASC standards are written to allow for practitioners to gather information about their teaching practices through reflection and self-assessment. This information can serve as a guide to grow and improve their professional practice as teachers become aware of their needs. Furthermore, the CCSO (2013) assert teachers should work through a learning cycle that enables them to teach, assess, and adjust in order to improve student learning. They emphasize if a teacher is to become effective and sensitive to student learning needs, this process should be undertaken at every opportunity.

Despite these endorsements, the teaching of reflection or self-assessment practices in initial teacher licensure coursework may be occurring in an informal manner or not at all (Boud, 2003; Francis, 1995). Reflection and self-assessment practices can be quite challenging to master if there is insufficient guidance and instruction provided for teachers to learn their appropriate implementation (Boud, 1999; Francis, 1995). Furthermore, researchers (Lucero, Shanklin, Sobel, Townshend, Davis, and Kalisher, 2011; Hammerness, Darling-Hammond, Bransford, Berliner, Cochran-Smith, McDonald, & Zeichner, 2005) believe the manner in which teachers are trained in their initial teacher licensure programs carries through to their in-service work, which will ultimately affect their instruction and their students in the classroom. These skills have become necessary for the instruction a 21^{st} century learner (CCSO, 2013), therefore, if teachers are not prepared to utilize these practices in their initial teacher licensure programs, they are very unlikely to utilize them in the field.

What is a Reflective Teacher?

According to Tsangaridou and Siedentop (1995), the act of teaching has become extremely complex in pedagogical, moral, and political dimensions. They posit that reflective teaching has drawn continued attention because there is general concern for the thoughtfulness of teachers given various reform agendas, changing demographics of those entering teaching, and there has been continued research focusing on effective teaching that emphasizes technical skills. Furthermore, Shulman (1986) asserts reflective teachers are masters of their procedure, content, and rationale and should be able to explain why something was done. Thus, reflection can be seen as a series of steps one takes to confront a situation that is perplexing while envisioning or questioning the desired outcome (Dewey, 1933).

A reflective teacher is seen as having the ability to engage, pose, and solve problems regarding their own educational practice (Zeichner & Liston, 1996). Moreover, a reflective teacher can continuously formulate and contrive purpose, examine their beliefs and values and assumptions, and contribute to the overall learning of their students (Valli, 1992; York-Barr, Sommers, Ghere, & Montie, 2006; Zeichner & Liston, 1996). These characteristics are what Zeichner and Liston (1996) believe to be key features for a reflective teacher. These and other key features for a reflective practitioner are described in Table 6.

Table 6.

Key Features of a Reflective Teacher

Key Features of a Reflective Teacher
1. Examines, frames, and attempts to solve the dilemmas of classroom practice
2. Is aware of and questions the assumptions and values he or she brings to teaching
3. Is attentive to the institutional and cultural contexts in which he or she teaches
4. Takes part in curriculum development and is involved in school change efforts
5. Takes responsibility for his or her own professional development.

Note: These are the key features of a reflective teacher as described by Ziechner and Liston (1996) (p. 6).

Reflection is a way to generate new knowledge about teaching while bridging pre-service pedagogy and content knowledge with experience (Shulman, 1987). White (1991) argues that researchers have yet to understand how teachers themselves organize and understand their problems as they relate to curriculum and learner goals, goals for specific individuals, and feelings or emotion that a researcher may not understand or value. It is believed teachers have a unique perspective and relationship with their students that allow them a window into their students' minds, classroom context, and school/social environment that cannot be captured by external classroom researchers (Lytle & Cochrane-Smith, 1990). Therefore, teachers have a unique type of knowledge called *knowledge-in-action.* Schön (1983) defines *knowledge-in-action* as a belief that practitioners hold expert-level knowledge about their learners and their classrooms.

Further Theoretical Underpinnings of Reflective Teaching

Dewey and Schön have helped frame reflective teaching practices (Artz et al., 2008; Boud, 1999; McCombs, 1997; Valli, 1992; Zeichner & Liston, 1996). Dewey (1933) proffered reflection to be a cycle of active problem solving, thinking about ways to resolve an issue, and then formulating ideas that would then connect these experiences to solve the issue at hand. Furthermore, he proposed reflection is an active and deliberate cognitive process. Hatton and Smith (1995) expound on this premise and stated that reflective thinking addresses practical problems by allowing utilization of perplexity and doubt to drive the search for a solution. Dewey (1933) made a distinction between human action that can be seen as reflective and that which can be seen as routine. He theorized reflective thinking,

> Emancipates us from merely impulsive and routine activity…enables us to direct our actions with foresight and to plan according to ends in view of purposes of which we are aware. It enables us to know what we are about and when we act. (p. 17)

Furthermore, reflective action can be seen as having active, persistent, and careful consideration of individual practices or beliefs despite the possible consequences or outcomes in any context (Dewey, 1933). Reflective teachers will stop and actively utilize reflection during their teaching despite the contexts involved. They will inhabit three essential attitudes Dewey postulated are essential of a practitioner: open-mindedness, responsibility, and wholeheartedness.

Open-mindedness can be seen as the ability or desire to hear and see various situations. A teacher will allow himself or herself to be open to seeing various solutions, opportunities, barriers, and they will allow themselves to even question their most cherished beliefs (Grant & Ziechner, 1984; Zeichner & Liston 1996). They will also continually reexamine deeply held beliefs and procedures in an effort to find conflicting evidence on which to base their educational practice.

The second characteristic is responsibility. A responsible teacher is seen as one that considers both consequences and outcomes prior to taking action. According to Pollard and Tann (1993), there are three kinds of consequences: personal, academic, and social/political consequences. Personal consequence involves the perceived effect of a teacher's instruction on a student's understanding. Academic consequence is the perceived effect a teacher's instruction can have on a student's academic and intellectual growth. The last consequence is a social/political consequence, which has to do with the perceived impact a teacher's instruction can have on a student's future. Zeichner and Liston (1996) state responsible teachers "ask themselves what they are doing in a way that goes beyond questions of immediate utility (i.e. does it work) to consider the ways in which it is working, and for whom it is working" (p. 11).

The final characteristic of a reflective practitioner is whole-heartedness. A reflective teacher that utilizes responsibility and open-mindedness to frame judgment and actions is believed to be whole-hearted (Grant & Zeichner, 1996; Hatton & Smith, 1984). A whole-hearted teacher dedicates themselves to all students while fighting for their beliefs and equitable education (Grant & Zeichner, 1996). According to Dewey (1933), the understanding and utilization of open-mindedness, responsibility, and wholeheartedness characteristics while undertaking problem solving, engaging in teaching-inquiry, and utilizing technical teaching skills (PCK) is the definition of being reflective. Dewey emphasized the need for their intentional application, rather than forming a routine around them.

Dewey (1933) believed routine action is guided by habit, impulse, and influence. Furthermore, he asserted unreflective activity could lead to "further enslavement for it leaves the person at the mercy of appetite, sense, and circumstance" (p.89). Hence, an unreflective practitioner will find himself or herself reacting to a situation without forethought and responsible thinking. According to Grant and Zeichner (1984), an everyday social school setting can lead to a reality in which problems, goals and the means for solving them become routine, much like Dewey described. Hence, unreflective teachers uncritically accept the routine of everyday school reality (Dewey, 1933; Grant & Zeichner, 1984). Additionally, unreflective practitioners will utilize this "reality" and focus their efforts on solving problems defined by others rather than solving problems that are meaningful and more effective for themselves or their learners (Grant & Zeichner, 1984). Dewey (1933) postulated that reflection and routine must remain balanced for a teacher to develop proper habits of mind in their teaching.

Schön (1983) furthered extended Dewey's reflective practitioner framework with *reflection-on-action* and *reflection-in-action* frameworks. Schön postulated reflection occurs at distinct times: before, during, and after a lesson. Reflecting prior to a lesson and after a lesson is considered reflection-on-action. Hence, a teacher is framing and solving problems after they encountered problems in either planning or delivering a lesson. Reflection-in-action occurs as a teacher adjusts their instruction based on student needs and reactions. He further hypothesized that knowledge, actions, and understandings are occurring simultaneously.

Schön (1983) stressed the importance of framing and reframing a problem while reflecting. He encouraged the use of a contextual application during the act of reflecting. He states, "problems do not present themselves to practitioners as givens. They must be constructed from the materials of problematic situations which are puzzling, troubling, and uncertain" (Schön, 1983, p. 40). He asserts teachers cycle through in-action and on-action thinking while going through three stages: appreciation, action, and reappreciation. As this iterative cycle is occurring, teachers are framing and reframing their problem through a collection of appreciative systems including teacher values, knowledge, theory, and practices they apply to their own experiences. After this process, they reinterpret the situation and reframe it through a new perspective. Figure 3 illustrates this iterative process.

There has been some criticism and resistance to Schön's reflective teaching framework (Zeichner & Liston,1996). One criticism is that his dimension of reflection is extremely isolated and does not allow for collaborative reflection. It is believed that a teacher can reflect individually, however through collaboration with either grade-level teachers or other peers, a teacher can maximize their level of critical reflection (Zeichner & Liston,1996). Secondly, he is also criticized for not adequately considering context and social setting in reflection. Loursen (1994) asserts teaching to be too complex of a practice to be compartmentalized within reflection-in-action. He claims various types of feedback should guide teaching and reflection.

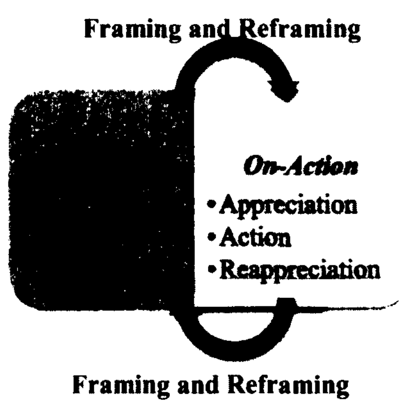

Figure 3. This figure illustrates Schön's (1983) process of framing and reframing a situation or problem during reflection. As a teacher engages in in-action or on-action reflection, they go through the process of appreciation, action, and reappreciation as they frame and reframe a problem until they can properly reflect on the situation or problem.

This feedback can come from a teacher's peers or the institution they work in. Zeichner and Liston (1996) state,

> Critics argue, and we agree, that teachers should be encouraged to focus both internally on their own practices, and externally on the social conditions of their practice, and that their action plans for change should involve efforts to improve both individual practice and their situations" (p. 19).

Therefore, by uniting both internal and external reflection practices, a teacher can gain an encompassed view of their actions.

What is Teacher Self-Assessment?

Self-assessments are often characterized as a powerful technique a teacher can use as a basis for improving their own achievement and practice (Ross & Bruce, 2007a; Boud, 2003; Francis, 1995). According to Ross and Bruce (2007a), "self-assessments contribute to teachers' beliefs about their ability to bring about student learning; i.e., teacher efficacy, a form of professional self-efficacy. Teacher self-efficacy is particularized to teaching specific content, to particular students, in specific instructional contexts" (p. 4).

Boud (2003) further expounds the definition of self-assessment as "the involvement of [teachers] in identifying standards and/or criteria to apply to their work and making judgments about the extent to which they have met these criteria and standards" (pp.12-13). The practice of self-assessment plays a key role in teachers learning about their instruction (Artz et al., 2008). Furthermore self-assessment involves the questions teachers should ask themselves while reflecting on their thinking (Artz et al., 2008). Table 7 illustrates several features and questions involved in good self-assessment practice.

Table 7

Features of Good and Poor Practice in Self-Assessment

Good Practice in Self Assessment	***Poor Practice in Self-Assessment***
✓ The *motive* for its introduction is related to enhancing learning	✓ It is related to meeting institutional or other external requirements
✓ It is introduced with a *clear* rationale and there is an opportunity to discuss it with [teachers]	✓ It is treated as a given part of course *requirements*
✓ [Teachers] perceptions of the process are considered to the idea being introduced	✓ It is assumed that processes which appear to work elsewhere can be introduced without modification
✓ [Teachers] are involved in *establishing criteria*	✓ [Teachers] are using criteria determined solely by others
✓ [Teachers] have a *direct role* in influencing the process	✓ The process is imposed on them
✓ *Guidelines* are produced for each stage of the process	✓ Assessments are made impressionably
✓ [Teachers] learn about a particular subject through self-assessment which engages them with it	✓ Self-assessment is only used for apparently 'generic' learning processes such as communication skills
✓ [Teachers] are involved in expressing understanding and judgment in *qualitative* ways	✓ Assessment are made on rating scales where each point is not explicitly defined
✓ Specific judgments with *justifications* are involved	✓ Global judgments without recourse to justificatory data are acceptable
✓ [Teachers] are able to *use information* form the contest and from other parties to inform their judgment	✓ The activities do not draw on the kinds of data which are available in authentic settings
✓ It makes an identifiable contribution to formal *decision-making*	✓ No use is formally made of the outcome
✓ It is one o a number of complementary strategies to promote *self-directed and interdependent learning*	✓ It is tacked on to an existing subject in isolation from other strategies
✓ Its practices *permeate* the total course	✓ It is marginalized as part of subjects which have low status
✓ [Administration] are willing to *share control* of assessment and do so	✓ [Administration] retain control of *all* aspects (sometimes despite appearances otherwise)
✓ Qualitative *peer feedback* is used as part of the process	✓ It is subordinated to quantitative peer assessment
✓ It is part of a profiling process in which [teachers] have an active role	✓ Records about [teachers] are produced with no input from them
✓ Activities are introduced in step with the [teachers] capabilities in *learning-how-to-[teach]*	✓ It is a one-off event without preparation
✓ The implications of research on gender *differences* and differences of presentational style are considered	✓ The strategy chosen is assumed to work equally for all
✓ The process is likely to lead to *development of self-assessment skills*	✓ The exercise chosen relates only to the specific needs of the topic being assessed
✓ *Evaluation* data are collected to assist in improvement and for determining its contribution to [teacher] learning	✓ Evaluation is not considered or is not used

Note: This table is adapted with permission from Boud's (2003) "Features of Good and Poor Practice in Self-Assessment" (pp. 208-209).

McCombs (1997, 2001) has provided evidence that self-assessment practices influence teacher beliefs regarding their teaching and learning. In her research, K-20 teachers who utilized self-assessment practices to determine any content or instructional needs reported feeling more empowered. McCombs asserts an impetus for change is easier for teachers when they are aware of their own needs. Thus, for effective self-assessment to take place, a teacher should be able to assess what they do, how they do it, and modify their own learning (Boud, 2003; Schön, 1983; Valli, 1992).

Further Theoretical Underpinnings of Self-Assessment

Self-assessment did not begin as an individualistic improvement process. Rather, it began in eastern civilizations where self-criticism was done to shame those who shunned the current ideology in post-revolutionary China (Boud, 2003). Self-criticism requires an individual to think and reflect about their actions and thoughts and then convey them to another individual in hopes of aligning with the current doctrine or rules of a religion or organization. Various civilizations and religious groups have also engaged in forms of self-criticism. Judeo-Christians have been considered to use self-criticism as a form of confession in their spiritual routines and activities for some time. Other forms of self-assessment practice have evolved through time. Examples include the Hebrew confessions via God, Catholic confessions via a Catholic priest, a Marxists corrections to the current doctrine, and secular confessions to a therapist or educator (Boud, 2003, p. 23). Self-assessment is considered a component of reflection (Boud, 1999). Furthermore, it is seen as both a process and cognitive activity with distinct identity (Boud, 2003). It is also considered a foundational practice in metacognition (Artz et al., 2008; McCombs, 1997; Schoenfeld, 1987).

Livingstone (1997) defines metacognition as "higher order thinking which involves active control over the cognitive processes engaged in learning" (para. 1). She asserts metacognitive processes occur everyday and contribute to successful student learning. Yet, metacognition is often confused with cognition of which Livingstone defines simply as a knowledge gain. According to Livingstone, metacognition occurs after a cognitive event or activity. Therefore, cognition and metacognition are linked by a dynamic process in which the must rely on one another.

The process begins when a cognitive goal is set. The process of metacognition proceeds only after we question whether or not we achieved a particular goal, thus questioning and thinking about our learning. Schoenfeld (1987) believes its practice is part of intellectual behavior where you assess the knowledge of your own thought processes and question the accuracy of your own thinking. Thus, engaging in the metacognitive process of self-assessment can allow individuals, such as teachers, to determine whether or not a goal has been successfully achieved. Hammerness et al. (2005) concurs and states, "people with high-levels of metacognitive awareness have developed habits of mind that prompt them to continually self-assess their performances and modify their assumptions and actions as needed" (p. 376). Furthermore, they believe that for a teacher to be effective, they must be 'metacognitive' or self-monitoring about their practice.

Schunk (1997) postulates self-assessment practices have ties to Bandura's social cognitive theory framework. In this framework, Bandura (1986) theorizes that people are motivated by the implications incurred during self-monitoring or self-assessment while in a social context. Bandura asserts that people compare internal standards with personal achievement in order to ascertain three factors: self-monitoring, self-judgment, and self-reaction. Hence, these comparisons influence goal progress and they also yield motivational effects on how a person will perform in the future (Schunk, 1997). During self-monitoring, a person simply makes observations about themselves. However, they cannot formulate a plan of action as self-judgment and self-reaction must occur. Subsequently, self-judgment occurs as one compares a present performance or experience to an ultimate desired goal. Bandura (1986) asserts that an individual must feel as though they are making progress and achievement toward the goal in order to sustain endured motivation. During this time, self-monitoring is occurring and informing the individual on the status and progress of goal achievement. Bandura (1986) asserts that people who engage in self-assessment will interpret themselves as having a mastery experience of which can be a powerful form of self-efficacy.

Bandura (1997) considers mastery learning to be an integral tool in teacher self-efficacy. If a teacher perceives themselves as successful in a current task, they are more likely to believe they will be successful in the future on a similar task (Bandura, 1997). Self-assessment contributes to teacher perceptions about their ability to perform certain tasks and will likely influence their perception about performing these tasks in the future (Ross, 2006). Thus, a teacher improves their self-efficacy when they believe their own actions have improved student-learning outcomes (Ross, Cousins, & Gadalla, 1995). Furthermore, teachers who foresee success will also set higher goals not only for themselves, but also for their students (Ross & Bruce, 2007a; Ross, Cousins, & Gadalla, 1995). Consequently, teachers with low self-efficacy are resistant to implement new things in their classrooms and can affect student efficacy levels (Ross & Bruce, 2007a).

The Link Between Reflection and Self-Assessment

Reflection and self-assessment are linked in that self-assessment is a critical element in the reflective process (Brookfield, 1995; Schunk, 1997). According to Schunk (1997), by engaging in reflective practices one must be allowed to self-monitor and self-evaluate (self-assess) prior to being able to make performance adjustments. Therefore, a purposeful adjustment, such as that to teaching, can only occur if a learner has conducted a self-assessment in order to establish or achieve a new goal. Artz et al. (2008) postulate the process of self-assessment involves actual reflective dimensions depending on which activity or context it is being utilized. According to Artz et al., reflection occurs as a teacher is self-assessing because they are influencing professional growth by drawing on previous experiences.

