

AN EXPLORATORY CROSS-SECTIONAL SURVEY STUDY OF ELEMENTARY  
TEACHERS' CONCEPTIONS AND METHODS OF STEM INTEGRATION

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by

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The undersigned, appointed by the dean of the Graduate School, have examined the dissertation entitled

AN EXPLORATORY CROSS-SECTIONAL SURVEY STUDY OF ELEMENTARY  
TEACHERS' CONCEPTIONS AND METHODS OF STEM INTEGRATION

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## **CHAPTER ONE: INTRODUCTION TO THE DISSERTATION IN PRACTICE**

According to the President's Council of Advisors on Science and Technology (2010), "the success of the United States in the 21st century will depend on the ideas and skills of its population" (p. 5). Science, Technology, Engineering, and Mathematics (STEM) Education works to develop students who have the technical skill-set necessary to boost the United States back into the global economic competition (PCAST, 2010). While STEM Education lacks a formal, universally accepted definition, there is an overwhelming consensus regarding the importance of the need to develop STEM literate individuals. Trygstad (2013) stated "A new workforce of problem-solvers, innovators, and inventors who are self-reliant and able to think logically is one of the critical foundations that drive innovative capacity" (p. 1). Elementary teachers are charged with building the foundation for this STEM workforce, but the task is riddled with challenges.

### **What is STEM?**

Despite the consensus among the education community regarding the importance of STEM Education, there isn't agreement regarding what STEM is and what qualifies as best practice for teaching it. According to Zollman (2012), the term STEM was created as an acronym for science, technology, engineering, and mathematics in 2001 by Judith Ramaley as the assistant director of the Education and Human Resources Directorate of the National Science Foundation (p. 12). However, the consensus across the education community regarding the fundamental definition of STEM education has been a source of confusion and debate ever since. Sanders wrote, "By 2008, I was convinced STEM Education was (and always will be) a hopelessly ambiguous phrase..." (2015, p. 1).

The STEM acronym has become the “buzzword”, and those who claim to promote STEM Education have different understandings of the term (Breiner et al., 2012). Surveys of stakeholders including government officials, teachers, parents, businesses, and students revealed there is no solid, universally agreed upon definition of STEM Education (Breiner et al., 2012; Brown, 2011; Angier, 2010). Indeed there “was no operational definition or clear conceptualization of STEM Education” among faculty in higher education who were involved in STEM projects and centers (Breiner et al., 2012 p. 9). There is similar confusion among the general public. Angier (2010) presented a study conducted by The Entertainment Industries Council where 5,000 participants were asked if they understood the term “STEM Education.” Most participants (roughly 85%) did not understand the term, and many participants even confused the term with everything from STEM cell research to broccoli stems.

Adding to the confusion are variations of “STEM Education” which have been created to include other disciplines. One modification includes an “A” to make “STEAM Education” (Tarnoff, 2010). However, the “A” can represent “Art” or “Agriculture” depending on the user. There is even a “STREAM education” term in use today by the Boulder Valley School District (2015) in Colorado that stands for “Science, Technology, Reading and Writing, Engineering, Art, and Math.” Another modification uses “STEMM” to represent “Science, Technology, Engineering, Mathematics, and Medicine” (Kimmel, 2012). It seems as though there is more focus on the acronym itself than there is on the meaning of the process as a whole.

The STEM acronym itself is a source of significant ambiguity and mystery. In fact, many people, even those in education, use “STEM” when they should be using

“STEM Education.” According to Sanders (2009), those who only say "STEM" when talking about education are missing that using the STEM acronym by itself without “Education” is a reference to only the disciplines that scientists, mathematicians, and engineers work as opposed to the *teaching of* those subjects. Sanders further argued that the term “STEM Education” itself has become overused and “worn out” in the United States, and proposes that the term “Integrative STEM Education” (p. 1) or “iSTEM” (Sanders, 2009; Nadelson, 2012) be used instead. This idea is illustrated by the previous discussion on the acronym as it is being modified to represent disciplines outside of those initially included and thus detracts from the broader meaning of the acronym itself.

Regardless of the fact that there is no consensus concerning a STEM Education definition (or universal use of the acronym), there have been some who have attempted to pen a definition in hopes of providing clarity for those concerned with STEM Education. Table 1 below illustrates a sampling of common definitions of STEM Education.

However, this listing is far from exhaustive.

Table 1  
*Comparison of STEM Education Definitions*

Author	Definition
Tsupros (2009)	“STEM Education is an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy” (p. 14).
The California STEM Learning Network (CSLN) (2015)	“STEM Education is an interdisciplinary and applied approach to teaching that is coupled with hands-on, problem-based learning.”