Reflection and self-assessment contribute to the foundations of professional practice (Boud, 2003; Boud, 1999) as utilizing these skills can lead to professional growth and improvement in teaching. This professional growth is influenced by the context and environment in which a teacher is engaging their reflection and self-assessment. A teacher can either utilize these contexts as barriers to reflecting and self-assessing, or a teacher can take the contexts as a challenge in which to engage in these practices and grow their craft (Boud, 1999; Loursen, 1994). Furthermore, Ross and Bruce (2007a) assert that as a teacher reacts to their self-assessment through reflection, they will determine how satisfied they are and make adjustments accordingly. However, as with any practice, there are some limitations to reflection and self-assessment that must be considered.

Perceived Limitations of Reflection and Self-Assessment

Reflection and self-assessment are beneficial practices for teachers, however there are some perceived limitations to their use. One perceived limitation of reflection is that when done at superficial levels, reflection can lead to a false sense of security. This false sense of security is created because teachers feel they are truly reflecting, even at superficial levels. However, if critical levels of reflection are not undertaken often, students may be impacted because a teacher may not catch those essential components they should adjust for. Hence, a teacher must reflect at critical levels often in order to challenge and maintain their preset assumptions for the purpose of improving student learning and so they may hone and shape their own professional practice (Brookfield, 1995).

Another potential limitation of reflection is that it can challenge certain democratic educational ideologies that are established for the purpose of societal good. Gutmann (1987) argued that a democratic education could limit what is considered acceptable educational actions. Thus, Ziechner and Liston (1996) proffer reflective teaching could be considered a bad practice when it challenges the benefits of living in a democratic society that is committed to equitable education.

Evidence on the validity of self-assessment is mixed, however there is more compelling evidence to support its widespread use than evidence on the contrary (Ross, 1986). Schunk (1997) posited that although the process of self-monitoring is beneficial in motivating change, desire alone cannot make this change occur. Schunk (1997) asserts that sustained motivation is dependent on one's self-efficacy and the outcomes the individual has set for themselves. Another limitation of self-assessment is developing an understanding of its actual process (Boud, 1999, Francis, 1995) and thus, making accurate judgments about perceived needs. Kruger and Dunning (2009) assert that unskillfulness in self-assessment can result in an inflated perception of what is "truly" known and what is not. Furthermore, they state this unskillfulness can also lead to failure of recognizing what is "truly" known and what is not.

Another perceived limitation to both reflection and self-assessment are the complexities of a classroom (Zeichner & Liston, 1996). These complexities include students, environments, experience, and efficacy (Hammerness et al. 2005). Hence a teacher must be fully aware of these factors and the role they play in their self-monitoring and reflection. Therefore, reflection and self-assessment can be beneficial practices because they allows a teacher to consider and utilize these and other complexities to their advantage for the purpose of making the best decision in their classroom.

Perceived Benefits of Utilizing Reflection and Self-Assessment by Teachers

Teachers that utilize reflection and self-assessment can see their practice from a wider perspective (Brookfield, 1995; Zeichner & Liston, 1996) and can take corrective action for improving their self-efficacy and craft (McCombs, 1997; Ross & Bruce, 2007a). Furthermore, they stand to develop habits of mind that they can carry throughout their teaching career that will improve their teaching.

Brookfield (1995) asserts that a critically reflective teacher will take informed action into their teaching. Hence, they will be better able to communicate with their students and peers about instructional goals. They will also take more responsibility for their teaching because as they investigate the levels of student learning in their classroom, they are less prone to develop habits of self-blame that can then lead to professional unhappiness (Brookfield, 1995).

Another potential benefit of reflective practitioners is that their students can also become reflective because their students believe there is a democratic trust between the teacher and their students. Zeichner and Liston (1996) believe reflection involves, "a recognition that teachers should be active in formulating the purposes and ends of their work, that they examine their own values and assumptions, and that they need to play leadership roles in curriculum development and school reform" (p. 5). They also claim that reflection leads to a recognition that teachers hold beliefs, ideas and theories that can improve teaching and professional practice.

Self-assessment can also contribute to a teacher's professional development and growth during their career (Hammerness et al., 2005; McCombs, 1997). In practice, teachers should be able to achieve the ability to measure their own learning, determine its inconsistencies, and be able to seek out knowledge to address their needs. Schön (1983) believes the information needed to assess deficiencies will emerge in the context of teaching. So as a teacher is planning their lesson, they are utilizing self-assessment in information gathering from their students' previous learning experiences, from their own previous teaching, and from their knowledge repertoire as a basis for developing future instruction. Therefore, the processes of reflecting and self-assessing are linked to teaching and instruction (Hammerness et al., 2005).

Another benefit of self-assessment is that teachers tend to establish higher goals for themselves and their students (Ross & Bruce, 2007a). Teachers who understand their own efficacy are more flexible and willing to take on various instructional methods and proceed through posed obstacles (Ross & Bruce, 2007a). They are also more willing to question established routines and undertake voluntary change (Gusky, 2002). Other benefits include improved time management, energy-focus, revitalization of a teachers' sense of accomplishments, professionalism, and personal control (McCombs, 1997).

Role of Reflection and Self-Assessment in a Lesson

A teacher needs to carefully consider the essential standards, content, instructional approach, and knowledge a student must learn prior to instruction (Hunt et al., 2009). Furthermore, they must set instructional goals and objectives, consider their learner needs, and create a balanced environment that is conducive for integrative STEM education prior to delivering a lesson. Hence, planning is a critical step in teaching (Johnson, 2000). Reflection and self-assessment practices can be a tool to support practitioners during their instructional planning (Art et al., 2008; McCombs, 1995; Ross & Bruce, 2007a; Tabachnick & Zeichner, 1991; Valli, 1992; York et al., 2006). By utilizing these practices throughout the lifecycle of a lesson, a practitioner can make needed adjustments to enhance lesson and instructional effectiveness because they are aware of their own needs in addition to their learner needs (Artz et al., 2008; McCombs 1997).

Artz et al. (2008) posit that a lesson has two dimensions. The fist dimension is encompassed in their model, the *Teacher Cognitions Framewo*rk (TCF). Utilizing Schoenfield's (1998) work as an underpinning for TCF, Artz et al. claim that teacher goals, knowledge and beliefs are a factor in creating effective lessons. The second dimension is called the *Phase-Dimensional Framework* (PDF). The PDF divides the lifecycle of a lesson into three stages: Pre-Active, Interactive, and Post-Active, and is interlaced with the TCF model.

The *Teacher Cognitions Framework* (TCF) considers three essential cognitions in the planning of a lesson: goals, knowledge, and beliefs (Artz., et al, 2008). The first cognition, *goals,* is the consequence a student receives from a teachers expectations regarding their intellectual, social, and emotional outcomes. Goals are impacted by a practitioner's self-observations of their own practice. The next cognition, *knowledge,* is defined as a system of internalized information that a teacher acquires over time about students, content, and pedagogy. Lastly, *beliefs* are defined as a system of personal assumptions regarding the nature of a subject, students, learning, and teaching.

These three cognitions provide a basis for the Phase-Dimensional Framework (PDF) (Artz et al., 2008). Artz et al. (2008) assert a teacher should reflect and self-assess throughout the lifecycle of a lesson. The Phase-Dimensional Framework (PDF), divides the lifecycle of a lesson into three stages: Pre-Active, Interactive, and Post-Active.

In the Pre-Active stage, teachers begin to think about their lessons. They begin to consider subject matter knowledge, students, standards, curricular goals, and school/environmental goals (Artz., et al., CCSO, 2013). Hence, learning outcomes and considerations for the desired instructional strategies a teacher will utilize begin to develop in this stage (Artz et al., 2008).

In the interactive stage, a teacher delivers the planned lesson. During this stage, teachers are utilizing a lesson plan as a guide for their instruction. However, Artz et al. (2008) assert teachers are cognizant of their students during this stage. They are actively monitoring and sensing student reactions and perceptions. In addition, they are self-assessing as they instruct to determine if they are reaching their preset goals. Artz et al. (2008) posit monitoring and regulation can be used to modify actions of instruction that will ultimately enhance student learning.

In the Post-Active stage, teachers reflect, evaluate, and then revise their prior lessons. During this stage, teachers revisit their lessons to determine whether student and teacher goals were adequately met. Artz et al. assert that by doing this, teachers become aware of strengths and weaknesses in their practice and are better able to revise their lessons and instruction, which can lead to enhanced student learning. Figure 5 illustrates and describes the progression of these stages.

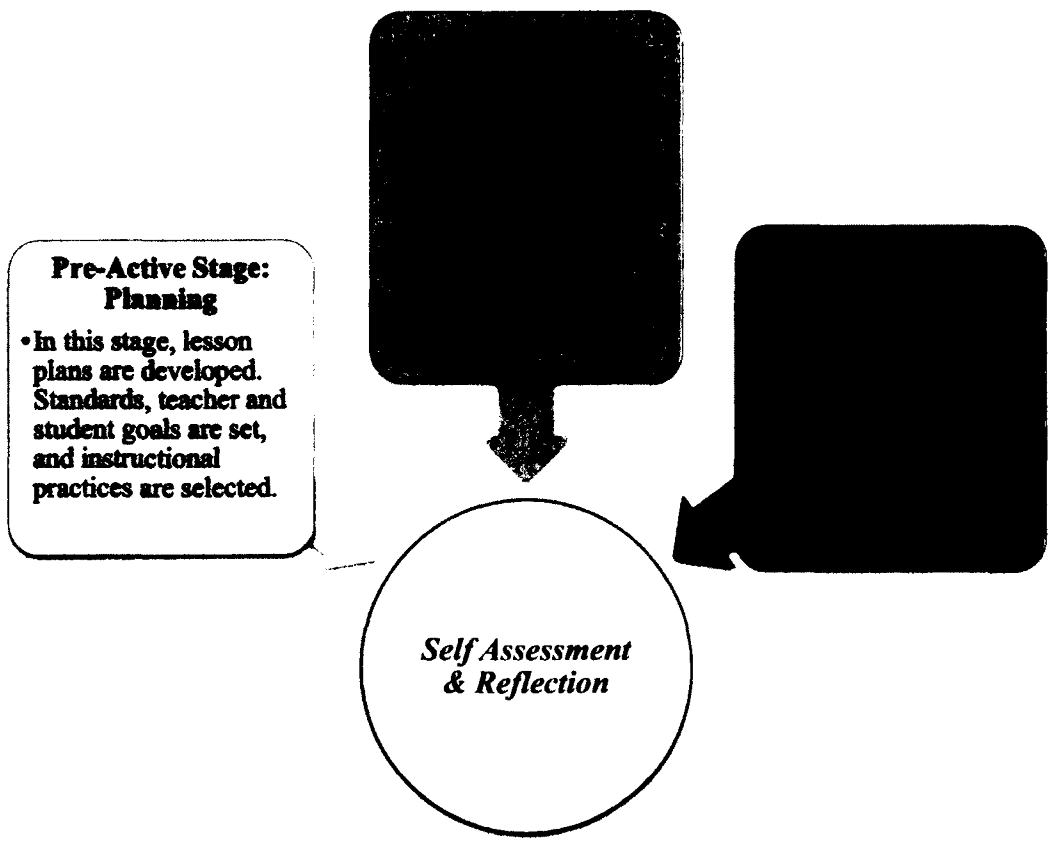

Figure 4. This figure illustrates the stages of a lesson from planning, to delivery to post delivery and assessment of the lesson for a teacher (Artz et al., 2008).

Purpose of Research

Statement of Problem

Teacher self-assessment and reflective practices have seen cyclical patterns of use over the last century (Boud, 2003; Valli,1992; Zeichner & Liston, 1996). Despite these trends, research shows the classroom benefits offered through their practice may be too valuable to overlook. In addition, as the push for STEM education continues to grow (Honey et al., 2014; National Governors Association, 2011; National Research Council, 2007; President's Council of Advisors on Science and Technology, 2010), it becomes necessary to provide primary teachers with tools that can assist in creating and assessing their integrative STEM lessons and instruction to achieve desired student outcomes.

Purpose Statement and Research Goals

The purpose of this study was to develop a reflective and self-assessment practice tool elementary teachers can utilize in preparing and assessing integrative STEM lessons and instruction. Three research goals guided the development of this tool:

1. Determine the initial STEM self-efficacy level for the study's participants.
2. Utilize theories of reflection and self-assessment to create an instrument for preparing and assessing an integrative STEM lesson.
3. Refine the instrument through two Design-Based Research macro cycles to ensure appropriate content and applicability for use in a K-2 elementary classroom.

CHAPTER II

METHODS

Participants

According to Leedy and Ormond (2005), selection of a population that will yield the best information in all aspects of a study is imperative for research. Research (Berry et al., 2005; Nadelson et al., 2012; Rogers et al., 2009) has shown elementary school exposure to integrative STEM education is integral for students to achieve the full potential of what integrative STEM education stands to offer. Therefore, the population for this study will consist of a purposive sample of six K-2 elementary school teachers from one suburban elementary school in the southeastern United States. The sample will comprise of two kindergarten, two first grade, and two-second grade teachers.

The school district's online mission statement and curriculum framework were used to ensure that the study's participants were drawn from a district that endorses STEM education and 21st century skills. Additionally, the targeted elementary school's vision statement and instructional approaches had to align with STEM education and 21st century skills. As described in the literature review, science and mathematics instruction is often more prevalent in elementary education than technology and engineering instruction (Bybee, 2009; Williams, 2011). Therefore, an additional criterion for this study was that the targeted elementary school would have been nationally recognized by a teaching organization as providing high quality instruction not only in science and mathematics, but also in technology and engineering instruction. This recognition assures that all four STEM disciplines are equally represented, thus the elementary school would be utilizing integrative STEM instruction.

Lastly, early elementary grades were chosen because foundational skills in STEM education are introduced and established in these grades (Berry et al., 2005; Nadelson et al., 2012; Swift & Watkins, 2004). The National Center for Educational Statistics (2000) stresses that most elementary education studies focus on latter elementary grades (3-5). Thus, they emphasize that developing an understanding for early elementary grades (K-2) is an important contribution to educational research.

Design

The researcher will utilize a design-based research approach that will consist of both qualitative and quantitative methods. Data will include a survey, teacher interviews, classroom observations, and teacher/researcher journals. The researcher will triangulate the data collected from the study's instrument developed in the study, teacher observations, clinical interviews, teacher/researcher journals, and lesson plans in order to ascertain refinement of the final instrument (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003).

A design-based research approach was selected because researchers (Cobb et al., 2003; The Design-Based Research Collective, 2003; Gravemeijer & Cobb, 2006; Plomp & Nieveen, 2007) have indicated this type of methodology allows for the blending of empirical educational research with theory-driven research that can provide a deeper understanding of the phenomenon that is being studied. Furthermore, it allows the participants of a study to assist in the identification of relevant contextual factors while aiding and enriching the researchers understanding of the intervention itself through continuous cycles of design, enactment, analysis and redesign (Cobb, 2001; Design-Based Research Collective, 2003).

Moreover, design-based research works by implementing interventions in iterative macro cycles in order to develop theories about both learning processes and the means that are designed to support that learning (Cobb, et al., 2003; Gravemeijer & Cobb, 2006). Through its iterative cycles, Cobb et al. (2003) believe, "conjectures are generated and perhaps refuted, new conjectures are developed and subjected to test. The result is an iterative design process featuring cycles of invention and revision" (p. 10). The intended outcome of each macro cycle is to develop a framework from a retrospective analysis (that is conducted at the end of the macro cycle) that will provide a refined instrument for the second iterative cycle (Cobb et al., 2003). Gravemeijer and Cobb (2006) have outlined three phases for this research design. These include preparing for the experiment, experimenting in the classroom, and conducting a retrospective analysis. The researcher will provide an overview of these phases as they apply to this study in the procedures section.

Instruments

STEM Teacher Self-Efficacy Survey. A survey (*Appendix A*) will be administered at the beginning of the study (permission granted for its use from the original author). It will solicit initial study participation, demographic data and measure initial teacher self-efficacy in engaging through integrative STEM education practices.

Demographic Data Collection. Six teacher demographic questions were developed. They documented gender, age, education, years in the teaching profession, and grade(s)-level teaching responsibilities. All items were select-response with the exception of one item that had an option to provide how the teacher defined an effective integrative STEM lesson.

STEM Teacher-Efficacy Scale. Nadleson, Callahan, Pyke, Hay, Dance, and Pfiester (2013) created a STEM teacher self-efficacy scale that measures teacher perceptions of their effectiveness to teach STEM. According to Nadelson et al. (2013), this scale was created using a modified version of the *Science Teaching Efficacy Belief Instrument*, initially developed by Riggs and Enoch in 1990. Nadleson et al. replaced the word "science" throughout the instrument to reflect "STEM". The instrument utilizes a five-point Likert scale with forward and reverse phrased questions to assess a teachers' STEM efficacy. Nadelson et al. (2013) report the internal reliability alpha at .85 which indicates a good level of instrument reliability for the modified instrument.

Reflection and Self-Assessment Instrument. A self-assessment and reflective practice instrument was created from the study's literature review. The researcher utilized Artz et al. (2008) Phase Dimensional Framework (PDF) as a basis for establishing the lifecycle of a lesson: Pre-Active, Interactive, and Post-Active stages. The questions were developed for each stage utilizing Zeichner and Liston (1996) (Table 6) key features of good teacher reflection and Boud's (2003) (Table 7) criteria for good self-assessment practices previously described in the study's literature review. These sources provided set criteria and features of quality reflection and self-assessment. They were then cross-referenced with the definition and characteristics required of integrative STEM education. Furthermore, some questions were also developed utilizing the identified integrative STEM characteristics and InTASC standards alignment (Table 3), and the features of a thoughtful lesson (Table 5). This triangulation and cross-referencing allowed the researcher to create the initial instrument so an elementary teacher can engage in reflective and self-assessment practices throughout the lifecycle of an integrative STEM education lesson.

A scale was set for the instrument from 1-10 to determine comfort levels for each phrased posed. According to Nadleson et al. (2012), comfort level scales such as the one used in this study's self-assessment and reflective instrument "have generated data that were highly correlated with the outcomes from instruments used to measure the same construct or variable with established reliability and validity" (p. 72).

Clinical Interviews. The primary researcher will conduct clinical interviews on the first, third, and fifth day the instrument is implemented. An initial interview protocol (*Appendix B*) was created for day one. An additional protocol (*Appendix C*) was created to guide the researcher through days three and five of the interviews. These clinical interviews will serve as concurrent validity evidence that the teachers are utilizing the self-assessment and reflective practice tool developed in this study. The interviews will be audio recorded and transcribed in order to establish a coding protocol. In addition, the researcher will take field notes during each clinical interview. An external coder will be utilized to establish validity of the collected interviews.

Observations. The primary researcher will also conduct observations during the study. The researcher will use a checklist (*Appendix D*) and keep detailed field notes during the observations. The observations will serve as concurrent validity of teachers engaging in reflection and self-assessment prior, during, and after their integrative STEM lessons. Lesson plans will also be reviewed in order to ascertain integrative instructional strategies and STEM content.

Journals. Teachers will be asked to keep daily journals during their respective macro cycle. Writing helps to facilitate intellectual growth because it allows a teacher time to hold an idea or thought still in order reflect upon it (Goldsmith & Schifter,1997). The teachers will be asked to note any thoughts, comments, opinions, changes, and/or additions that need to be made to the instrument. In addition, the teachers will be asked to comment on their integrative lesson of the day. They will be asked to consider how they could improve their lesson or any actions they could have taken during the lesson to improve student learning. Teachers will utilize a pre-set journal page (*Appendix E*) to ensure they are capturing the required information for the study. If a teacher fails to complete a section of the journal, the researcher will follow up with the teacher in order to ensure all sections are fully completed. Journal data will be utilized to help support any needed changes to the instrument. The researcher and an external coder will review and code the journals in order to establish concurrent validity.

Procedures

There will be three phases to this study. In *Phase One*, preparing for the experiment, Gravemeijer and Cobb (2006) assert a researcher must formulate a local instruction theory that can be tested and refined while carrying out the study. They also believe it is crucial in establishing the start and end point as it clarifies the theoretical intent. For this study, the starting point, or where the need for the study's intervention began, was originally noted by Stinson et al., (2009) and Stohlmann et al. (2012). These researchers postulated some teachers might have content and instructional gaps that may prevent them from fully utilizing integrative STEM instructional approaches. Furthermore, Nadelson et al., (2012) believe development of foundational STEM knowledge occurs at elementary levels, thus it should be implemented as early as possible. McCombs (1997) proffers that self-assessment and reflective practices are tools teachers could use to help identify such gaps and improve their lessons and instruction. Therefore, in this particular study, the researcher conjectures that teachers who engage in using a reflective and self-assessment practice tool for creating and assessing integrative STEM lesson plans will be able to identify their instructional and content needs in order to improve their lessons and instruction.

Phase Two will consist of the design experiment. The study consists of two macro cycles. Each macro cycle will consist of an instructional school week (five days) in which the first day will be utilized for initial observation, initial interviews, and instrument introduction. This will allow for four mini-cycles to occur throughout the week of thought, instruction, and planning experiments. Figure 5 illustrates this process.

This study received all necessary approvals in Fall 2014 from the university IRB (Appendix H), the school district, and selected elementary school. The researcher contacted the school administrator and discussed the parameters of the study. The researcher received consent from two-K, 1^{st}, and 2^{nd} teachers to volunteer for the study. Once these participants were identified, the researcher met with each of the participants and explained how the study would work. The researcher notified the participants of their designated macro cycle (one K, 1^{st}, and 2^{nd} grade teacher would be in macro cycle one and then the other K, 1^{st}, and 2^{nd} grade teacher would be in macro cycle two).

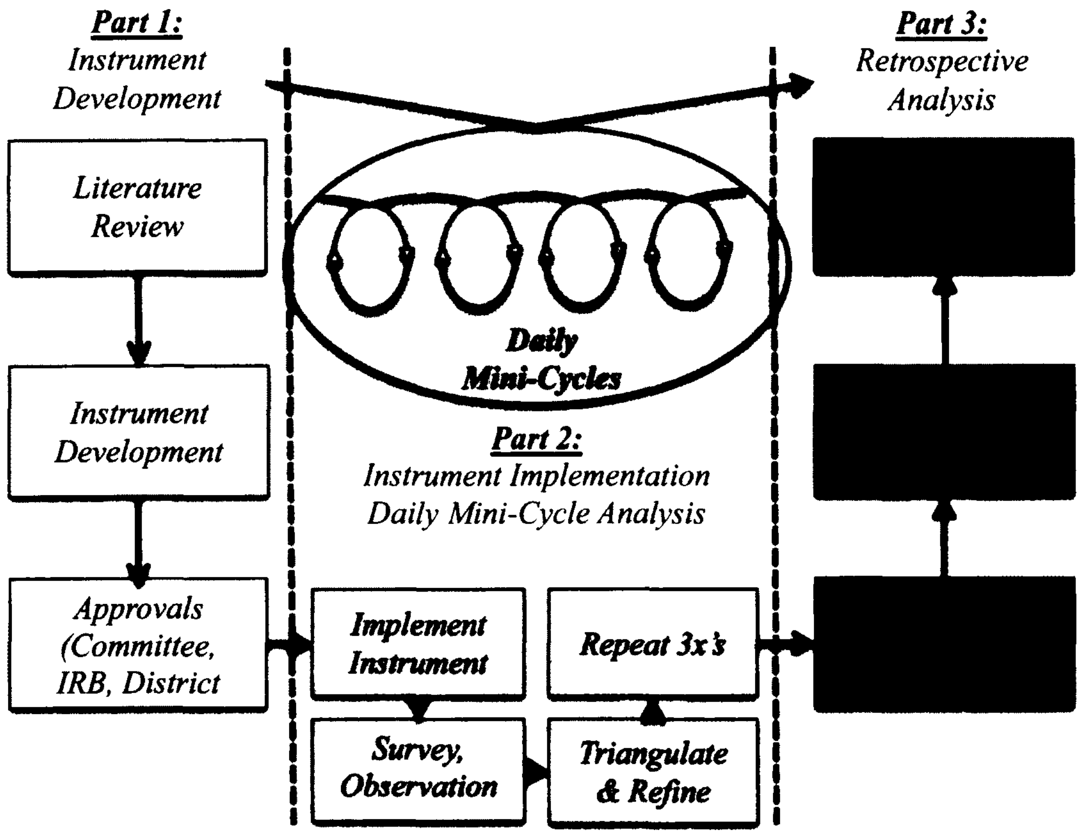

Figure 5. This figure illustrates the cumulative cycles that are utilized in a macro cycle with the study's local instructional theory interjected into each cycle. Each day, the theory is tested and thoughts are collected on its' utility (Gravemeijer & Cobb, 2006).

The teachers were given journals. The researcher explained the use of the journal in regards to the study. They were encouraged to utilize the journal daily to note any thoughts, comments, opinions, changes, and or additions that need to be made to the instrument. In addition, the teachers were asked to record any thoughts on their daily integrative STEM lesson. Lastly, teachers were asked to record any thoughts on how they could improve or change their lesson; or any instructional actions they could have taken during the lesson to improve student learning.

During the first macro cycle, the participants completed a survey to determine their STEM teacher self-efficacy levels prior to utilizing the study's instrument and at the end of the macro cycle to determine any STEM efficacy changes. Next, an observation of an integrative STEM lesson was conducted for each teacher on the first day along with a clinical interview. Afterwards, the teachers employed the initial self-assessment and reflective practice tool developed for this study. The participants were interviewed on days one, three, and five regarding the tools utility and possible refinement suggestions.

Phase Three will consisted of the retrospective analysis phase. According to Gravemeijer and Cobb (2006), the primary goal of this phase is to support the revision of the local instruction theory. The data collected from the clinical interviews, observations, and journals were triangulated. Thus, there can be empirical grounding in which to adjust and refine the initial conjecture (Gravemeijer & Cobb, 2006). Figure 6 diagrams the two macro cycles, instructional design, and retrospective analysis.

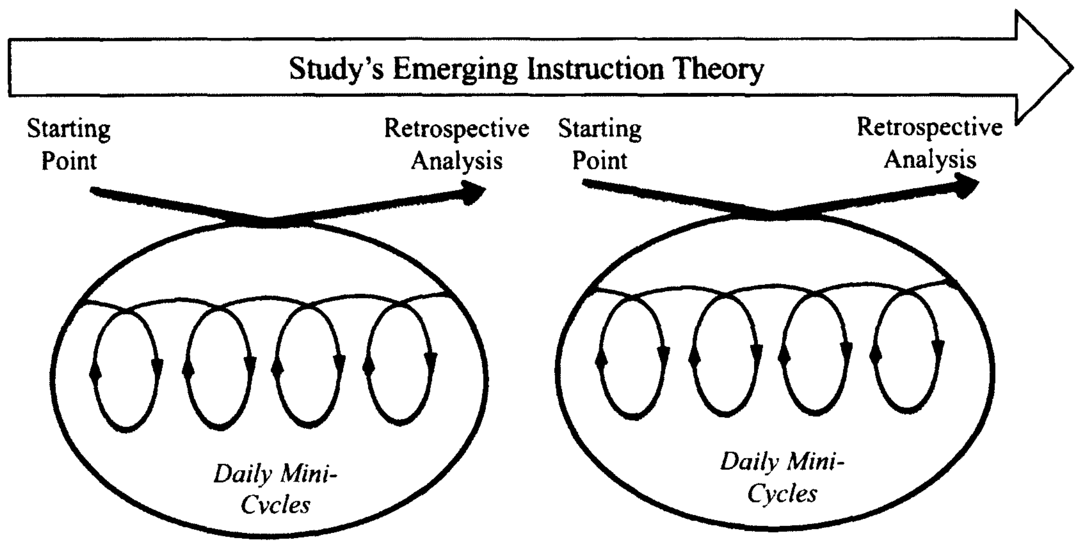

Figure 6. This figure illustrates the two macro cycles. It depicts the mini-cycles conducted within each macro cycle in order to achieve retrospective analysis to adjust and refine the study's instrument (Gravemeijer & Cobb, 2006).

The three phases were conducted twice over two macro cycles in order to achieve a refined instrument at the end of the study. Therefore three K-2 participants were used in the first macro cycle to test and refine the instrument, and the other three K-2 participants were used in the second macro cycle of the study to further refine and validate the instrument. The researcher initiated each macro cycle with a survey to generate a baseline and create demographic quantitative data for each macro cycle. Figure 7 and 8 illustrate the events of the first and second mini cycle respectively.

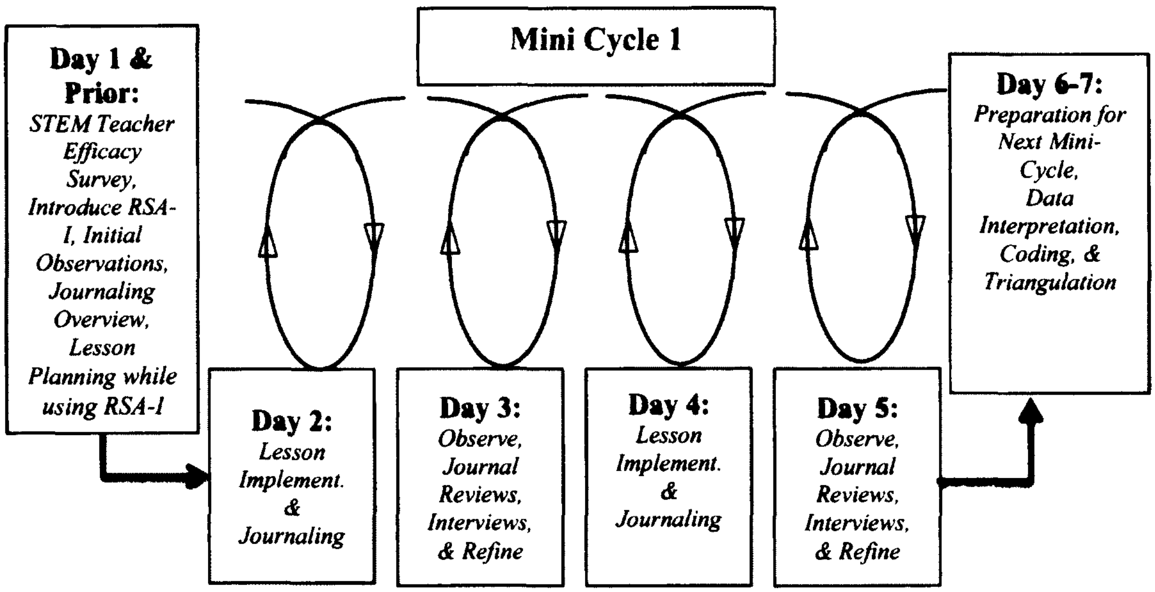

Figure 7. This figure illustrates the first mini-cycle in the study.

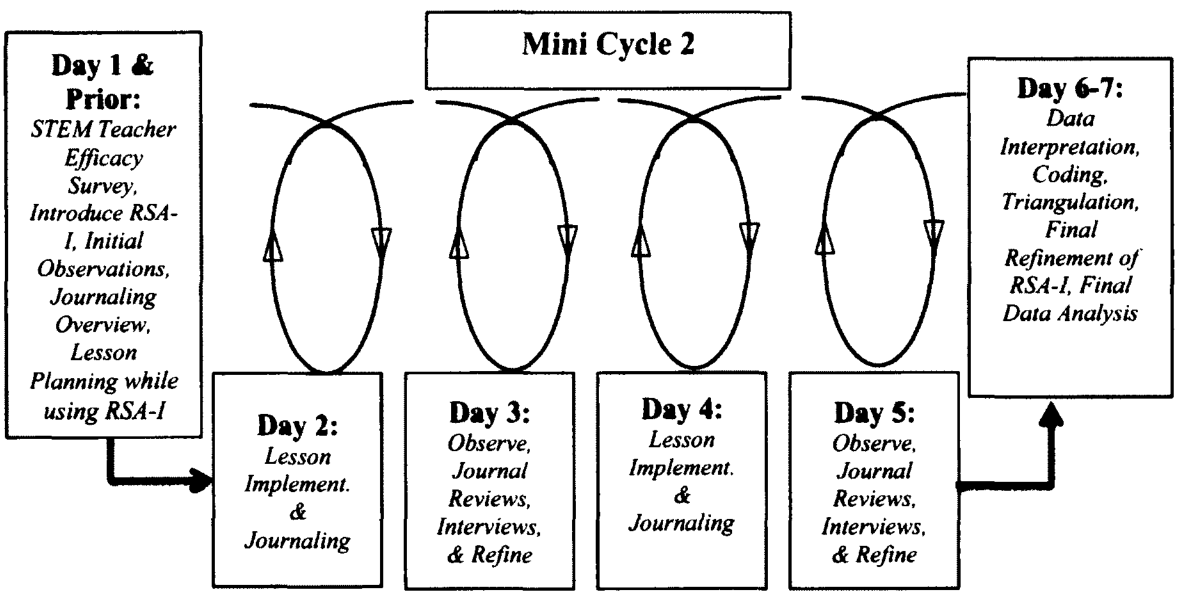

Figure 8. This figure illustrates the second mini-cycle in the study.

Classroom Observations and Clinical Interviews. The researcher observed each teacher giving an integrative STEM education lesson on Day One, prior to implementation of the instrument. This allowed the researcher to establish a baseline integrative STEM education lesson for the study. The researcher observed another lesson on Day Three. This allowed the teacher two days of implementing the self-assessment and reflective practice tool. The researcher then observed the teacher giving another integrative STEM lesson on day five, the final day (Day Five) of the macro cycle. Furthermore, integrative STEM lesson plans were collected each day to determine any changes or improvements made utilizing the instrument. The researcher also met with each teacher on the first, third, and fifth day to conduct clinical interviews regarding the study's instrument.

Analysis

Teacher STEM Efficacy Survey. Demographic responses were analyzed using frequencies and measures of central tendency. The demographic data provided a description of the study's participants. The STEM self-efficacy responses were also analyzed utilizing measures of central tendency (mean, median, standard deviation, and frequency). Any comments or open-ended responses were grouped into common themes and reported accordingly.

Reflection and Self-Assessment Instrument. For this portion of the study, teacher interviews, observations/field notes, and journal data were analyzed utilizing a grounded theory approach. According to Corbin and Strauss (1990; 2007), researchers should utilize grounded theory in qualitative research when they are trying to move beyond description and generate or discover a theory. They assert that as participants experience an intervention/instrument, the development of the theory might help explain the practice, and it can lead to the development of a framework for research. Hence, the participant data that is collected will generate an explanation of a process or action shaped by the view of the participants. Table 8 provides an overview of the Research Goals and data analysis techniques that will be utilized for this study.

Table 8

Research Goals and Analysis Methods

Research Goal	***Focal Component***	***Instrument***	***Analysis***
RG_1: Determine the initial STEM self-efficacy level for the study's participants.	Initial STEM self-efficacy levels	STEM Teacher Efficacy Scale/Clinical Interviews	• Descriptive Statistics (Frequency; Mean, Median, Standard Deviation); Clinical Interviews
RG_2: Utilize theories of reflection and self-assessment to create an instrument that an elementary teacher could use to prepare and assess an integrative STEM lesson.	Self-Assessment & Reflection Theories/ Practices Requirements of an integrative STEM education lesson	STEM Self-Assessment and Reflective Practice Instrument	Triangulation & Cross-Referencing of: • Artz et al. (2008) Phase Dimensional Framework (PDF) • InTASC/Integrative STEM Education characteristics (Table 3) • Thoughtful Lesson Plan Benefits Characteristics (Table 5) • Zeichner and Liston (1996) Key Features of Good Teacher Reflection (Table 6) • Boud's (2003) Criteria for Good & Poor Self-Assessment Practices (Table 7)
RG_3: Refine the instrument through two design-based research macro cycles to ensure appropriate content and applicability for use in a K-2 elementary classroom.	Instrument Application Instrument Utility	Clinical Interviews Classroom Observations Teacher Lesson Plans	• Grounded-Theory Coding for patterns, themes, and categories • Triangulation of data to refine STEM Self-Assessment and Reflective Practice Instrument

CHAPTER III

RESULTS

In Chapter II, a conjectured local instruction theory on the use of self-assessment and reflection in creating and assessing integrative STEM lessons was presented. An instrument that embodied this proposed instruction theory was developed, tested, and refined through two DBR macro cycles (Figure 6). In addition, the local instruction theory was tested through each macro cycle to determine needed modifications. During the two macro cycles, data from surveys, observations, journals, lesson plans, and interviews were collected and analyzed to help achieve the following research goals:

1. Determine the initial STEM self-efficacy level for the study's participants.
2. Utilize theories of reflection and self-assessment to create an instrument for preparing and assessing an integrative STEM lesson.
3. Refine the instrument through two Design-Based Research (DBR) macro cycles to ensure appropriate content and applicability for use in a K-2 elementary classroom.

In this chapter, the analyzed data will be presented in two sections. The first section will focus on research goal one, which was to determine the initial STEM self-efficacy levels for the study's participants. Participant STEM self-efficacy levels were established by analyzing the results of the *STEM Teacher Efficacy Scale* (Nadleson et al., 2013) and through data collected from clinical interviews and journals.

The next section will satisfy research goals two and three. By triangulating various research-based studies and theoretical scaffolds (see Table 8), the study's instrument statements for the pre-active, active, and post-active stages were developed and the instrument was then tested. The researcher and a co-researcher independently analyzed data from lesson plans, observations, clinical interviews, and journals to ensure inter-rater reliability. These data were used to further support any modifications of the study's instrument during both macro cycles. A retrospective analysis is provided at the end of macro cycle one and macro cycle two.