Sanders (2012)	“Integrative STEM education refers to technological/engineering design-based learning approaches that intentionally integrate the concepts and practices of science and/or mathematics education with the concepts and practices of technology and/or engineering education. Integrative STEM education may be enhanced through further integration with other school subjects, such as language arts, social studies, art, etc.” (p. 2).
The United States Department of Education (2007)	“Science, Technology, Engineering, and Mathematics education programs are defined as those primarily intended to provide support for, or to strengthen, science, technology, engineering, or mathematics (STEM) education at the elementary and secondary through postgraduate levels, including adult education” (p. 11).
Merrill (2009)	“A standards-based, meta-discipline residing at the school level where all teachers, especially science, technology, engineering, and mathematics (STEM) teachers, teach an integrated approach to teaching and learning, where discipline-specific content is not divided, but addressed and treated as one dynamic, fluid study” (as cited in Brown, 2012, p. 7).
Teaching Institute for Excellence in STEM (2015)	“STEM education is trans-disciplinary in nature offering students the ability to use project-based learning to address real-world issues that affect their family, their community and their world.”
The National Science and Technology Council (2013)	“Formal or informal (in school or out) education that is primarily focused on physical and natural sciences, technology, engineering, and mathematics disciplines, topics, or issues (including environmental science education or environmental stewardship)” (p. 54).
Gomez and Albrecht (2014)	“STEM pedagogy is rooted in interdisciplinary applied applications of knowledge. STEM Education is a philosophy designed around a cooperative effort to provide students with a comprehensive, meaningful, real-world learning experience” (p. 8).
Johnson et al. (2015)	“The teaching and learning of the content and practices of disciplinary knowledge which include science and/or mathematics through the integration of the practices of engineering and engineering design of relevant technologies” (p. 24).
Vasquez (2013)	“STEM education is an approach to learning that removes the traditional barriers separating the four disciplines (science, technology, engineering, and mathematics) and integrates them

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	into real-world, rigorous, relevant learning experiences for students” (p. 4).
Wells and Ernst (2012)	“Integrative STEM Education is the application of technological/engineering design based approaches to intentionally teach content and practices of science and mathematics education concurrently with content and practices of technology/engineering education. Integrative STEM Education is equally applicable at the natural intersections of learning within the continuum of content areas, educational environments, and academic levels" (as cited in Virginia Tech., 2016).
Nadelson and Seifert (2017)	“We define integrated STEM as the seamless amalgamation of content and concepts from multiple STEM disciplines. The integration takes place in ways such that the knowledge and process of the specific STEM disciplines are considered simultaneously without regard to the discipline, but rather in the context of a problem, project, or task” (p. 221).

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In the definitions of STEM Education shown in Table 1, several patterns emerge. First, STEM Education is conceptualized in three distinct ways-- as an approach to learning, as an approach to teaching, and as a philosophical stance toward education. Across these three categories, however, there are some commonalities. For example, the need for providing opportunities for students to apply their knowledge is prevalent among most of the definitions. Perhaps the most consistent commonality across the board is a focus on integration.

However, in that lies another source of confusion as the term integration can mean different things to different people. Most educators agree that the need for an interwoven, cross-disciplinary curriculum is needed, but to many, the nature of the interdisciplinary problem is not apparent (Davison, 1995). According to Banks (1993), “integration deals with how teachers use examples, data, and information from a variety of disciplines to illustrate the basic concepts and ideas in their subject area or discipline” (p. 25). This

view is embraced by some researchers and educators who refer to STEM as “Integrative STEM Education” (Sanders, 2009) or “iSTEM” (Nadelson, 2012) as opposed to the traditional “STEM” term. Additionally, there have been multiple researchers who have identified benefits to integrated instruction over the traditionally segregated style approach (Becker & Park, 2011; Hartzler, 2000; Beane, 1995; Greene, 1991). These discussions influenced the use of the term ‘iSTEM Education’ throughout this dissertation in practice.

Given this focus on STEM as *integrated instruction*, traditional approaches to preparing teachers in STEM disciplines are problematic. For example, some institutions of higher education promote iSTEM Education courses for teachers, but what they really are providing is a menu of various courses that fall into individual STEM disciplines, such as independent science, math, technology and engineering courses. Other institutions offer iSTEM Education courses that are broken up into “science integration” and “math integration” courses rather than one comprehensive STEM Methods course. A report on the status of current course offerings in iSTEM Education will be provided in a later chapter of this dissertation in practice.