Research Goal 1: Determine Initial STEM Self-Efficacy Level for the Study's Participants

The researcher utilized this research goal to determine each participant's initial STEM self-efficacy levels. This baseline was established utilizing Nadelson et al.'s (2013) *STEM Teacher Efficacy Scale*, which can be found in Appendix A. At the beginning of each macro cycle, six participants ($N = 6$) completed the survey prior to implementing the study's instrument.

For reporting purposes in macro cycle one, Participant 1, Participant 2, and Participant 3 were used. Additionally, for reporting purposes on macro cycle two, Participant 4, Participant 5, and Participant 6 were utilized. Questions one through five solicited demographic information such as age, education level, years of teaching experience, and grade level taught. Tables 9, 10, and 11 illustrate the frequency of response for questions two through six.

Table 9

Participant Demographics 1: Gender and Age Range

Gender		**Age**				
Male	*Female*	*20's*	*30's*	*40's*	*50's*	*60's+*
0	6	0	3	0	3	0

Table 10

Participant Demographics 2: Degree's and Years of Teaching

Degrees		**Years of Teaching**					
Bachelor's	*Master's*	*0-5*	*6-10*	*11-15*	*16-20*	*21-25*	*26+*
4	2	0	1	2	1	1	1

Table 11

Participant Demographics 3: Grade Levels

	Grade Levels Taught	
Kindergarten	*First*	*Second*
2	2	2

For participants to effectively implement the study's instrument, they needed to show knowledge of what integrative STEM education is. To confirm this knowledge, question six of the survey specifically asked participants to provide their own definition of integrative STEM education. Table 12 provides all six participant's integrative STEM education definitions.

Table 12

Participant Definitions of Integrative STEM

Participant	***Integrative STEM Education Definition***
1	Applying equal attention to the objectives of two or more of the STEM fields (science, technology, engineering, math). Also, involving students in the solution to a problem through hands-on experiences is an important learning process.
2	Incorporating as many of the key elements from STEM and planning and carrying out those in delivery of lesson.
3	Students have a solid knowledge base of the math or science to be integrated. They should have time to understand the problem given and they should have time to plan for the solution. They should also understand any technology that will be used. After engineering a solution, they should be able to communicate what worked and what could be better done. After he finished product is presented, it should show student's application of what they learned.
4	An effective integrative STEM lesson is an engaging lesson for students that integrates science, technology, engineering, and math to teach required content. For students, it should include hands-on activities and students should attain the lesson's objectives.
5	A lesson that touches on all aspects of STEM – science, technology, engineering, art, and math.
6	Incorporates science, technology, engineering, mathematics. Measurable. Consistent. Sets parameters that are equal.

Note: These definitions are verbatim, according to each participant listed.

It appeared that all participants did have adequate knowledge of integrative STEM education based on their given definitions. Responses varied from having to include the STEM strands or subjects (science, technology, engineering, arts, and mathematics) in a lesson to a more detailed definition of applying problem solving skills while allowing time for students to build knowledge in STEM areas.

Survey items seven through thirty-one utilized forward and reverse phrased questions that were used to assess each participant's STEM efficacy. A five-point likert scale was used starting with strongly disagree (1), disagree (2), uncertain (3), agree (4), and strongly agree (5). One hundred percent of participants (N = 6) provided responses to all remaining 25 questions. Table 13 provides a paraphrased version of the actual survey questions, number of participants (n), mean response (M), median response (*Mdn.*), standard deviation (*SD*), and interquartile range (IQR) for each question. See Appendix A for complete instrument.

From the survey results, it would appear participants felt confident that that they had the knowledge needed to teach STEM concepts and that they continuously try to find better ways to teach STEM. Survey results also appeared to indicate confidence in their ability to answer student STEM-related questions. Furthermore, participants felt confident that their own teaching effort would affect student performance in STEM areas. Yet, when this question was asked in a reversed-phrased manner, the study findings revealed participants did not feel quite as confident.

Table 13

STEM Efficacy Survey Results

Item	*Question*	*n*	*M*	*Mdn.*	*SD*	*IQR*
7	Teacher effort affects student performance	6	3.67	4.00	0.82	0.50
8	Teacher can find better ways to teach STEM	6	4.33	4.00	0.52	1.00
9	Not teaching STEM subjects as well as other subjects	6	3.33	3.50	1.21	2.25
10	Student grades improve because of teacher's approach	6	3.33	3.50	0.82	1.25
11	Teacher knows steps to teach STEM concepts	6	3.12	3.00	0.75	1.25
12	Not learning STEM can be due to ineffective teaching	6	2.83	2.50	0.98	2.00
13	Teacher ineffective at monitoring STEM experiments	6	2.50	2.00	0.84	1.25
14	Teacher teaches STEM content ineffectively	6	2.50	2.00	0.84	1.25
15	Student backgrounds overcome by good teaching	6	3.33	3.50	0.82	1.25
16	Low STEM success cannot be blamed on teachers	6	3.50	4.00	0.84	1.25
17	Extra attention helps low achieving students in STEM	6	3.50	3.50	0.55	1.00
18	Teacher understanding of STEM concepts allow for effectiveness in all endorsement areas	6	3.33	3.50	0.82	1.25
19	Increased effort in teaching STEM produces little change in STEM achievement	6	2.67	2.50	1.21	2.25
20	Teacher is responsible for achievement in STEM learning	6	3.33	3.50	0.82	1.25
21	Student achievement linked to teacher STEM effectiveness	6	3.00	3.00	0.89	2.00
22	Parent comments of children and STEM abilities related to teacher abilities and practices	6	3.67	3.67	0.52	1.00
23	Difficult to explain to students why some STEM experiments work	6	2.83	2.83	0.75	1.25
24	Teacher able to answer student STEM related questions	6	4.00	4.00	0.00	0.00
25	Teacher has skills necessary to effectively teach STEM concepts	6	3.50	4.00	0.84	1.25
26	Effectiveness in STEM teaching has little influence on student achievement with low motivation	6	2.33	4.00	0.52	1.00
27	Teacher would not invite principal to evaluate STEM teaching	6	2.17	2.00	0.41	0.25
28	Teacher at a loss on how to help student when they have difficulty understanding STEM concepts	6	2.17	2.00	0.41	0.25
29	Teacher welcomes questions when teaching STEM content	6	3.50	4.00	0.84	1.25
30	Teacher does not know how to motivate students to learn STEM content	6	2.17	2.00	0.41	0.25
31	Even teachers with good STEM teaching abilities cannot help some students learn STEM concepts	6	3.33	3.00	0.52	1.00

Note: Questions listed are paraphrased from original survey. See Appendix A for complete survey. Also, *n* denotes number of participants, *M* denotes mean, *Mdn.* denotes median, *SD* denotes standard deviation, and *IQR* denotes interquartile range.

Consequently, the study's participants also showed some uncertainty in their own STEM abilities. For example, they were uncertain about their ability to teach STEM subjects as well as other subjects and felt uncertain about the steps needed to teach STEM concepts. Yet, when the participants were asked if they had the skills necessary to teach STEM concepts, they strongly agreed with a mean (*M*) response of 3.50. Despite some participant apprehensions in their STEM self-efficacy, participants would still invite the principal in to see their STEM lesson, indicating confidence in their ability to teach an integrative STEM lesson.

Teacher clinical interview analysis – Initial STEM self-efficacy in planning and instruction of integrative lessons. Further evidence of teacher STEM self-efficacy was found in the clinical interview data. Day one of each macro cycle was used to establish a self-efficacy baseline in creating and assessing integrative STEM lesson plans through use of the survey. Additionally, each participant was explicitly asked about their perceived self-efficacy level in creating integrative lessons during the day one interview. Participant self-efficacy levels were mixed in each of the study's macro cycles.

In macro cycle one, responses ranged from comfortable to a moderate-comfort level. For example, Participant 1 rated themself as comfortable in creating integrative lesson plans with comments such as, "*I feel right now pretty confident.*" Furthermore, this participant indicated she felt this way because she had received formal training at a university to create STEM lessons and design briefs. Participant 3 also felt comfortable and had also received formalized university training for children's engineering. She stated, "*I've used technology and children's engineering for at least three or four years. I pretty much can do an engineering project in any subject, so I do.*" Participant 2 indicated a moderate–comfort level and had received no formal university training, only professional development training provided by her school and colleagues. She stated, "*Current comfort level would be somewhat comfortable only because I know the acronym of each of those pieces is and so I can, you know, generally pulling the big pieces it.*" She further elaborated that it was sometimes a challenge to include all four STEM disciplines into one particular lesson. She stated, "*I am definitely not an expert and I am still learning.*"

In macro cycle two, perceived self-efficacy levels for creating integrative lessons varied greatly from comfortable, to moderate-comfort, and moderately uncomfortable. Participant 4 felt comfortable in creating integrative STEM lessons and had received formalized university training. She stated, "*I feel rather comfortable. I've done it for so long. It doesn't mean that I can't improve and do better, but I feel pretty comfortable.*" Participant 5 indicated a moderate-comfort level and said, "*It's not the easiest thing. But I don't feel like it's the hardest thing ever either.*" According to her interview, she had no formal university training in STEM integration, just a school-wide professional development session. Participant 6 felt she was moderately uncomfortable. She had also not received formalized training like Participant 2 and Participant 5. Participant 6 indicated she would rate herself as maybe a four on a scale of one to ten because she was unsure whether she her STEM lessons were aligning with actual integrative STEM components. Table 14 shows participant self-efficacy levels.

When asked about their perceived self-efficacy in instructing an integrative STEM lesson, participants' specified two differing levels of comfort. Participants 1, 2, 3, 5, and 6 indicated some level of ease when instructing integrative STEM lessons. For example, Participant 3 stated she was very comfortable and had, "*also taught other teachers how to do a children's engineering so yes I have a wealth of children's engineering briefs. We even made our own website here at this school, of different briefs we can choose from. So, pretty much you can go there and have a folder and just pull one out that goes language arts, or math or science.*" Participant 6 stated that the instructional piece is easier than the planning piece. She stated, *"I feel pretty confident with thinking on my feet and judging the class where we are at the moment. So the instruction piece is easier for me than the planning piece and that's okay because once you put it down on paper you've kind of learned it, right?"*

Table 14

Self-Efficacy Levels in Creating and Planning an Integrative STEM Lesson

Participant #	***Macro Cycle #***	***Efficacy in Planning an Integrative STEM Lesson***	***Efficacy in Instructing an Integrative STEM Lesson***	***Level of Training***
1	1	Comfortable	Comfortable	University Course
2	1	Comfortable	Comfortable	Professional Development
3	1	Moderate-Comfort	Comfortable	University Course
4	2	Comfortable	Moderate-Comfort	University Course
5	2	Moderate-Comfort	Comfortable	Professional Development
6	2	Moderately-Uncomfortable	Comfortable	Professional Development

Note: This table depicts the study's participant comfort levels in planning and instructing integrative STEM lessons. Furthermore, it shows the type of training received in creating and teaching integrative STEM lessons.

Participant 4 was the only one who indicated her perceived self-efficacy level for instructing an integrative STEM lesson was moderately comfortable. She explained that she felt that way because she had limited knowledge of the technology component in STEM, and felt her instruction might suffer due to this gap in her knowledge. *"If I'm prepared I feel good. It kind of depends on if I have time maybe during morning to make sure I have all the pieces and parts that I need because I just feel like when you're prepared, things usually go better. I'm more uncomfortable to teach it now. Probably the technology to me would be the part I would say I might struggle with the most."*

Research Goals 2 and 3: Create and Refine an Instrument for Preparing and Assessing Integrative STEM Lessons

The researcher established research goals two and three to develop and refine the study's *Reflection and Self-Assessment Instrument*. These research goals also helped to assess and modify the local instruction theory. The study's initial instrument was developed after conducting an extensive literature review. It underwent some revisions during both of the study's macro cycles before achieving final validation. The study's validated instrument can be found in Appendix G.

Retrospective Analysis: Macro Cycle One

The kindergarten, first, and second grade teacher participants were asked to provide an initial integrative STEM lesson plan and to teach a lesson that would be observed by the researcher and a co-researcher. Upon observing each participant's lesson independently, the researcher and co-researcher found that only Participant 1 and 3 had developed an integrative STEM lesson, while Participant 2 only had a science component in her two-day proposed lesson. Participant 1 developed a STEM lesson with social studies focus and Participant 3 also developed a STEM lesson with a mathematical focus.

Participant 1. During macro cycle one, it was noted that Participant 1, a kindergarten teacher, had the necessary components of an integrative STEM lesson. This was further validated after reviewing her lesson plans for the week. In addition to the science, technology, engineering, and mathematics, she also integrated social studies and language arts into her weeklong lesson. The focus of her lesson was on the social studies component and the other STEM components helped to support the social studies lesson that was centered on Christopher Columbus and his journey into the Americas.

Participant 1's lesson began with establishing the necessary science and social studies knowledge her students would need to engage in the week ends design brief that consisted of students designing and constructing a boat just like Christopher Columbus'. For the science component, the class discussed what a hypothesis was. They formed a class hypothesis about Christopher Columbus' crew and how they fit within the various STEM roles. They gathered data to support their hypothesis by reviewing a story they had read earlier in the day. Students also tested objects for buoyancy and made predictions about whether an object would float or not and formulating a hypothesis for each tested object. The mathematics component consisted of students utilizing numbers to sort through data such as number of ships, crewmembers, and establishing a timeline of when Christopher Columbus conducted his journey. Furthermore, Participant 1 had students discuss the mass, size, shape, number, and color of the objects they were testing.

The technology and engineering components consisted of a design brief that was presented at the end of the week. Students had to apply engineering design to create their technological artifact: a boat that could float across a tub of water. Students were challenged to create a mast utilizing one of the geometrical shapes they had discussed in mathematics. They also had to formulate a hypothesis about whether the size of their mast would affect the boat's ability to float. Students gathered data to support their hypothesis by testing their boats in a tub of water. Students were required to brainstorm and provide a design for their mast. Figures 9 and 10 show some of the planning students conducted and the completed project, respectively.

Initially, Participant 1 indicated that she based most of her reflection and self-assessment practices on student feedback and performance. She also stated that she makes notes on her lesson plans of what worked and what did and didn't work. She stated, " *I make notes to myself as I am working with the children particularly, um... for example when I am working in a guided-reading lesson, I will keep sticky notes close by* *and I just make notes to myself, oh I need to go back and re-work this, or this skill needs to be practiced again or this worked well, got it, we are moving on.*"

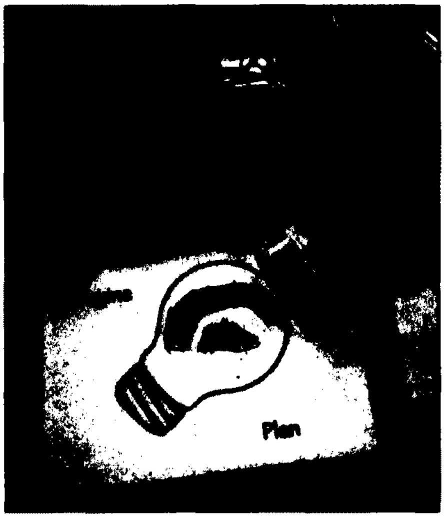

Figure 9. Student Planning.

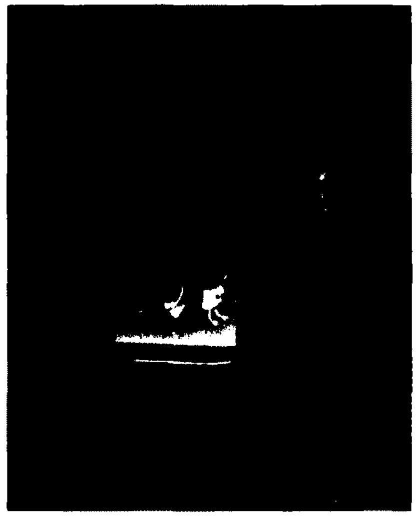

Figure 10. Completed Boat.

It would appear that she describes herself as a reflective practitioner. Yet, the findings of the study seem to show Participant 1's level of reflection and self-assessment improved after the implementation of the study's instrument. She indicated that she enjoyed using the instrument and felt that it provided additional meaningful reflection opportunities, which were very helpful in making adjustments to her integrative STEM lesson. She said, "*When I am looking at the pre-planning and then reflecting on some of these questions that you have written, I think it is important for us to do that. So many times we get in a hurry and we are just trying to get you know that thoughts down and we do not spend the time to reflect on it and those of us who have had the experience, it is important to do that and to remember where these children are coming from and how to begin the process. I felt like this was easy to implement; to take a look at, and then work into my lesson.*" She also stated, "*I just think it is an excellent tool for pre-planning.*"

It is important to note that Participant 1 initially had many integrative STEM characteristics incorporated in her weeklong lesson. For example, she had opportunities for creating a collaborative working environment, utilizing a real-world context to frame a problem for students to solve, utilizing the STEM strands in a trans-disciplinary approach, and motivating and engaging students while allowing them to engage a problem in order to find its solution in her lesson. As her lesson progressed from day one to day five, she refined several features of her integrative STEM lesson. For example, she created an opportunity for students to tinker and test buoyancy. Her initial proposal was for this part of the lesson to be teacher-driven, but she modified it to be more student-driven. Another example involves the design brief. Initially, Participant 1 was only going to have the students tinker with the materials in order to create their prototype. However, she realized that designing and brainstorming is an important step in engineering design, so she created a brainstorming worksheet to guide her students through this process which she felt allowed her students to better understand the engineering design cycle.

Participant 2. For Participant 2, a first grade teacher, the researcher and co-researcher concurred that her proposed lesson plans were based solely on science concepts. There was no evidence of other integrative STEM components. She had indicated this particular lesson would only be two days long: Monday and Friday. On Friday, her intent would only be to have students record final science data in their notebooks. Her science lesson involved scientific inquiry. Students developed a hypothesis on the effect yeast would have on a banana achieving ripeness. Students recorded their initial hypothesis in their science journal and were told they would observe the bananas on Friday to try and validate their initial hypothesis.

Participant 2 supplemented her lesson plans with a midweek lesson that focused on creating a jack-o-lantern (carved pumpkin design) utilizing a children's engineering design brief. After observing the lesson and reviewing the lesson plans, the researchers concurred that this particular day's lesson was an integrative STEM lesson. This day's lesson was mathematics driven and she utilized the other STEM components to support her mathematics lesson. Participant 2 had utilized the pumpkin growth cycle (science), geometrical shapes and counting (mathematics), and a design brief (engineering) that challenged students to create a jack-o-lantern (technological artifact) within the given criteria and constraints. The class had previously read a story that illustrated the pumpkin growth cycle from which the context of the design problem was being derived. Students worked independently to design their own jack-o-lantern. Student's applied problem-solving skills and engineering design to meet the brief's criteria. Student's successfully completed their technological artifacts within the allotted time.

After implementing the study's instrument for several days, Participant 2 revisited her initial science lesson about the ripeness of a banana. Her initial intent was to conclude the science lesson by having student's simply record data in their science notebooks. However, she revised the lesson so she could include integrative STEM components, however her focal subject was science. For example, she had students review their initial hypothesis before revealing the actual results of the banana experiment. Students shared their hypothesis with their classmates. Participant 2 then revealed the bananas and students discoursed whether their hypothesis matched the results. She then provided the students with pictures of the bananas and what they looked like throughout the ripening phase. Another revision included providing a real-world context for the students to ground their hypothesis and data. Participant 2 conveyed that scientists in the field have to find ways to sort their data in order to analyze it properly. Figures 11 and 12 show the sorting circles and the ripened bananas.

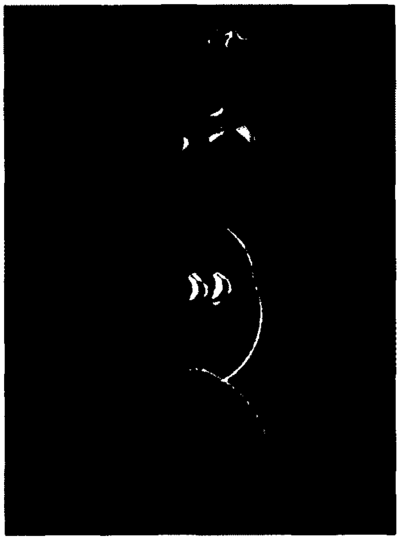

Figure 11. Sorting circles.

Figure 12. Ripened bananas.

Students suggested the use of sorting circles to help analyze some of the data as a class. They sorted the banana pictures by using various criteria: color, size, shape, ripeness, and other similarities (mathematics). Students were then challenged to create a tool (technology and engineering) to display the data prior to writing up their findings in their science journals. Most students created a bar graph to illustrate their data. Furthermore, students completed their inquiry process by recording the findings of the experiment (science). A class discussion ensued to determine why the banana with the yeast had ripened so quickly.

Participant 2 initially indicated a shallow level of reflection and self-assessment practices. She said, "*I do just a brief reflection on what I have, I thought the students might have picked up what they need more time on, what needs to be changed and I* *usually write that at the end of the day in my lesson planning. Um, self-assessment kinda the same thing.*" As the week progressed and she implemented the instrument in her classroom, Participant 2's level of reflection and self-assessment practices seemed to show some improvement. She indicated this had happened because the study's instrument had guided her in creating an improved integrative STEM lesson, which is why she completely revised her initial science lesson.

She also stated it was helpful for her to develop an understanding of what she should expect from her students while conducting integrative STEM lessons. She indicated the instrument provided guidance in how to develop, deliver, and assess her overall integrative STEM lesson, thus she could improve her overall teaching craft. According to Participant 2, " *I feel like I can grow in this. I haven't like... mastered it but I'm not very novice in it either.* " Moreover, Participant 2 said she felt more efficacious by weeks end in her ability to design integrative STEM lessons as a result of the study's instrument.

As the week progressed, both the researcher and co-researcher noticed improved changes to Participant 2's lesson plans and instruction. Initially, she isolated her science content, however by weeks end she had fully integrated it with technology, engineering, and mathematics. Furthermore, she began to include various characteristics indicative of an integrative STEM lesson such as collaboration, real-world problem utilization, cross-curricular connections, problem solving, and she used student motivation and engagement factors to help students stay connected through-out the lesson.

Participant 3. The researcher and co-researcher both agreed that Participant 3, a second grade teacher, had designed a weeklong integrative STEM lesson. She had also included social studies content which would serve as the focal subject for her lesson. Students utilized their fact family knowledge and map skills for their assigned project. Participant 3 introduced students to a children's engineering design brief in which students were asked to design and create a map using fact families (mathematics) as the roads and neighborhoods within their maps. Students would record their process by taking pictures and they were to use calculators to self-assess their proposed fact-families.

Students produced a map (technological artifact and social studies) by employing engineering design throughout the week. For the science component, students used weather concepts and observations for weather phenomena in their planned fact family city. Students were required to present their maps to the class while identifying the STEM concepts they chose, they had to discuss their planning and engineering process, and they had to reflect on what they could do to improve their overall designs. Figures 13 and 14 show some examples of the maps in progress and a completed version.

Participant 3 indicated her level of reflection and self-assessment was not at a critical level. She said, "*[My level of reflection and self-assessment] is probably surface; like I don't go in-depth but I do try, I do try new things and I will try to change things up if I know it didn't work before.*" However, after instrument implementation, it was noted that Participant 3 appeared to be engaging in deeper levels of reflection and self-assessment. For example, in her daily journal she had written about her students' engagement and discussed how to improve it for the next day's lesson. She also contemplated prior knowledge needs, group size for the project, and varied instructional strategies she could use to improve her lesson.

[redacted]

Figure 13. Map in progress.

[redacted]

Figure 14. Completed map.

She noted in her journal, "*I'm reconsidering instructional strategies…using more visuals and changing grouping from 4 to six.*" She also stated in her journal entry, "*Since it is the beginning of the year and they have not worked together that much, smaller groups may be easier for students to understand their job and get along. I think pre-requisite skills for using technology needs to be considered.*" In parentheses she had also noted whether her students would know how to use a calculator or a camera for their projects. As the week progressed, she continued her deeper levels of reflection and consequently, she added an opportunity for her students to reflect on their work during their presentation. She said, "*Thinking about what works and what did not work.. I thought that might be a good question to add like did I provide time for students to reflect on their project.*"

Participant 3 had initially included several integrative STEM components in her lessons, so her lesson plans only underwent slight modifications after instrument implementation. For example, she initially had students using a camera to record their engineering design process. However, she removed the camera component of her lesson because she felt the students needed to document their engineering design process on paper rather than taking pictures while concurrently building their prototype. Another example is the use of the group reflection rather than individual assessment of their project. Because students had worked collaboratively on their map, she also had them assess collaboratively on ways to improve their project as a team.

Retrospective analysis: Macro cycle one instrument modifications. The researcher reviewed all proposed instrument modifications after reviewing Participant 1,2, and 3's lesson plans, journals, and interviews. Furthermore, the researcher triangulated all macro cycle one findings to also assist in the final instrument modifications. Table 15 summarizes all suggested and actual modifications after macro cycle one.

The retrospective analysis for macro cycle one revealed that each participant had strengthened their STEM lesson and planning after instrument implementation. This was most notable in Participant 2's lesson. Her final lesson had all required STEM components, real-world contexts, and students showed great interest in the lesson during the observation. When each participant was asked if they felt that this particular instrument could be helpful in creating and assessing integrative lessons, participants 1,2, and 3 responded that it could.

Participant 1 felt she reflected more critically as a result of utilizing the instrument. Participant 2 stated she was able to draw upon the instrument statements for guidance so she was challenged to revisit her lesson plans and to transform them into integrative lessons. Furthermore, she felt the instrument statements also made her hold herself accountable for areas that she might not have previously considered.

Table 15

Macro Cycle One: Instrument Suggested and Actual Changes

Suggested Changes	Actual Instrument Changes
Pre-Active Phase:	***Pre-Active Phase:***
• Separate STEM into separate disciplines • Remove the word "easily" • Reword "I can make a real-world context" to "students can" make real-world connection • Switch content needs to ability (add differentiate) • Shorten overall instrument • Include a comments sections • Add a statement about grouping students • Teacher needs to consider student grouping for lessons. • Narrow scale; maybe change to 1 to 5 • Change "create" to "design" • Add a statement that allows for student self-reflection	• Statement 1 changed to separate each S.T.E.M. discipline - provided its own scale. • Statement 2 reworded to state "*I can differentiate between each of my students' science, technology, engineering, and mathematics ability levels and learning styles as I plan my lesson*" • The word "easily" was removed from all statements. • Statements 6, 7, & 8 changed from "I can create" to "I can design" • Statement 11 changed from identifying a real-world context to give students to "*I can tie my lesson to a real-world context or problem*" • A statement that reads, "*I have considered how students will need to be grouped for successful completion of this lesson (individual/team sizes)*" was added. • A statement that reads, "*I have allotted time in the lesson for students to reflect on their work*" was added.
Interactive Phase	***Interactive Phase:***
• No change	• No change
Post-Active Phase:	***Post-Active Phase***
• Take out "I gauged my students' STEM content needs correctly"; reword to do they need more content prior to this lesson.	• The statements changed in the Pre-Active stage were also changed to reflect a past tense format of the questions in this section. ***Other Changes***: Extra space was added under Interactive Stage for Comments or Notes.

Note: "*Suggested Instrument Changes*" were proposed by study participants. "*Actual Instrument Changes*" were done based on some participant suggestions and on triangulation of all data from macro cycle one.

She acknowledged that her lessons may not have been collaborative in nature but she said, "*I was thinking 'okay, how can I make this more collaborative next time'.*" She felt the instrument made her reflect and assess her lessons more deeply. Another notable finding is that Participant 2 expressed an increase in her perceived self-efficacy level toward the end of the week. Participant 3 also acknowledged the instruments utility and said, "*I think that would be a great guide for when teachers are learning to integrate*."

Both researchers rated each participant's lesson plans to find an exemplary sample of an integrative STEM lesson plan for macro cycle one. Both researchers concurred that Participant 1's weeklong lesson plan was exemplary because it was found to have strong evidence of many integrative STEM lesson components. Participant 1's lesson plans can be found in Appendix G.

Retrospective Analysis: Macro Cycle Two

The kindergarten, first, and second grade teacher participant provided an initial integrative STEM lesson plan and taught a lesson that was observed by the researcher and a co-researcher. The researcher and co-researcher concurred that that all three participants in this macro cycle had provided a lesson plan that contained integrative STEM components.

Participant 4. After reviewing Participant 4's lesson plans, the researcher and co-researcher found that her lesson was an integrative STEM lesson. She indicated her weeklong lesson would be science-centered and based on pumpkins. At the beginning of the week, Participant 4 established some foundational knowledge in science and mathematics. The class discussed buoyancy and the scientific inquiry process while making predictions regarding the sinking or floating of different objects they were going to test. Furthermore, the class discussed the various mathematical properties of the tested objects. Participant 4 explained how these objects were also technological tools. In addition she had students discourse about how each object they tested qualified as a technological artifact.

Once this knowledge was established, Participant 4 introduced the pumpkin growth cycle (science). Student knowledge was assessed by ordering a pumpkin's growth cycle on a piece of yarn that would be used in their culminating engineering project at the end of the week. Participant 4 then read a story that served to introduce a problem that was being posed to the students through the children's engineering design brief: students were challenged to create any geometrically shaped pumpkin (mathematics) that had two cutout eyes, a nose, and a mouth. In addition, students were also challenged to figure how to attach their life-cycle yarn (technology and engineer) onto their finished artifact. Students produced various shaped pumpkins that met the design briefs criteria. Figures 15 and 16 show two completed technological artifacts.

Similar to Participant 3, Participant 4 had also initially embedded several integrative STEM components in her lesson so her lesson plans only underwent slight modifications after instrument implementation. For example, she had not initially included a real-world context to her lesson, so she added that component. She also included more opportunities for creating technological artifacts that tied back to her lesson. It was noted by the researcher that her overall lesson also improved after instrument implementation. For example, Participant 4 had expressed concern over her technology knowledge. She had initially indicated her self-efficacy in this area as needing improvement. Yet, she worked toward adding opportunities to apply technology throughout the week after instrument implementation.

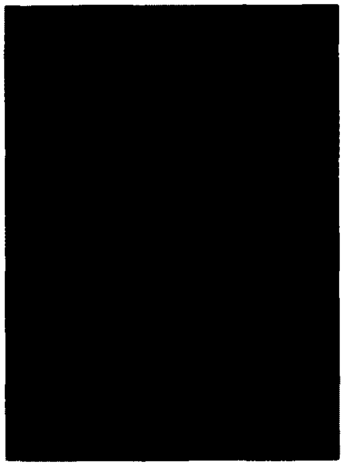

Figure 15. Completed pumpkin with planning shown.

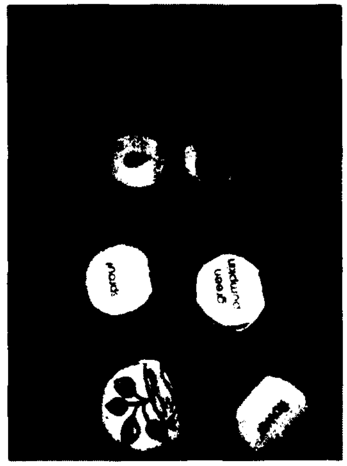

Figure 16. Completed pumpkin with life cycle attached.

Participant 4 had indicated her reflection and self-assessment practices were done sporadically throughout her instructional time. She explained that she did this type of reflection because she was trying to make her instruction purposeful. Furthermore, she did not feel like she had any other time to consistently reflect at deeper levels. She stated, "*I feel we have so little time in the day to reflect. We're going from one thing to the next. And we're trying to stick to that timetable. I would try to fit so much into the day I feel like there's not much time for me to reflect until after school when the kids are gone. And then there are other things to do like errands, and life happens.*" When the researcher inquired if she did that type of reflection for most her lessons she said yes. This appeared to indicate there wasn't a deep level of reflection she felt she was engaging in.

It appeared that Participant 4 felt reflection and self-assessment was not a practical strategy for her based on her initial interview and journal entry. However, after implementing the instrument throughout the week she said the instrument made her "*go back and focus much more in depth than I think I would have.*" She indicated the instrument helped her improve her overall lesson as it helped her consider integrative STEM components she may not have initially focused on prior to its implementation.

Participant 5. After reviewing Participant 5's data, the researcher and co-researcher concurred that her weeklong lesson plan was also an integrative STEM lesson. She indicated her lesson was science-centered and would focus on pumpkins as well. Students investigated the various mathematical and science properties of pumpkins during the week. Science components included the pumpkin growth cycle, five senses, and scientific inquiry.

Mathematics components included the use of weights, measurement, temperature, and discourse of geometric concepts utilizing pumpkin characteristics. Participant 5 also provided a real-world context by challenging students to determine how they could act like scientists to sort collected data to compare pumpkin features. Collaboratively, students suggested and created a graph for their data (technology and engineering components).

Both the researcher and co-researcher observed students working through their culminating engineering project at the end of the week. Students created a pumpkin that had one moveable part and fit within the other parameters set in the engineering design brief: two cutout eyes, one nose and a mouth. Students were instructed to draw upon their previous knowledge of pumpkins to create their technological artifact. Students underwent the engineering design process to complete their project. Figures 17 and 18 show completed pumpkin artifacts.

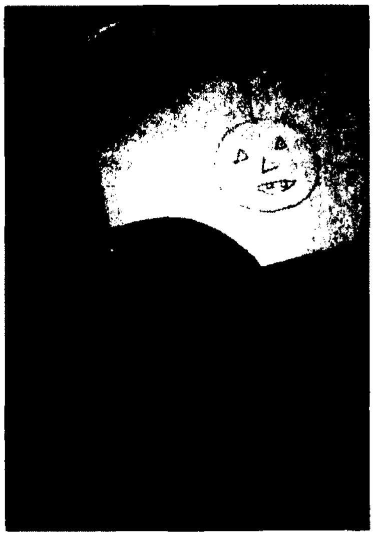

Figure 17. Pumpkin with moveable part and planning.

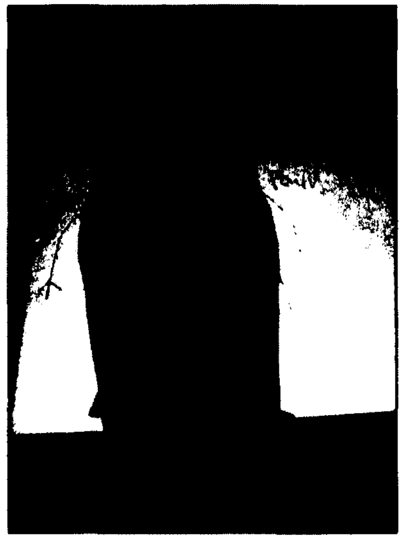

Figure 18. Pumpkin undergoing improvements. After self-assessing his work, this student found he had forgotten the moving part component.

As Participant 5's lesson progressed during macro cycle two, it was noted that her lesson plans also improved. Although she did integrate science, technology, engineering, and mathematics in her lesson, it was noted that she revised a few details in her plans in order to improve her lesson. For example, Participant 5 had originally planned on having students individually utilize a pre-made diagram for comparing pumpkin characteristics. She chose to do this collaboratively and to allow students to decide what type of technological tool they felt was most applicable and useful. Another example is that of her mathematics components. In her original plans, Participant 5 only had students graphing as her mathematics component. However, as her lesson progressed, her she included standard and non-standard measurement skills, utilization of a scale for measurement, and temperature. This revision was notable as she used mathematics concepts students were learning as an integration medium to connect the use of mathematics and science to appropriate technological tools. Finally, she also included a self-reflection component for her students during her culminating project that led students to undertake an improvement step in their technological artifact development.

The reflection style of Participant 5 was similar to that of Participant 4's; she also reflected sporadically during instruction. However, it appeared she was more open to the benefits of reflection than Participant 4. Participant 5 said, "*I think definitely the more you kind of think about what you're doing and take a deeper look at your lessons I could definitely benefit from that and I think it would definitely make me feel more comfortable [in teaching integrative lessons].*" She also expressed that time constraints limited her reflection time. Participant 5 also felt the instrument was helpful to her as it drew her attention to the various integrative STEM components she may have not fully considered. It seemed Participant 5 had become more reflective in her practice after the weeklong instrument implementation as she was no longer reflecting and self-assessing concurrently and sporadically, but rather she was utilizing these practices more purposefully. She said she thought more and more, "*Did I really have the components that I thought I had? Was I doing science, technology, engineering, math? And did I hit on what my targets or objectives were? So, it really helped me to go back and think about all these things*."

Participant 6. The researcher and co-researcher concurred that Participant 6 had the components necessary to conduct a weeklong integrative STEM lesson in her class. Her integrative STEM lesson for the week would be social studies driven. Participant 6 assessed her students' prior map skills knowledge through a written assessment then reviewed cardinal directions, a compass rose, and basic map skills. The class discoursed about the importance of utilizing maps in a real-world context. The students were then instructed to create a floor plan of their room as homework and to provide directions from the front door to their room. Students were encouraged to measure length and width of their room using non-standard measures and using standard measures with aid from a parent.

As the lesson progressed during the week, Participant 6 discussed how maps use mathematical concepts such as patterning, geometric shapes, angles, measurement, scales, and size. The students also discussed types of maps and other ways they could be used, particularly if they were scientists. Students discussed map utilization in tracking weather phenomena over various geographical locations, topography, animal habitats, and other such phenomena (science concepts).

Students received their culminating project directions at the end of the week through a design brief (engineering). In the given design brief, students were tasked to design a map of the school (technological artifact) and surrounding area. Students had to create directions to get to their classroom from the school entrance and use repeated patterns in their directions (mathematics). Furthermore, students were instructed to use a compass rose, scaling, and geometric shapes in their maps (social studies and mathematics). Students completed their maps in class and shared with the class. Figures 19 and 20 show some student artifacts in progress. Participant 6 considered herself a reflective practitioner as she indicated she said she found a lot of value in the act of reflecting and self-assessing.