## **Problem**

### **Problem of Practice**

Because elementary teachers are typically responsible for teaching all subjects, there is a unique opportunity for integrative approaches to teaching iSTEM Education at the elementary level (Becker & Park, 2011). A challenge, however, is that prepared as generalists--they take few courses in STEM content, and experiences with iSTEM Education in their teacher preparation programs are rare (Fulp, 2002). As emphasized by

Heil and colleagues (2013) in their examination of the current status of iSTEM Education, "...teachers need to be exposed to, understand, and experience first-hand, integrated STEM to be proficient in teaching in an integrated manner" (p. 6). Yet, there are few elementary specific iSTEM Education professional development opportunities (as opposed to specific to individual disciplines of STEM) (Hanover, 2012).

There is widespread agreement on the need for professional development in iSTEM Education if teachers are to be successful in teaching it (NRC, 2011). This need is particularly acute at the elementary level, where teachers may lack strong content knowledge in STEM disciplines (Ginns & Waters, 1995; Trygstad, 2013; Honey et al., 2014; Fulp, 2002; Ma, 1999; Hanover, 2012). According to the 2012 National Survey of Science and Mathematics Education (Trygstad, 2013), less than two percent of K-5 elementary teachers have had any college coursework in engineering. Furthermore, when teachers were asked to rate their comfort level in teaching science, just over one-third (39%) of teachers felt very well prepared to teach life, earth, or physical science.

### **Research Gap**

Just as differing perceptions of iSTEM Education exist (Brown, 2011), there are a variety of ways in which STEM content can be integrated (Becker & Park, 2011). However, the current literature focuses primarily on the integration of math and science, rather than on integration across all STEM disciplines (Heil et al., 2013). Additionally, 'many programs claim to use an integrated STEM approach but under closer examination may not be as integrated as their promotional materials imply' (Heil et al., 2013, p. 8). We know very little about elementary teachers' conceptions of and instructional approaches to iSTEM Education. It is important to consider teacher beliefs and

perceptions regarding integrative approaches among STEM content as teacher professional development programs work to develop teacher thinking and practice (Richardson, 1996). Richardson (1996) suggested that both teacher attitudes and perceptions “drive classroom actions and influence the teacher change process” (p. 102). Thus, to address the practice gap identified, further research about elementary teachers’ conceptions and iSTEM practices is needed to inform the design of professional development.

### **Purpose of the Study and Research Questions**

To contribute to the research on iSTEM Education at the elementary level, this study identifies and explores the way in which elementary teachers conceptualize iSTEM Education and the extent to and methods by which they integrate STEM disciplines in their instructional planning. To contribute to iSTEM Education practice, the researcher will use the results of this study to revise a sample online professional development course specific to iSTEM Education for elementary teachers.

Based on the iSTEM framework (Honey et al., 2014) described in a later section in this chapter, the following research questions will guide the study:

1. To what extent are elementary teachers’ prepared to implement iSTEM Education?
  - a. What are elementary teachers’ perceived levels of preparedness to implement iSTEM Education?
  - b. What is the nature of iSTEM Education opportunities in which elementary teachers have participated?

2. In what ways do elementary teachers approach iSTEM Education in their lesson plans?
3. How do elementary teachers conceptualize iSTEM Education?
  - a. What learning goals do elementary teachers have for students as part of their iSTEM Education lessons?
  - b. What do teachers see as the benefits of students learning about iSTEM Education (outcomes)?
  - c. What is the nature and scope of teachers' integration of STEM disciplines?
  - d. What instructional designs, supports, and adjustments to the learning environment do teachers utilize when integrating STEM content?

These research questions, and the use of the findings to inform the design of a sample online professional development course are framed by notions of integrated STEM education and transformative learning, outlined in the sections that follow.

### **Theoretical and Conceptual Frameworks**

#### **Integrated STEM Education**

This study is framed by the iSTEM Education framework by Honey and colleagues in the report *STEM Integration in K-12 Education: Status, Prospects and an Agenda for Research* (2014). This framework includes four main features: (a) goals of integrated STEM Education, (b) outcomes of integrated STEM Education, (c) the nature and scope of integrated STEM Education, and (d) implementation of integrated STEM Education (p. 31). This framework is intended to provide researchers with the vocabulary to “identify, describe, and investigate specific integrative STEM initiatives...” (Honey et

al., 2014, p. 31). This framework informed the research questions, which are aimed at understanding teachers' conceptions and practice for iSTEM education.

The study uses the integration approaches from Davison, Miller, and Metheny (1995) as an analytical framework. Davison et al. (1995) described five types of integration specifically related to math and science. However, this study has expanded the model to include disciplines beyond just math and science. These five methods include: (a) Discipline Specific Integration (b) Content Specific Integration (c) Process Integration (d) Methodological Integration and (e) Thematic Integration. Like many integrative models, these approaches are not grounded in studies of actual teachers' integrative practices; they are merely presented as options for integration. Thus, this dissertation in practice represents an empirical test of the framework.