Participant 6 based her reflections on her own desires to improve her level of instruction as she felt it ultimately impacted her students' learning. She indicated that reflection and self-assessment helped improve her teaching because it allowed her to view her instruction and lesson components from a wider lens so she could alter her activities to provide better learning opportunities. She said, "*I think that assessing yourself along the way, you're checking points to make sure you have all those pieces. You're kind of picturing it in your mind the actions that are going to be taking place during the lesson.*" Participant 6 indicated the instrument was helpful in helping her improve her overall integrative STEM lessons.

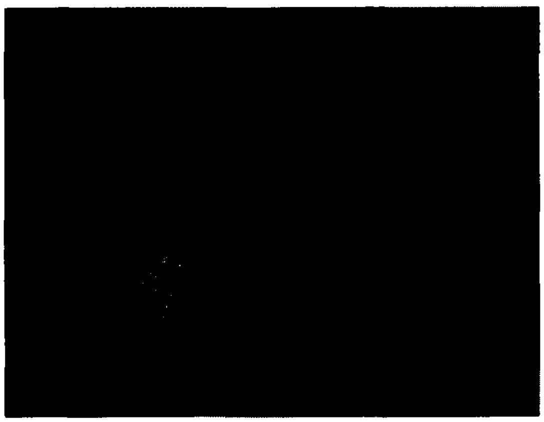

Figure 19. Map in progress with some of the required criteria from the brief.

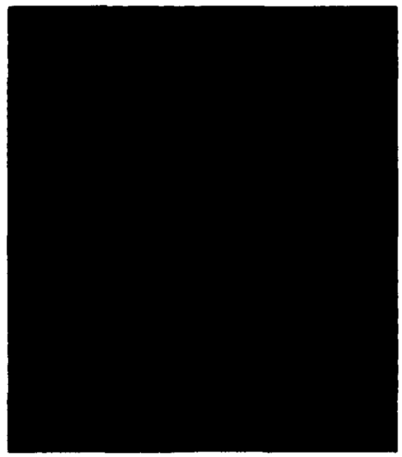

Figure 20. Map in progress with some of the required criteria from the brief.

After triangulating data for Participant 6's lesson, it was determined that she had also improved her integrative STEM lesson. Participant 6 modified several components in her lesson to further align with the characteristics of an integrative STEM lesson. For example, her initial plans revealed her students would be working independently on their design brief. She changed that part of her lesson to create a more collaborative environment.

Furthermore, Participant 6 had students brainstorm, plan, and create maps throughout the week, not just on the culminating project. She promoted the continued use of the engineering design process. She was able to assess knowledge levels of students by conducting a pre-assessment on maps skills, so she was able to modify her instruction accordingly. She also added a real-world context to her map design brief. Additionally, Participant 6 had students reflect and self-assess as they utilized their week's work to assess their own map skills, which seemed to allow for students to extend their learning.

Instrument modifications and summary of retrospective analysis - Macro cycle two. The researcher and co-researcher coded and triangulated all interviews, journals, lesson plans, and observations for this macro cycle to determine any additional modifications that would be made to the instrument. From these data, only a few changes were identified and made this macro cycle. Table 16 illustrates the suggested and actual changes made to the instrument. The study's final instrument is found in Appendix F.

Of notable consideration in macro cycle two is the improved quality of the lessons that were provided throughout the week. The researchers found that teachers became more detailed, noted characteristics of integrative STEM lessons they could further embed in their lessons, and began to contemplate how they could improve the details they were noticing. For example, Participant 6 had noted on her instrument that she decided to "*change a procedure at the last minute to allow for more creativity and collaboration*" so it was "*not too well developed and structured for the kids.*" Participant 5 noted that her day five "*lesson went well and the more hands on it is for the kids, the more engaged in it*" they seemed. Participant 4 noted an opportunity to involve students in the use of her Smartboard during part of her lesson on buoyancy, which she felt would be of benefit to her students. She stated, "*I did [notice that opportunity] because of this instrument. That was something I reflected on how I could've tied that in; and I just didn't think to do it originally.*" After rating this particular macro cycle's lesson plans, it was determined that

Participant 1 still had the most exemplary integrative STEM lesson plan of both macro cycles. However, macro-cycle two had the most consistent integrative STEM components throughout the two macro cycle lesson plans collected.

Table 16

Macro Cycle Two: Instrument Suggested and Actual Changes

Suggested Changes	***Actual Instrument Changes***
Pre-Active Phase:	***Pre-Active Phase:***
• Create two statements for state and country standards/requirements. • Create two statements for state and country standards/requirements. • Separate abilities and learning styles • Add space for comments and examples under STEM strands.	• Statement 1 changed to allow space for comments or examples under each STEM strand • Statement 2 split into two separate statements to state "*I can differentiate between each of my students' science, technology, engineering, and mathematics ability levels as I plan my lesson*" and "*I am taking into consideration each of my students' learning styles (auditory, kinesthetic, visual, etc.) for this particular STEM lesson.*"
Interactive Phase:	***Interactive Phase:***
• No changes/no suggestions;	• No changes
Post-Active Phase:	***Post-Active Phase***
• No changes/no suggestions	• The statements changed in the Pre-Active stage were also changed to reflect a past tense format of the questions in this section. In addition, in statement 1, a space for comments or examples under each STEM strand was also added.

Note: "*Suggested Instrument Changes*" were proposed by study participants. "*Actual Instrument Changes*" were done based on some participant suggestions and on triangulation of all data from macro cycle two.

Lastly, after coding and triangulating all observations, field notes, interviews, and instrument revisions, the researcher felt confident in not making any further changes to the instrument within this study's context. Therefore, the study's established research goals two and three, which were to create and refine the reflective and self-assessment instrument through two DBR macro cycles have been fulfilled.

CHAPTER IV

DISCUSSION AND CONCLUSIONS

Findings

The researcher aimed to develop a reflective and self-assessment instrument elementary teachers can utilize in preparing and assessing integrative STEM lessons. Three research goals guided the development of this tool:

1. Determine the initial STEM self-efficacy level for the study's participants.
2. Utilize theories of reflection and self-assessment to create an instrument for preparing and assessing an integrative STEM lesson.
3. Refine the instrument through two Design-Based Research macro cycles to ensure appropriate content and applicability for use in a K-2 elementary classroom.

This study began with the design of a conjectured local instruction theory about the use of reflection and self-assessment in the planning and assessment of integrative STEM lessons. This conjectured instruction theory relied on two parts: a learning process and the means to support that process (Gravemeijer et al., 2006). For this study, a way to support teachers in the creation and assessment of integrative STEM lessons was through the development of the study's instrument that embodied the conjectured local instruction theory. Using the results, this chapter will present how this conjectured instruction theory is supported through the modifications made to the study's instrument. In addition, the researcher will also present how teacher's self-efficacy levels and integrative STEM lessons were impacted through the implementation of the study's instrument.

Conjectured Local Instruction Theory

As previously noted, a conjectured local instruction theory requires a means to achieve a certain learning process (Gravemeijer et al., 2006). For this study, the conjectured local instruction theory was based on the use of self-assessment and reflection in creating and assessing integrative STEM lessons. Researchers have found compelling evidence to support practitioner use of reflective and self-assessment in order to assess and improve instruction and planning (Art et al., 2008; McCombs, 1995; Ross & Bruce, 2007a; Tabachnick & Zeichner, 1991; Valli, 1992; York et al., 2006). Therefore, the researcher developed the study's instrument to serve as a means to test the conjectured local instruction theory. Furthermore, the instrument allowed the researcher to determine if the conjectured instruction local theory needed to be extended or modified. Study findings showed that through the use of the study's reflection and self-assessment instrument, practitioners were able to create, assess, and even improve their lessons by applying these strategies throughout the pre-active, active, and post-active stage of a lesson.

Participants also showed improved teacher self-efficacy toward the end of their respective macro cycles. For example, Participant 4 indicated a gap in her initial STEM subject knowledge. Nevertheless, at the end of her respective macro-cycle, she felt more efficacious in her ability to design, instruct, and assess an integrative STEM lesson. Another example of improved teacher self-efficacy came from Participant 2. She was able to revise her initial science lesson to include integrative STEM components which she believed better aligned with her desired student learning outcomes. As the conjectured instruction theory proffers, teachers who self-assess and reflect are better able to create and assess integrative STEM lessons. The study's instrument provided teachers with opportunities and insight into utilizing self-assessment and reflection as they created and assessed their integrative STEM lessons. Thus, tools that allow teachers the opportunity to self-assess and reflect, such as the study's instrument, can contribute to improved teacher self-efficacy. Therefore, the conjectured instruction theory can be extended to include improved teacher self-efficacy beliefs.

The study findings also appear to show that implementation of the study's instrument allowed teachers to utilize self-assessment and reflective practices to organize and better understand the integrative STEM lesson components that should work toward improving their students' learning. As White (1991) proffered, researchers have struggled to understand how teachers themselves organize and understand their problems as they relate to curriculum and learner goals, goals for specific individuals, and feelings or emotion. As shown in study data, participants were able to connect curriculum with individual student learning goals as they assessed their lessons and instruction. As participants questioned themselves using the instrument's statements they were able to focus on their student's learning needs. This was most notable with Participant 2, who indicated she revised her science lesson because she felt it was not meeting her students' individual STEM objectives or learning goals. Hence, the conjectured local instruction theory can also be extended to include how the use of such a tool can appear to improve organization and understanding of curriculum and learner goals.

Participant Self-Efficacy Levels

Notable efficacy changes were seen throughout macro cycle one and macro cycle two in the study's participants. According to Zeldin, Britner, and Pajares, (2008), self-efficacy beliefs are important in STEM domains, particularly for elementary practitioners (Brand & Wilkins, 2007). Furthermore, research shows low efficacy beliefs impact student learning as they can lead to misconceptions and improper instruction of STEM concepts (Nadelson et al., 2013). As shown in studies conducted by Ross and Bruce (2007), efficacy is something that can be improved, particularly if a practitioner engages in some sort of professional development. While the study's instrument was not considered professional development, the participants did express better self-awareness for what an integrative STEM lesson should be after utilizing it for the week. Gusky (2002) asserts that teacher attitudes and beliefs are derived from classroom experiences, hence if a teacher tries out a new planning approach or teaching strategy and it is deemed successful by the teacher, then the teacher is likely to change their beliefs. As participants engaged in the use of the study's instrument, self-efficacy levels and teacher beliefs seemed to improve and change as each participant expressed that the instrument was helpful and allowed them to look at their planning and instruction in a different way. This was evident through the interviews, journals, and lesson improvements seen toward the end of each macro cycle.

Utility of Reflection and Self-Assessment Practices and the Study's Instrument

Another conclusion that can be drawn from this study's findings is that although some lessons already had integrative STEM lesson qualities, the use of the research instrument helped the participants continuously improve their integrative lessons. For example, Participant 2 revisited a lesson she noted was not a true integrative STEM lesson and revised it in order to make it more characteristic of an integrative STEM lesson. She said she felt it allowed her students to make better cross-curricular connections rather than to just isolate the science component. Participant 6 also felt compelled to make a last minute change to allow for more collaboration as she felt it would keep her students more engaged.

Participant 4, who initially acknowledged a technology knowledge gap, became more efficacious in this area after implementing the study's instrument. Furthermore, the interviews and journals showed Participant 4 changed her beliefs about the use of reflection and self-assessment as she saw through her classroom experience how through the use of the instrument her lessons, STEM self-efficacy, and also student engagement improved.

Importance of Thoughtful and Effective Lesson Planning

An important finding in this study was developing an understanding of the importance of lesson planning, particularly integrative STEM lesson planning. While lesson plans are already an enigmatic process for some teachers, developing a thoughtful and effective lesson plan while utilizing STEM concepts proved to be important.

As evident in the lesson plan evaluation process, the researcher and co-researcher were able to easily identify the STEM components present in the lesson. The lesson plan also served as a reflective and self-assessment tool for the study's participants as they were also able to gauge what integrative STEM components they had and what they did not have. Participant 2 was able to revise her initial plan to create a successful integrative STEM lesson. Had she not utilized her plan and the reflective process, she may not have realized what components she was missing.

Furthermore, the better devised lesson plans, like that of Participant 1 who's lesson plan was deemed the most exemplary of the participants, connected student learning to the desired lesson plan objectives and met the state/county required standards. Her students were able to successfully connect their cross-curricular learning to a real-world context while understanding the importance of problem solving.

Limitations of the Study

There are several limitations the researcher considered for this study. One limitation included the definition of STEM education. STEM education has many meanings and definitions; therefore there is no universally accepted definition of STEM education (Ostler, 2012; Sanders 2009). For the purposes of this study, STEM education was defined as an opportunity for students to learn through a trans-disciplinary approach by applying science, technology, engineering, and mathematics in real-world contexts while allowing teachers the ability to apply rigorous academic concepts in order to bridge classroom learning with global 21st century skills (Lantz, 2009; Tsupros, Kohler, & Hallinen, 2009).

Another limitation included participant reflection levels. While the study's instrument intended to have the participants reflect at more critical levels, there is no true way to test for the level of criticality of their reflective practices during their respective macro cycles. Although the participants were explicitly asked what they currently did for reflection and self-assessment, it is still subject to self reporting which has limitations of its' own. Kruger and Dunning (2009) posit that unskillfulness in self-assessment can result in an inflated perception of what is "truly" known and what is not. Hence, this unskillfulness can also lead to failure of recognizing what is "truly" known and what is not. Therefore, this becomes a limitation to the study.

The another proposed limitation for this study included the study's population. For purposes of this study, the researcher chose to utilize six participants in total, two kindergarten, two first, and two second grade teachers. This population size may not be generalizable to the population at large. Additionally, the criteria set forth for choosing the study's school is limiting. At the time the study was implemented, only nine elementary schools had been recognized by a particular teaching organization to receive the distinct STEM award chosen by the researcher for study purposes. Other schools that have outstanding STEM elementary programs could have been used who may not have heard of this particular award, thus rendering a small population size. Furthermore, only primary elementary teachers were selected to utilize and refine the study's instrument. Although foundational STEM knowledge is developed throughout elementary school, this study limited its participant to early elementary (primary), excluding the latter elementary grades that could have provided further data.

Another limitation is in the study's design. To try and limit the possibility of the Hawthorn Effect, the researcher only observed the participants three times during the week instead of everyday. This allowed the participants space and time to determine if they wanted and how to implement the study's instrument.

Areas for Future Study

Upon completion of the study, there were several areas the researcher identified for future research based on the findings presented. For this study, the researcher focused on early elementary (primary) grades because foundational STEM concept knowledge is developed during this time. A study focusing on the latter elementary grades and teacher's utilization and refinement of the study's instrument should be considered. The researcher also suggests conducting a longitudinal study to determine the long-term utility of the instrument, as this study was limited to two weeklong macro cycles.

Another suggested study includes determining if a teachers' belief system changes after the utilizing the instrument should be conducted to determine if the instrument can alter their initially held beliefs. Also, a study to determine what professional development endeavors teachers' undertake once they utilize the study's instrument is recommended. Finally, a study to determine if teachers who utilize this instrument positively affect student-learning outcomes in STEM content areas is also suggested.

Conclusion

The researcher contributed an instrument that could benefit elementary practitioners in their already daunting task of creating and assessing integrative STEM lessons. As Gusky (2002) proffered, "[to a] vast majority of teachers, becoming a better teacher means enhancing student learning outcomes" (p. 382). For teachers' beliefs to be positively changed, they need to perceive the results of their actions as having a positive impact on their students. Furthermore, Gusky asserts teachers' attitudes, efficacy, and beliefs are grounded in their classroom experience. As the study's participants saw the success and engagement of their students through each of the study's macro cycle, their beliefs, attitudes, and efficacy appeared to shift a more positive level.

Professional development is another key area that research (Nadleson et al., 2012, 2013; Ross & Bruce, 2007; & Stohlman et al., 2012) shows will contribute in STEM content areas, particularly in primary grades as students are immersed in 21st century skill development and STEM foundational knowledge is developed. As shown in the findings of this study, the more professional development the participant had the more confident they appeared to feel in their ability to deliver an integrative STEM lesson. Longitudinal studies that follow STEM professional development, particularly at an elementary level, should be undertake to determine its' impact on teachers and learners.

If K-12 practitioners are going to be required to integrate STEM education, 21st skills, and habits of mind in their daily school routine, then it is imperative to provide them with the necessary tools to accomplish this means. Research-based, well-rounded, and teacher-tested and teacher-approved instruments or professional development can make a difference in how we move forward in preparing students to face a globally competitive society.

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Appendix A: Teacher Consent and Survey Instrument

You are invited to participate in a research study that seeks to develop, refine, and validate a reflective and self-assessment practice instrument that can be utilized in creating and assessing integrative STEM lessons and instruction. The study is being conducted as part of the dissertation requirement by Diana V. Cantu, a PhD Candidate at Old Dominion University with direct oversight by Dr.'s Phil Reed and Helen Crompton of Old Dominion University.

There are several components to this research. The time commitment for this study is five instructional workdays. The first part of the study is this online survey that measures your comfort level in delivering integrative STEM instruction. Integrative STEM education is defined as the bridging of two or more STEM subjects during instruction. During the next part of the study, you will be asked to evaluate and refine a reflective and self-assessment practice instrument in creating and assessing your integrative STEM lessons and instruction. During this time, you will be asked to participate in several clinical interviews, allow the researcher to conduct classroom observations of integrative STEM lessons, and maintain a journal on your reflection/self-assessment process. You will receive a $75.00 Visa gift card for participating in the weeklong study.

This survey should take approximately 20 minutes to complete. The survey will ask you to provide: (1) demographic information about yourself, your teaching experience, and your current grade level; (2) and your comfort level in teaching integrative STEM education. For purposes of this study, integrative STEM education will be defined as the purposeful and natural integration of science, technology, engineering, and mathematics through student application of technological or engineering design problems.

Data will be compiled into an aggregate summary report format for use by XXXX. You will be asked to create a codename that only you and the researcher will be aware of in order to protect your identity and data. Any data collected from you will be secured on a password-protected computer and password encrypted file. Please be aware that there are no known risks for participation in this study. Your participation is completely voluntary and there is no penalty or loss of benefits if you choose not to participate or exit the survey at any time. You may choose not to answer any question just by skipping it.

By clicking on the start button, you are indicating your consent for the answers you supply and participation in this research. This consent also includes permission for classroom observations and subsequent interviews. Thank you for your cooperation and willingness to assist me in this research!

If you have any questions, you may contact Diana V. Cantu at 804-318-7237 or through email at dcant005@odu.edu. You may also reach Dr. Phil Reed or Helen Crompton by calling (757) 683-4305.