### **Transformative Learning**

The development of the sample online professional development course, in particular, is framed by an adult learning theory called transformative learning. The theory of transformative learning has undergone many revisions and changes over the past few decades, but its roots were developed by Jack Mezirow, beginning in 1978. Mezirow has since revised his definition of transformative learning to the following:

Transformative learning refers to the process by which we transform our taken-for-granted frames of reference (meaning perspectives, habits of mind, mindsets) to make them more inclusive, discriminating, open, emotionally capable of change, and reflective so that they may generate beliefs and opinions that will prove more true or justified to guide action. (Mezirow, 2000, pp. 7-8)

According to Mezirow (2000), there are three separate ways of making meaning, also called meaning structures, within transformative learning theory which include frame of reference, habit of mind, and point of view. The first meaning structure is frame of reference, which is how a person filters what they understand through their own set of expectations (Mezirow, 2000). This meaning structure would be similar to a paradigm as Mezirow drew inspiration from the work of Thomas Kuhn (Kitchenham, 2010), however in Mezirow's theory, a paradigm becomes a frame of reference. The second meaning structure is habit of mind. The habit of mind meaning structure is how a person defines an experience based upon a set of generalized ideas (Mezirow, 2000). These can include sociolinguistic, epistemic, moral-ethical, psychological, aesthetic, and philosophical perspectives (Mezirow, 2000). Finally, the last meaning structure is point of view. A person's point of view, or meaning scheme, consists of groupings of beliefs, expectations, mindsets and personal conclusions that help to establish a reasoning for why things happen and why certain things are a particular way (Mezirow, 2000). Figure 2 provides an illustration of these meaning structures.

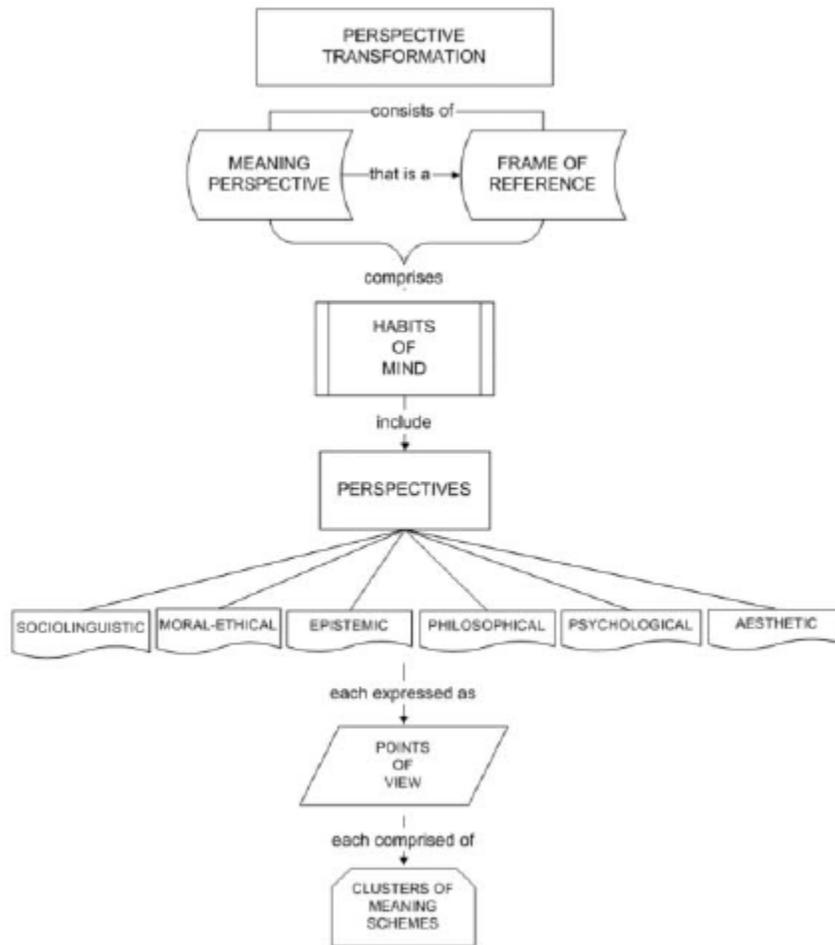


Figure 1  
*Diagrammatic Representation of Mezirow's (2000) Revised Transformative Learning Theory*  
 (Kitchenham, 2010)

Transformational learning can occur when these meaning structures are challenged by (a) Elaborating existing frames of reference, (b) Learning new frames of reference, (c) Transforming habits of mind or (d) Transforming points of view (Kitchenham, 2010). The process for experiencing transformational learning within these four areas includes ten separate phases. The ten phases of how meaning becomes clarified for a learner (or experiences transformative learning), are included in Table 2.

Table 2  
*The Ten Phases of Transformative Learning*  
 (Mezirow, 2000, p. 22)

Phase #1	A disorienting dilemma
Phase #2	Self-examination with feelings of fear, anger, guilt or shame.
Phase #3	A critical assessment of assumptions
Phase #4	Recognition that one is discontent and the process of transformation are shared.
Phase #5	Exploration of options for new roles, relationships, and actions.
Phase #6	Planning a course of action
Phase #7	Acquiring knowledge and skills for implementing one's plans.
Phase #8	Provisional trying of new roles.
Phase #9	Building competence and self-confidence in new roles and relationships.
Phase #10	A reintegration into one's life on the basis of conditions dictated by one's new perspective.

A major piece of transformative learning theory is reflective discourse. Mezirow (2012) cited reflective discourse as what Greek skeptics called “epoch,” which is a “provisional suspension of judgment about the truth or falsity of, or the belief or disbelief in, ideas until a better determination can be made” (p. 80). Through the practice of critical reflection, a learner can reflect on deeply rooted assumptions to determine if frames of reference are sufficient. Similarly, practicing in discourse is equally as important in the transformative learning process as it helps learners to discern if their frames of reference are problematic or not (Mezirow, 2012).

Additionally, transformative learning theory is not a “one size fits all” kind of theory as transformative learning is a complex process and can look different among

individual learners. According to the Handbook of Transformative Learning (Taylor & Cranton, 2012):

It may be that for one person in one context, transformative learning is a rational endeavor; for that same person in another context, it could be emotional and intuitive; in some contexts, social change may need to precede individual change, and in another context, individual transformation drives social transformation, and so forth. The outcome is the same or similar— a deep shift in perspective, leading to more open, more permeable, and better-justified meaning perspectives (Mezirow, 1978)—but the ways of getting there can differ depending on the person or people and the context or situation. (p. 3)

Transformative learning theory is an appropriate frame for this study as it is useful for exploring how elementary teachers perceive and understand integrated STEM Education teaching and learning. While this study does not look at how teachers may experience transformative learning within the context of the study, the final product of this dissertation in practice is a sample online professional development course in iSTEM Education that has been designed to provide opportunities for elementary teachers to experience transformative learning should they participate. The study described in chapter four of this dissertation in practice is intended to identify the current ways in which elementary teachers conceptualize iSTEM Education as well as the way in which those ideas influence their teaching practice.

### **Significance of the Dissertation-in-Practice**

The *Rising Above the Gathering Storm* report (NAS, 2007) aimed to increase the STEM abilities of the United States by improving K-12 science and math education.

Additionally, the National Science and Technology Council (NSTC) addressed in their 2013 progress report the goal of improving STEM instruction by preparing 100,000 quality new K-12 STEM teachers as well as providing support for existing STEM educators. To achieve these goals fully, we need not only to offer elementary specific professional development opportunities related to iSTEM Education but also knowledge about how to ensure these are high-quality programs that address elementary teachers' unique needs and the affordances of their context for promoting iSTEM Education. Wang et al. (2011) suggested that for iSTEM Education to be sustainable, professional development is required, which further emphasizes the need for more education opportunities for elementary teachers tasked with teaching STEM content. The U.S. Department of Education (2014) stated that teacher training is critical in developing teacher leaders who will advocate for iSTEM Education. Given the importance of early education, if iSTEM Education is going to be sustainable and successful in the long term, quality professional development opportunities specific to the needs of a K-5 educator must be provided for elementary teachers, who are building a foundation for students' future iSTEM Education learning.

### **Scholarly Contributions**

The findings of this study shed light on the ways in which elementary teachers are integrating STEM content in the classroom. Additionally, the way in which elementary teachers conceptualize iSTEM Education is illustrated. These contributions are important first steps in addressing current gaps in the literature regarding elementary teachers' understanding of and implementation of iSTEM Education as well as understanding the

unique professional development needs of elementary teachers regarding iSTEM Education.

### **Contributions to Practice**

The need for professional development in iSTEM Education specifically for elementary teachers is critical if the U.S. wishes to attain its goal of producing a skilled workforce in STEM areas. Elementary teachers have the unique opportunity of engaging young students in STEM experiences at an early age when they are most likely to develop their perception of STEM (NRC, 2011). The teaching of iSTEM Education at the elementary level has the ability to capitalize on student curiosity and enthusiasm for exploring STEM concepts (Nadelson, 2013). However, one of the biggest barriers to igniting this curiosity and enthusiasm is the lack of teacher preparedness in teaching STEM concepts (Nadelson, 2013). To address these obstacles, it is critical for elementary teachers to engage in professional development (Davis, 2003). This information provides an important foundation and a starting point for teacher educators and professional developers to support elementary teachers' integration of STEM content.