Appendix A: Teacher Consent and Survey Instrument

Demographic Information:

Q1. Select your gender: ___ Female ___ Male

Q2. Select your age range from the list below.

- □ 20s
- □ 30s
- □ 40s
- □ 50s
- □ 60+s

Q3. Select your highest level of education completed:

- □ Bachelors degree
- □ Masters degree
- □ Doctorate degree

Q4. Select the number of years you have been in the teaching profession.

- □ less than 4
- □ 5-10
- □ 11-15
- □ 16-20
- □ 21-25
- □ 26-30
- □ 30+

Q5. Select the grade level you are teaching this year (check all that apply):

- □ Kindergarten
- □ 1^{st}
- □ 2^{nd}

Q6. How would you define an effective integrative STEM lesson?

STEM Efficacy Survey:

Q7. When a student does better than usual (or expected) in STEM content, it is often because the teacher exerted a little extra effort.

□ *Strongly Disagree* □ *Disagree* □ *Uncertain* □ *Agree* □ *Strongly Agree*

Q8. I am continually finding better ways to teach STEM concepts.

□ *Strongly Disagree* □ *Disagree* □ *Uncertain* □ *Agree* □ *Strongly Agree*

Q9. Even when I try very hard, I don't teach STEM topics as well as I do other subjects.

□ *Strongly Disagree* □ *Disagree* □ *Uncertain* □ *Agree* □ *Strongly Agree*

Q10: When the STEM grades of students improve, it is most often due to their teacher having found a more effective teaching approach.

□ *Strongly Disagree* □ *Disagree* □ *Uncertain* □ *Agree* □ *Strongly Agree*

Q11: I know the steps necessary to teach STEM concepts effectively.

□ *Strongly Disagree* □ *Disagree* □ *Uncertain* □ *Agree* □ *Strongly Agree*

Q12: If students are underachieving in learning STEM content it is most likely due to ineffective STEM teaching.

□ *Strongly Disagree* □ *Disagree* □ *Uncertain* □ *Agree* □ *Strongly Agree*

Q13: I am not very effective at monitoring STEM related experiments.

□ *Strongly Disagree* □ *Disagree* □ *Uncertain* □ *Agree* □ *Strongly Agree*

Q14: I generally teach STEM content ineffectively.
□ *Strongly Disagree* □ *Disagree* □ *Uncertain* □ *Agree* □ *Strongly Agree*

Q15: The inadequacy of students' STEM backgrounds can be overcome by good teaching.

□ *Strongly Disagree* □ *Disagree* □ *Uncertain* □ *Agree* □ *Strongly Agree*

Q16: The low STEM achievement of some students cannot generally be blamed on their teachers.

□ *Strongly Disagree* □ *Disagree* □ *Uncertain* □ *Agree* □ *Strongly Agree*

Q17. When a low achieving child progresses in learning STEM content, it is usually due to extra attention given by the teacher.

□ *Strongly Disagree* □ *Disagree* □ *Uncertain* □ *Agree* □ *Strongly Agree*

Q18. I understand STEM concepts well enough to be effective in teaching all levels for which I am endorsed.

□ *Strongly Disagree* □ *Disagree* □ *Uncertain* □ *Agree* □ *Strongly Agree*

Q19: Increased teacher effort in teaching STEM produces little change in some student's science achievement.

□ *Strongly Disagree* □ *Disagree* □ *Uncertain* □ *Agree* □ *Strongly Agree*

Q20. The teacher is generally responsible for the achievement of students in STEM learning.

□ *Strongly Disagree* □ *Disagree* □ *Uncertain* □ *Agree* □ *Strongly Agree*

Q21: Students' achievement in STEM learning is directly related to their teacher's effectiveness in STEM teaching.

□ *Strongly Disagree* □ *Disagree* □ *Uncertain* □ *Agree* □ *Strongly Agree*

Q22: If parents comment that their child is showing more interest in STEM at school, it is probably due to the abilities and practice of the child's teacher.

□ *Strongly Disagree* □ *Disagree* □ *Uncertain* □ *Agree* □ *Strongly Agree*

Q23: I find it difficult to explain to students why some STEM experiments work.

□ *Strongly Disagree* □ *Disagree* □ *Uncertain* □ *Agree* □ *Strongly Agree*

Q24: I am typically able to answer student' STEM related questions.

□ *Strongly Disagree* □ *Disagree* □ *Uncertain* □ *Agree* □ *Strongly Agree*

Q25: I have the skills necessary to effectively teach STEM concepts.

□ *Strongly Disagree* □ *Disagree* □ *Uncertain* □ *Agree* □ *Strongly Agree*

Q26: Effectiveness in STEM teaching has little influence on the achievement of students with low motivation.

□ *Strongly Disagree* □ *Disagree* □ *Uncertain* □ *Agree* □ *Strongly Agree*

Q27: Given a choice, I would NOT invite the principal to evaluate my STEM teaching.

□ *Strongly Disagree* □ *Disagree* □ *Uncertain* □ *Agree* □ *Strongly Agree*

Q28: When a student has difficulty understanding a STEM concept, I am usually at a loss as to how to help the student understand it better.

□ *Strongly Disagree* □ *Disagree* □ *Uncertain* □ *Agree* □ *Strongly Agree*

Q29: When teaching STEM content, I usually welcome student questions.

□ *Strongly Disagree* □ *Disagree* □ *Uncertain* □ *Agree* □ *Strongly Agree*

Q30: I don't know what to do to motivate students to learn STEM content.

□ *Strongly Disagree* □ *Disagree* □ *Uncertain* □ *Agree* □ *Strongly Agree*

Q31: Even teachers with good STEM teaching abilities cannot help some kids learn STEM concepts.

□ *Strongly Disagree* □ *Disagree* □ *Uncertain* □ *Agree* □ *Strongly Agree*

Appendix B
Initial Clinical Interview Protocol

Hello! Thank you again for your willingness to contribute to this study. As you may or may not have already heard from your administrator, I am conducting a study on the use of reflection and self-assessment practices during integrative STEM lessons and instruction. I am trying to determine if these practices assist teachers in creating improved integrative STEM education lessons. In addition, I am trying to determine if by engaging in reflection and self-assessment, a teacher is better able to ascertain their and their students' content and instructional needs when it comes to STEM integration.
This research study utilizes a Design-Based Research approach. What that means is that we will utilize an iterative weeklong cycle to test and refine the instrument I give you. Think of yourself as a fellow researcher. You will essentially be helping me refine this instrument through daily utilization and feedback cycles.

I have a few questions that I want to ask you before you begin using this instrument. I just want to reaffirm that you are in agreement that I may record this interview for review at a later time (allow for teacher to answer). Great! Thanks! In addition, I also want to ensure that you are willing to implement this tool throughout the week (allow teacher to answer), meet at a time that is convenient for you and after you have implemented the instrument for the day (allow for teacher to answer), you are willing to keep a journal during the week on your thoughts about the instrument, your integrative STEM lesson, and on your overall thoughts about your content and instructional needs (allow for teacher to answer). I will collect this journal at the end of the week. Don't worry, we will utilize your code name previously established so your identity can remain protected. During our latter interview times, I will ask your opinion regarding the utility of the instrument and any changes or additions you believe are essential to making it work effectively. I ask that you be honest and forthcoming with any thoughts you may have. There are no wrong or right answers. I am simply seeking your thoughts, opinion, and expertise as a (kindergarten; first; second grade) elementary teacher. In regards to today's interview, I only have a few questions for you to answer. Shall we begin (allow for teacher to answer)?

- Could you tell me what reflection and self-assessment practices you currently utilize in your daily lesson planning?
  - Can you elaborate on those practices?
  - Can you elaborate on how you use those practices?
  - How in-depth do you go into these practices?
- What is your current comfort level with creating integrative STEM lessons?
  - Can you elaborate on why you feel that way?
- What is your current comfort level of instructing integrative STEM lessons?

  - Can you elaborate on why you feel that way?
- Do you believe self-assessment and reflective practices can assist in improving your comfort level of creating and improving your integrative STEM lessons and instruction?
  - Can you elaborate on why you feel that way?

Appendix C
Clinical Interview Protocol (Days 3 & 5)

Hi there! I hope you had a great day in your classroom today. As I mentioned on Day One, I am going to be coming to see you and record a brief interview on days 1, 3, & 5 on what you think about the self-assessment and reflective practice tool I gave you. I will ask your opinion regarding the utility of the instrument and any changes or additions you believe are essential to making it work effectively. I stress the importance of being honest and forthcoming with any thoughts and suggestions you may have. There are no wrong or right answers. I am simply seeking your thoughts, opinion, and expertise as a (kindergarten; first; second grade) elementary teacher. Remember, you are like a fellow researcher and your thoughts, opinions, and critiques are essential in helping to improve this instrument. Are you ready to begin (allow teacher time to answer)? We are going to take these questions in sections as they are listed on the instrument.

Let's begin with the pre-active or pre-planning stage:

- What were your thoughts when you used the instrument to *create and plan* an integrative STEM lesson?
    - Can you elaborate on that?
    - Did the questions help you or hinder you? Why?
        - Can you elaborate on that?
    - Did you find the questions easy to think about and consider during planning?
        - Can you elaborate on that?
    - Did they help you think about any pre-set assumptions you may have had prior to planning the lesson?
        - Can you elaborate on that?
    - Do you think the questions helped you create an effective, integrative STEM lesson prior to instructing it?
    - Did this section of the instrument help you identify any content or instructional areas you my need to address?
        - Can you elaborate on that?
        - If it did, how did it help?
    - Can you think of any additional questions we can add or take out of this section?
        - Tell me why you think that question is essential?
        - Tell me why you think that question should be taken out?
    - Can you tell me your thoughts on the overall utility of this section?
        - Can you elaborate on that?

- o Do you have any additional thoughts or suggestions for this particular section?

Lets move on to the interactive or lesson delivery stage:

- ❖ What were your thoughts when you used the instrument to *instruct and self-monitor* during you integrative STEM lesson?
  - o Can you elaborate on that?
  - o Did the questions help you or hinder you? Why?
    - ▪ Can you elaborate on that?
  - o Did you find the questions easy to think about and consider while instructing?
    - ▪ Can you elaborate on that?
  - o Did they help you think about any pre-set assumptions you may have had while teaching the lesson?
    - ▪ Can you elaborate on that?
  - o Do you think the questions helped you instruct an effective, integrative STEM lesson?
  - o Did this section of the instrument help you identify any content or instructional areas you my need to address?
    - ▪ Can you elaborate on that?
    - ▪ If it did, how did it help?
  - o Can you think of any additional questions we can add or take out of this section?
    - ▪ Tell me why you think that question is essential?
    - ▪ Tell me why you think that question should be taken out?
  - o Can you tell me your thoughts on the overall utility of this section?
    - ▪ Can you elaborate on that?
- ❖ Do you have any additional thoughts or suggestions for this section?

Lets go on to the post-active or after delivery stage.

- ❖ What were your thoughts when you used the instrument to *reflect* on your previous integrative STEM lesson?
  - o Can you elaborate on that?
  - o Did the questions help you or hinder you? Why?
    - ▪ Can you elaborate on that?
  - o Did you find the questions easy to think about and consider after the lesson?
    - ▪ Can you elaborate on that?

- Did they help you think about any pre-set assumptions you may have had that you did not previously consider?
  - Can you elaborate on that?
- Do you think the questions helped you reflect critically on your planning and instruction of an integrative STEM lesson?
- Did this section of the instrument help you identify any content or instructional areas you my need to address?
  - Can you elaborate on that?
  - If it did, how did it help?
- Can you think of any additional questions we can add or take out of this section?
  - Tell me why you think that question is essential?
  - Tell me why you think that question should be taken out?
- Can you tell me your thoughts on the overall utility of this section?
  - Can you elaborate on that?

❖ Do you have any additional thoughts or suggestions for this section?

I only have a few more questions on the overall utility of the instrument.

- ❖ Overall, do you believe this instrument assisted you in creating an effective STEM lesson?
  - Can you elaborate on your answer a little more?
- ❖ What are your overall thoughts on this instrument?
  - Can you elaborate on that?
- ❖ Are you ready to use it for planning another lesson tomorrow?

Thank again for your thoughts and opinions! They will be essential in helping to fine-tune our reflection and self-assessment tool. I appreciate your time and willingness to be so candid! Don't forget to keep your journal handy and take any notes or record any thoughts for each day. I am so thankful for your time, enthusiasm, and willingness to help! See you tomorrow!

Appendix D
Classroom Observation Checklist

This checklist is to be used during classroom observations of K, 1st, and 2nd grade STEM integrative lessons. Using the following scale, rate the teacher on their lesson. *(0)-there was no evidence of the teacher utilizing/covering this* *(1)-there was very little evidence to support the teacher utilizing/covering this* *(2)-there was some evidence of the teacher utilizing/ covering this* *(3)-there is strong evidence the teacher utilized/covered this*

Teacher Behavior/Lesson Characteristic	***Score***	***Comments***
It was evident the teacher utilized science, technology, engineering, and mathematics content in the integrative STEM lesson.		
It was evident the teacher utilized STEM/ state standards in the integrative STEM lesson.		
It was evident the teacher established appropriate learning goals for this integrative STEM lesson.		
It was evident the teacher was knowledgeable in STEM content areas to deliver this integrative STEM lesson effectively.		
It was evident the teacher utilized the appropriate instructional strategies needed for this particular integrative STEM lesson.		
It was evident the teacher fostered a collaborative learning environment during the integrative STEM lesson.		
It was evident the teacher put a lot of thought into his/her lesson.		
Student Behaviors	***Score***	***Comments***
It was evident the students were motivated to learn STEM concepts during the integrative STEM lesson.		
It was evident the students were able to be creative and innovative during the integrative STEM lesson.		
It was evident students drove some of their own learning during the integrative STEM lesson.		
It was evident the teacher posed a problem and provided a real-world context during integrative STEM lesson		
It was evident the integrative STEM lesson was successful overall.		

Appendix E
Daily Journal Entry Form

Please use this form as your daily journal entry. This study is asking you to journal daily on any thoughts, opinions, changes, feelings, etc. regarding the instrument pre/post lesson. It will be extremely beneficial to the study if you can provide detailed information on this form. If you have any questions, please contact Diana Cantu at (804)-318-7237 or dcant005@odu.edu.

<table>
<tr><td>Circle Week Day:

Mon. Tues. Wed. Th. Fri.</td><td>Teacher Code Name:</td></tr>
<tr><td>Did you fully utilize the instrument in planning your lesson?

Y N

Please comment on your answer:</td><td>Did you fully utilize the instrument after your lesson?

Y N

Please comment on your answer:</td></tr>
<tr><td>Please list any thoughts, comments, or opinions about your STEM lesson below:</td><td>Please list any changes, and/or additions that you believe need to be made to the instrument in order to improve it:</td></tr>
<tr><td colspan="2">Additional Comments:</td></tr>
</table>

Appendix F
Final Reflection and Self-Assessment Instrument

Pre-Planning (Lesson Planning Stage)	***Interactive (Lesson Delivery Stage)***	***Post-Active (After Lesson Delivery)***
[illegible]	[illegible]	[illegible]
I can identify the following content I will need to use in this integrative STEM lesson: Science 1 2 3 4 5 6 7 8 9 10 *Comment or Example:* Technology 1 2 3 4 5 6 7 8 9 10 *Comment or Example:* Engineering 1 2 3 4 5 6 7 8 9 10 *Comment or Example:* Mathematics 1 2 3 4 5 6 7 8 9 10 *Comment or Example:*	My students are engaged in this integrative STEM lesson. 1 2 3 4 5 6 7 8 9 10 I am confident in my instruction of this integrative STEM lesson. 1 2 3 4 5 6 7 8 9 10 Area for Comments/Notes:	I used the appropriate content for this particular integrative STEM lesson in: Science 1 2 3 4 5 6 7 8 9 10 *Comment or Example:* Technology 1 2 3 4 5 6 7 8 9 10 *Comment or Example:* Engineering 1 2 3 4 5 6 7 8 9 10 *Comment or Example:* Mathematics 1 2 3 4 5 6 7 8 9 10 *Comment or Example:*
I can differentiate between each of my students' science, technology, engineering, and mathematics ability levels as I plan my integrative STEM lesson. 1 2 3 4 5 6 7 8 9 10		I differentiated between each of my students' science, technology, engineering, and mathematics ability levels in this integrative STEM lesson. 1 2 3 4 5 6 7 8 9 10
I am taking into consideration each of my students' learning styles (auditory, kinesthetic, visual, etc.) for this particular integrative STEM lesson. 1 2 3 4 5 6 7 8 9 10		I believe I considered each of my students' learning styles (auditory, kinesthetic, visual, etc.) for this particular integrative STEM lesson. 1 2 3 4 5 6 7 8 9 10
I personally have the required knowledge in science, technology, engineering, and mathematics content areas to deliver this particular integrative STEM lesson. 1 2 3 4 5 6 7 8 9 10		I believe I did have the appropriate knowledge in STEM content areas for teaching this integrative STEM lesson. 1 2 3 4 5 6 7 8 9 10
I understand and can utilize varied instructional strategies needed for this integrative STEM lesson. 1 2 3 4 5 6 7 8 9 10		I believe I did utilize the required STEM instructional strategies need for this integrative STEM lesson. 1 2 3 4 5 6 7 8 9 10

Appendix F
Final Reflection and Self-Assessment Instrument, cont.

Pre-Planning (Lesson Planning Stage)		***Post-Active (After Lesson Delivery)***
I have considered county/district standards and/or school-based initiatives I can incorporate in my integrative STEM lesson. 1 2 3 4 5 6 7 8 9 10	Area for Comments/Notes:	I utilized the appropriate county/district standards and/or school-based initiatives I previously set for this integrative STEM lesson. 1 2 3 4 5 6 7 8 9 10
I have considered the required state standards needed to accomplish this particular integrative STEM lesson in order to establish the proper learning objectives for it. 1 2 3 4 5 6 7 8 9 10		I met the standards and learning objectives I previously set for this integrative STEM lesson. 1 2 3 4 5 6 7 8 9 10
I am designing a integrative STEM lesson in which my students will be motivated to learn STEM concepts. 1 2 3 4 5 6 7 8 9 10		This integrative STEM lesson motivated my students to learn STEM concepts. 1 2 3 4 5 6 7 8 9 10
I am designing an integrative STEM lesson in which my students will be able to use creativity and innovation. 1 2 3 4 5 6 7 8 9 10		My students showed creativity and innovation during this integrative STEM lesson. 1 2 3 4 5 6 7 8 9 10
I am designing an integrative STEM lesson that will create a collaborative learning environment. 1 2 3 4 5 6 7 8 9 10		I designed a collaborative learning environment during this integrative STEM lesson. 1 2 3 4 5 6 7 8 9 10
I have considered how students will need to be grouped for successful completion of this integrative STEM lesson (individual/team sizes). 1 2 3 4 5 6 7 8 9 10		I believe my students were grouped correctly for successful completion of this integrative STEM lesson (individual/ team sizes). 1 2 3 4 5 6 7 8 9 10
I have allotted time in the integrative STEM lesson for students to reflect on their work. 1 2 3 4 5 6 7 8 9 10		My students had time during the integrative STEM lesson to reflect on their work. 1 2 3 4 5 6 7 8 9 10
I am designing an integrative STEM lesson that allows for students to drive their own learning. 1 2 3 4 5 6 7 8 9 10		I allowed my students to drive some their own learning during the integrative STEM lesson. 1 2 3 4 5 6 7 8 9 10
I can tie my integrative STEM lesson back to a real-world problem and/or real-world context. 1 2 3 4 5 6 7 8 9 10		My students were able to relate my integrative STEM lesson to a real-world context/problem. 1 2 3 4 5 6 7 8 9 10
I feel overall this will be a successful integrative STEM lesson. 1 2 3 4 5 6 7 8 9 10		I feel overall this was a successful integrative STEM lesson. 1 2 3 4 5 6 7 8 9 10

Additional Comments or Notes:

Appendix G

Participant 1 Lesson Plan: Sample of an Exemplary Lesson Plan (pg. 1)

[redacted]

Lesson Objective: Build background knowledge and develop an understanding of Christopher Columbus. This study will build basic STEM vocabulary

Social Studies K.1

The student will recognize that history describes events and people of other times and places by identifying examples of past events in legends, stories, and historical accounts.