### **Organization of the Dissertation-in-Practice**

The dissertation in practice is organized in six chapters. This introductory chapter presented the problem of focus and the conceptual and theoretical frameworks to be utilized in addressing the problem. Chapter two presents a synthesis of key ideas from the literature that shaped my thinking about the formation of the sample online professional development course product and design of the study. Chapter three provides an analysis of a sampling of current course offerings on iSTEM Education. Chapter four describes the study conducted for this dissertation in practice. Chapter five includes a ready to

submit manuscript describing the study conducted for the scholarly contribution of this dissertation in practice. Chapter six provides a detailed description of the online professional development course developed as the product of this dissertation in practice. A description of the modifications made to the course reflecting the findings from this dissertation in practice is also included.

## **CHAPTER TWO: SCHOLARLY REVIEW**

### **Introduction**

This dissertation in practice is informed by several bodies of literature related to effective STEM integration, teachers' use of iSTEM Education, and the practices used for implementing effective professional development for teachers in iSTEM Education. The purpose of this chapter is to synthesize key ideas that shaped my thinking about the design of the study and the creation of the sample online professional development course. Bodies of literature in this review focused on iSTEM Education in general, integrative methods, and professional development. In particular, I sought literature specific to elementary iSTEM Education. In the sections that follow, I use the literature to clarify what is meant by integrating STEM, consider different ways in which STEM subjects can be integrated, and how professional development should be designed to support teachers in implementing iSTEM Education.

### **How can STEM be integrated?**

Regardless of the grade level, many proponents of iSTEM Education agree that an integrative approach is a key component of effective iSTEM Education instruction. For example, the American Institute of Biological Sciences (AIBS) emphasized the importance of teaching through an integrated approach when the Executive Director, Dr. Richard O'Grady (2010), made the following statement to the U.S. House of Representatives:

Teaching the way we did 100 years ago no longer meets the needs of students, scientist, or society. To be scientifically literate members of society or future

scientists, students must learn by engaging with real-world problems in an interdisciplinary manner. (“AIBS Position Statement”, 2010)

This comment promotes the idea that iSTEM Education should be taught in a way that is interdisciplinary and promotes hands-on, experience-based techniques; however, there is no consensus among the education community regarding the methodology of iSTEM Education (Means et al., 2008). In this section, an overview of some of the current literature on STEM integration is presented.

Hanover (2012) suggested that by taking an interdisciplinary approach to teaching, teachers can connect one or multiple topics together, allowing topics to “reinforce each other in support of the growth of each topic” (p. 19). The benefit of implementing an interdisciplinary (integrated) teaching approach is illustrated in Figure 2.

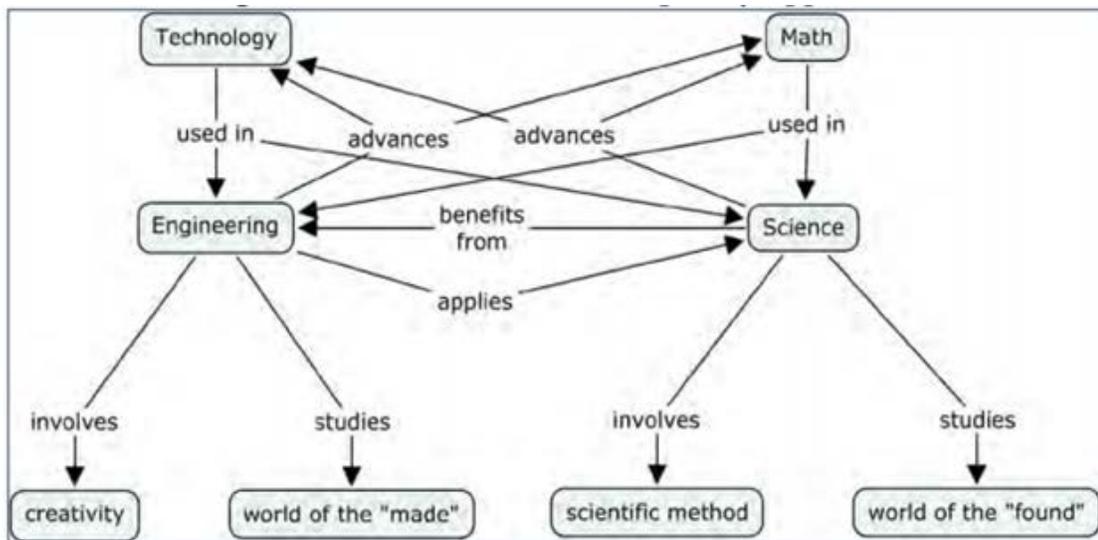


Figure 2:  
*The Value of an Interdisciplinary Approach*  
(Hanover, 2012, p. 19)

Stakeholders in each of the STEM education disciplines have expressed support in some way towards the goals and outcomes of iSTEM Education. In their meta-analysis, Becker & Park (2011) provided a brief overview of integrative efforts supporting iSTEM Education within each STEM discipline (a) Science educators support the idea of integration through design-based learning, (b) Technology education uses design technology projects so students may apply their knowledge developed in science, math, and technology, (c) Engineering education has used engineering design to integrate STEM subjects, and (d) Math educators provided justification for how integrative approaches among STEM subjects are needed for mathematics success.

Integrative approaches are defined as “approaches that explore teaching and learning between/among any two or more of the STEM subject areas, and/or between a STEM subject and one or more other school subjects (Sanders, 2009, p. 21).” Johnson and colleagues (2015) presented a Framework for STEM Integration in the classroom that includes six essential features, shown in Table 3.

Table 3  
*Six Essential Features of Effective STEM Integration*  
 (Johnson et al., 2015, p. 5)

Feature 1	In order to engage students in meaningful learning and provide access to the content, integrated STEM learning environments include a motivating and engaging context. These contexts should be personally meaningful and allow for students to connect with the content.
Feature 2	In order to develop problem-solving abilities, creativity, and higher-order thinking skills, integrated STEM Education should include engineering design challenges of relevant technologies for compelling purposes. This can also include engineering thinking, technological progress, and reverse engineering of technologies.
Feature 3	STEM integration should allow for students to learn from failure and to redesign based on what is learned. This is one of the hallmarks of engineering thinking and should not be overlooked.

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Feature 4	In order for learning to be meaningful and worth the time it takes to participate in project and problems-based learning challenges, integrated STEM Education should include standards-based mathematics and/or science objectives in the learning activities. In addition, real-world problems are interdisciplinary beyond just the STEM disciplines. This means that other disciplines, such as English/language arts and social studies, can be included as appropriate.
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Feature 5	In order to provide students with opportunities to learn the standards-based content deeply, it is imperative that content be taught in a student-centered manner. Students need opportunities to grapple with the content and think for themselves in order to deepen their conceptual knowledge.
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Feature 6	Integrated STEM learning environments should emphasize teamwork and communication abilities that are imperative for life in a 21st-century workforce.
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Even in the case of instruction that includes these features, there may be a variety of different ways in which a teacher might integrate STEM content. In the following section, I will present different conceptualizations of integration, and consider their applicability to iSTEM, specifically.

### **Types of Integration**

Throughout the past few decades, models, continuums, and approaches have been presented, all with the seemingly similar intent to clarify the methods and degrees of integration available to educators and curriculum designers. However, the multiple terms being used for similar ideas has had the opposite effect as intended by these same authors, as integration is still an ambiguous term. Just as there are a variety of specific forms of curriculum integration, its implementation can be just as unique as the teacher doing the instruction. While this allowance for creativity in curriculum planning can be a good thing, one of the main critiques of the practice is the inability for such practices to be easily replicated (Drake, 2007). Additionally, some teachers may integrate in ways

that differ from others as multiple integrative methods exist. The need for models of integrative methods is not novel, and there are multiple that exist in the literature. There are models set on continuums focused on math and science integration, models where integration is set on a hierarchical continuum, and models that describe various categories of integration. However, as will be discussed later in this chapter, few are grounded in studies of what teachers actually do. The following sections present some of the various models of integration found in the literature, with a conclusion regarding which approach will be used for the study described in chapter four of this dissertation in practice.

*Math and Science Continuums of Integration*

In a review of the literature, multiple models of integration were found that focused specifically on the integration of math and science. Table 4 provides an illustration of a few of the models set on a continuum where each end of the continuum includes either math or science only and moving towards the middle of the continuum suggests math and science integrated together. A description of each continuum is provided in the following paragraphs.

Table 4  
*Math and Science Continuums of Integration*

	Math Only<----->	Integration of Math and Science<----->		----->Science Only	
<b>Brown &amp; Wall (1976)</b>	Mathematics for the Sake of Mathematics	Mathematics for the Sake of Science	Mathematics and Science in Concert	Science for the Sake of Mathematics	Science for the Sake of Science
<b>Lonning &amp; DeFranco (1997)</b>	Independent Mathematics	Mathematics Focus	Balanced Mathematics and Science	Science Focus	Independent Science
<b>Huntley (1998)</b>	Mathematics for the Sake of Mathematics	Mathematics with Science	Mathematics and Science	Science with Mathematics	Science for the Sake of Science