Pre-Assessment:	K-W-L chart	Introduce the K-W-L chart and explain what each letter stands for on the chart (what they Know, what they Want to know and what they've Learned). Fill in the K column about what the students already know, or think they know about Christopher Columbus.
Materials/Resources	K-W-L chart Book: In 1492	
Anticipatory Set	What is an explorer? What is a scientist? What is a technologist? What is an engineer? What is a mathematician?	Explorer- one who explores unfamiliar land Scientist one who ask questions and uses their senses to learn about our world Technologist-one who makes things that makes life easier Engineer one who sees a need then solves the problem Mathematician-one who understands numbers, measurement, and shapes
Check and Review	Students will be evaluated based on their participation in completing the K-W-L chart and attention to the book. In 1492	
Modeling	Students observe how to use the processes and resources of historical inquiry Teacher will transcribe student ideas on K-W-L chart.	
Guided Practice	This lesson focuses student attention on early explorers and their ability to use STEM. This study will build basic STEM vocabulary	
Independent Practice		
Closing/Reflection	Review K-W-L chart. What do you know about Christopher Columbus? How is life today different from life of long ago?	

Participant 1 Lesson Plan: Sample of an Exemplary Lesson Plan (pg. 2)

4 TH

[redacted]

Lesson Objective: Build background knowledge and develop an understanding of Christopher Columbus This study will introduce sink and float.

Science K.5 The student will investigate and understand that water has properties that can be observed and tested. Some materials float in water, while others sink.

Pre-Assessment:	Will it float like a boat or sink like a rock?	Making predictions
Materials/Resources	Large tub of water Penny, crayon, toothpick, marble button, straw Student recording sheet	
Anticipatory Set	Make connections with sink and float Video link Sesame Street	http://www.youtube.com/watch?v=dy0S1PvOeOE
Check and Review	Defining STEM components is ongoing	Scientist one who ask questions and uses their senses to learn about our world Technologist one who makes things that makes life easier Engineer-one who sees a need then solves the problem Mathematician one who understands numbers, measurement, and shapes
Guided Practice	As a whole group, look at each object in the plastic bag and predict whether the object will sink or float Classify objects as to whether the students think they will sink or float when placed in water	
Independent Practice	Have students draw objects that sink and objects that float in the appropriate places on a piece of paper	
Closing/Reflection	Explain to them the predictions and testing that they did is how a real scientist works.	

Participant 1 Lesson Plan: Sample of an Exemplary Lesson Plan (pg. 3)

Lesson Objective: Students will participate in a STEM activity related to sailing. In this activity, children will create their own sail using colors and pictures that have a personal meaning. Students will then attach the sail to a small boat and test whether it will propel their boat forward.

Pre-Assessment:	What is a sail? How does it propel a boat forward?	
Materials/Resources	Juice boxes Brainstorm sheet Materials for engineering project	
Check and Review	Defining STEM components is ongoing	Explorer one who explores unfamiliar land Scientist one who ask questions and uses their senses to learn about our world Technologist one who makes things that makes life easier Engineer-one who sees a need then solves the problem Mathematician-one who understands numbers, measurement, and shapes
Guided Practice	Demonstrate how to blow on the sail to propel the boat forward	In this activity, students will understand how sails were used to propel ships through the ocean. In a large plastic container filled with water place a self-made boat with a sail
Independent Practice	Allow two students at a time to propel boat forward	Have students blow on the sail to propel the boat forward. Have students race their boats using their breath
Closing/Reflection	Did my boat float? Did my sail propel my boat forward? Can I try again? What would I do differently? Did I have fun?	

Participant 1 Lesson Plan: Sample of an Exemplary Lesson Plan (pg. 4)

Hooray for Columbus Day!

Background Knowledge: Christopher Columbus set out to prove that the world was round and not flat He used three ships to travel across the ocean Each ship was marked with a sail that held a design to communicate to others that the vessel belonged to Spain Sails help propel his boats forward through the water

Challenge: Create a sail for a ship using colors and pictures that have a personal meaning Attach the sail to the mast of your boat and test whether it will propel your boat forward

Criteria: Your sail must

- Communicate things that are important to you
- Include your name
- Help propel your boat forward

Materials: You may use all or some of these

- Variety of paper
- Tape
- Juice box

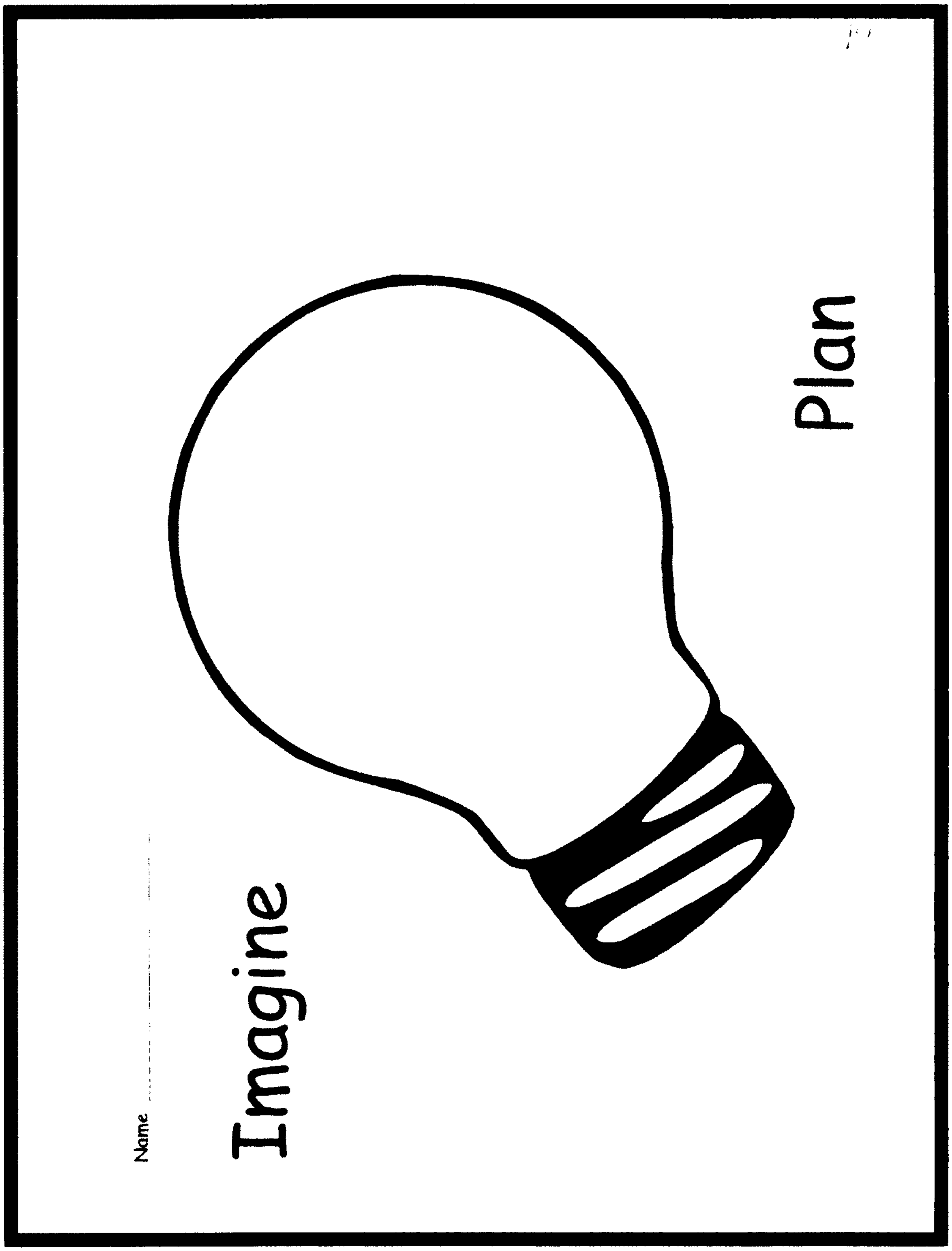
Tools: You may use all or some of these

- Crayons
- Markers
- Pencil

Kindergarten Virginia Standards of Learning

Oral Language K 2 Use listening and speaking vocabularies Oral Language K 3 Build oral communication skills Writing K 10 Print first name, Civics K 8 Being a good citizen Social Studies K 1 Recognize that history describes events and people of other times and places by identifying examples of past events in legends stories and historical accounts Science K 5 The student will investigate and understand that water has properties that can be observed and tested Some materials float in water while others sink

Participant 1 Lesson Plan: Sample of an Exemplary Lesson Plan (pg. 5)



Appendix H

IRB Approval Letter

OLD DOMINION UNIVERSITY
DARDEN COLLEGE OF EDUCATION
IDEA FUSION

DARDEN COLLEGE OF EDUCATION
Human Subject Committee
Norfolk, Virginia 23529-0156
Phone: (757) 683-6695
Fax: (757) 683-5756

June 23, 2014 Approved Application Number: 201403010

Dr. Phil Reed
Department of STEM Education and Professional Studies

Dear Dr. Reed:

Your Application for Exempt Research with Diana Cantu and Helen Crompton entitled "Applying Reflection and Self-Assessment Practices in Creating and Assessing Integrative STEM Lessons: Development of an Instrument for Elementary Practitioners Utilizing Design-Based Research" has been found to be EXEMPT under Category 6.2 from IRB review by the Human Subjects Review Committee of the Darden College of Education with the condition that the application is signed by the RPI.

The determination that this study is EXEMPT from IRB review is for an indefinite period of time provided no significant changes are made to your study. If any significant changes occur, notify me or the chair of this committee at that time and provide complete information regarding such changes. In the future, if this research project is funded externally, you must submit an application to the University IRB for approval to continue the study.

Best wishes in completing your study.

Sincerely,

Robert J. Spina, Ph.D., FACSM
Associate Dean for Undergraduate Education and College Assessment
Darden College of Education
Old Dominion University
rspina@odu.edu

Interim Chair
Darden College of Education Human Subjects Review Committee
Old Dominion University

Diana V. Cantu

Vita

Education

PhD. Education, Occupational & Technical Studies, ODU, Norfolk VA (4.0 GPA) 2015
MS Education, Occupational & Technical Studies, ODU, Norfolk VA (4.0 GPA) 2011
BS Business Administration, University of Phoenix, Santa Teresa, N.M. (3.73 GPA) 2002
Human Resources Management, University of Phoenix, Santa Teresa, N.M. (3.89) 2002

Associations

*International Technology and Engineering Education Association * National Council of Teachers of Mathematics* Iota Lambda Sigma* The American Society for Training and Development* Golden Key International Honour Society* Children's Council (Elementary Technology and Engineering) * Council for Technology and Engineering Teacher Educators* National Science Teachers Association**

Awards and Distinctions

ITEEA Leader to Watch Distinction 2015
ACTE Neven Frantz Leader of Tomorrow Scholoarship 2014
Old Dominion University, Technology Education Award for Academic Excellence 2014
21st Century Leadership Academy Scholar 2014
ITEEA - Don Maley Outstanding Graduate Student Award - Old Dominion University 2014
Iota Lambda Sigma, Chapter Scholar of the Year 2013
Graduate Teaching Assistant Mentor, Old Dominion University 2013
Technical Foundation of America, Student Award 2013
Graduate Teaching Assistantship, Old Dominion University 2012, 2013
Rookie Teacher of the Year, Highlands Elementary School 2003

K-16 Teaching Experience

MonarchTeach, Old Dominion University 2014 through present
Materials Manager, Field Observations, Instructor
Inquiry Approaches to Teaching STEM, STEM 101

Academic Innovation, West Virginia University, Morgantown, WV 2014 through present
Media Specialist/Instructional Design of an online course (Temporary Contract)

Old Dominion University, Norfolk, VA
Adjunct Faculty – Instructor, STEM 110T, Technology and Your World 2013 through 2013

Old Dominion University, Norfolk, VA
Graduate Teaching Instructor, STEM110 - Technology and Your World 2012 through 2013
STEM 310 - Transportation Technologies

Ironbridge Baptist Christian Community School, Chester, VA 2007 through 2010
PK Teacher, Teacher Professional Development

Garner Elementary, Grand Prairie, TX 2006 through 2007
Kindergarten Teacher, Teacher Professional Development

Highlands Elementary, Cedar Hill, TX 2003 through 2006
K & 1st Grade Bilingual Teacher, PEIMS Coordinator, Teacher Professional Development, & Technology Liaison

Teaching Certifications

Teaching Certification from the State Board of Certification in the State Of Texas:
Bilingual Elementary Education Generalist – Spanish & Elementary Education Generalist (PK-4 - current)

Corporate Work Experience

Horizon Lines, LLC (Formerly Sea-Land, CSX Lines), **Dallas, TX**
Business Process Analyst, Trainer and Curriculum Development 1999-2001 & 2002-2003

Leviton, Inc. El Paso, TX
Training Coordinator 2002 through 2002

Spherion, El Paso, TX
Client Service Manager 2001 through 2002

Publications and Presentations

Publications:

- Crompton, H. & **Cantu, D.** (2014). Know the ISTE standards for administrators: Create a learning culture. Retrieved from *The International Society for Technology's EdTekHub* http://www.iste.org/explore/articleDetail? articleid=230
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- Strimel, G., Reed, P., Bolling, J., Phillips, M., & **Cantu, D.** (2014). Integrating and monitoring informal learning in education and training. *Techniques, 89*(3), 48-54.
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- **Cantu, D**., Enderson, M. (2013). Fluttering with design: Building a butterfly terrarium. *Children's Technology and Engineering Journal, 18*(2), 6-10.
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- Roberts, A., & **Cantu, D**. (2012). *Applying STEM instructional strategies to technology and design curriculum*. In T. Ginner, J. Hallstrom, & M. Hulten (Eds.), *Technology Education in the 21st Century* (pp. 111-118). Sweden: LiU Electronic Press.
- **Cantu, D**. (2011). From trash to treasure: Recycling scrap metal into steel. *Technology and Engineering Teacher, 71(*1), 14-21.

Presentations:

- **Cantu, D.** (2015). Become a Resource to Other Teachers: Publish in the CTE Journal. *Virginia Children's Engineering Conference*, Williamsburg, VA.
- Crompton, H., & **Cantu, D.** (2014). Cloud Computing. *Mobile Learning Network at the International Society for Technology in Education* [Webinar]

- **Cantu, D.** (2014) *Great Lessons STEM from Integration.* ITEEA Conference, Orlando, FL.
- Strimel, G., **Cantu, D.**, & Roberts, A. (2014). *I Chose a Pre-Engineering Program in High School Because…* ITEEA Conference, Orlando, FL.
- **Cantu, D.** & Enderson, M. (2014). *Flying High with STEM Activities for Elementary Classrooms.* Virginia Council of Teachers of Mathematics Spring 2014 Conference. James Madison University. Harrisonburg, VA.
- **Cantu, D.** (2013). *Problem-Based Learning Professional Development Series.* Roper Mountain Science Center. Greenville, SC.
- **Cantu, D.** (2013). Influence of a university technological literacy course on career choices of undergraduate students. *Pupils Attitudes Toward Technology*, Christchurch, New Zealand.
- **Cantu, D.** (2013). *Engineering byDesign™ Elementary TEEMS Overview.* New York State Elementary Classroom Teachers Association Conference. Rye Brook, New York.
- **Cantu, D.** (2013). *Advanced Design Applications.* Maryland State Professional Development/Engineering byDesign™. Ridgley, MD.
- **Cantu, D.**, Roberts, A., & Strimel, G. (2013) *Challenges that Impede STEM Integration*, ITEEA Conference, Columbus, Ohio.
- **Cantu, D.**, Roberts, A., & Strimel, G. (2013) *Best Practices*, ITEEA Conference, Columbus, Ohio.
- **Cantu, D.** & Roberts, A. (2012). *Attributes of Successful Technology and Engineering Program Models*, ITEEA Conference, Long Beach, CA.
- Roberts, A., & **Cantu, D.** (2012) *Applying STEM Instructional Strategies to Technology and Design Curriculum*, Pupils Attitudes Toward Technology (PATT 26), Stockholm, Sweden.

Service & Professional Development

Field Editor, Children's Technology and Engineering Journal (ITEEA)	2014 to present
Chester Rotary Club – STEM, What are the STEAM Olympics?	2014
Omega Learning Academy –*Rethinking Assessments*	2014
Vice President of Programming, Children's Council	2014 to present
Engineering byDesign™, Teacher Effectiveness Coach (ITEEA)	2013-2014
OB Gates Elementary School –*STEM Olympic Competition Student Coach*	2012, 2013, 2014
OB Gates Elementary School – *Engineering Design (Student Program)*	2012, 2013, 2014
Old Dominion University – Graduate Teaching Assistant Development	2013
Chesterfield County Public Schools – *Problem Solving Seminar*	2013
Omega Learning Academy – *STEM Student Summer Program*	2013
OB Gates Elementary School – STEM Teacher Professional Development	2012
Omega Learning Academy – STEM Instructional Strategies Training	2012
Chesterfield Chamber of Commerce – What is STEM Education?	2012
Chesterfield Rotary Club – How to Create STEM Partnerships	2012
Ironbridge Baptist School – Developing Integrated Lessons	2010
Ironbridge Baptist School – Instructional Strategies/ Content Development	2010
Ironbridge Baptist School – Developing Language Arts Using Nursery Rhymes	2009
Dallas Baptist University – Student Teacher Mentor	2003–2006
Cedar Hill School District – Teacher Mentor for New Teacher Hires	2003–2006
Highlands Elementary School – Understanding Diverse Populations	2005
Highlands Elementary School – Equity in Teaching	2005
Highlands Elementary School – The Gifted Bilingual Learner	2004
Highlands Elementary School – Integration of Technology Basics	2003