Brown and Wall (1976) shared a continuum of integrative methods with each end of the continuum focusing on the mathematics for the sake of mathematics or science for

the sake of science then all integrative methods fall in between. Between the two ends of the continuum, there is mathematics for the sake of science, mathematics in concert with science, and science for the sake of mathematics. Brown and Wall (1976) claimed:

...the idea that we should now integrate science and math is fallacious since the two have never been conceptually separated. One discipline cannot advance indefinitely without the other, as many mathematicians are rediscovering to their dismay. At times, the impetus for new lines of research in mathematics comes from science. On the other hand, mathematics developed as “pure mathematics” years ago is currently being applied by scientists to explain present advances in science. (p. 551)

This continuum is suggested as a way to emphasize their point that any program that fails to include points from the span of the continuum does not adequately represent both mathematics and science. However, these claims and continuum, are not grounded in empirical studies.

Lonning and DeFranco (1997) created a theoretical model for the specific integration of science and math. The continuum begins with (a) Independent Mathematics where mathematics is taught independently with possibilities for integration within the mathematics discipline, (b) Mathematics Focus where a mathematics concept is taught but science activities or topics are taught to support the mathematics concepts, (c) Balanced Mathematics and Science where activities allow equal integration among mathematics and science concepts, (d) Science Focus where the primary emphasis is on the science concepts and the mathematics activities support the science topics, and (e) Independent Science which includes scientific topics taught in a strictly scientific way though

integration is possible within the discipline itself (Lonning & DeFranco, 1997). This continuum differs among the other continuums in that it does not build in a hierarchical fashion in the degrees of integration, but rather acts as a sort of weighted balance system where the seemingly best place to be located is in the middle. However, once again this model is not grounded in an empirical study.

Huntley (1998) presented a continuum that is similar to the continuum submitted by Lonning and DeFranco (1997) with two critical differences. The first difference is that in the middle of the continuum, Huntley (1998) has changed the focus from equal representation in both science and mathematics, to one that displays a synergistic role between both science and mathematics. Perhaps the greatest difference between the two presentations of the continuum is that Huntley's (1998) is grounded in a qualitative study that looked at integrated mathematics and science at the middle school level. The goal of the study was to provide an account, both analytically and descriptively, of the teaching and learning of mathematics and science in an integrated middle school classroom. The continuum was used to guide the study and to help select participants for the study whose goals were to blur the lines between both mathematics and science (Huntley, 1998).

In closing, while these continuums may be helpful in describing math and science integration approaches, these claims and continuums are not grounded in empirical studies. Furthermore, this conceptualization with science and math at opposite ends does not lend itself well to conceptualizing science, technology, engineering, and math integration, in which more than just math and science could be involved.

*Hierarchical Continuum of Integration*

The next models of integration found in the literature are described as hierarchical continuums of integration. Some researchers and theorists propose that integrative approaches are hierarchical, in that they begin from the least integrated and end with the most integrated (Jacobs, 1989; Erickson, 2001; Drake, 1993). Table 5 below includes an illustration of these continuums, and a description of each is included in the paragraphs that follow.

Table 5  
*Hierarchical Continuums of Integration*

	Least Integrative ←-----→ Most Integrative				
<b>Jacobs (1989)</b>	Discipline Based	Parallel Discipline	Complimentary Discipline	Interdisciplinary	Transdisciplinary
<b>Drake (2007)</b>	Fusion		Multidisciplinary	Interdisciplinary	Transdisciplinary

Jacobs (1989) presented a continuum of integration design options constructed for explaining the range of integrative options teachers and administrators have when designing their curriculum. The continuum is as follows:

1. Discipline-Based (segregated subjects taught at different times),
2. Parallel Disciplines (lessons scheduled to correspond to lessons in another discipline at the same time but still taught separately),
3. Complementary Discipline Units (a theme investigated in a formal unit in related content areas),
4. Interdisciplinary Units (all main disciplines brought together in periodic units),
5. Integrated Day (problem and theme-based experience that spans a full day), and
6. Complete Program (students create curriculum out of their every-day lives in the school environment) (Jacobs, 1989).

This continuum is not grounded in empirical studies, but rather presents ideas for teachers to use when planning instruction.

Another perspective comes from Drake (2007) in her book *Creating Standards-Based Integrated Curriculum* when she described four approaches to integration and the degrees by which each approach integrates. These approaches include fusion, multidisciplinary, interdisciplinary and transdisciplinary. Again, these approaches are presented without evidence of empirical study. However, examples from schools were given for each type of integrative method to illustrate the differences in integrative approaches.

The fusion approach is when there is an existing curriculum, and a topic or idea is infused into it (Drake, 2007). For example, using reading time to infuse a subject such as science, social studies, physical education or any subject other than reading to “boost” student exposure to the subject. A possible example would be to infuse the reading of science-based texts into a non-fiction reading program.

The next approach is multidisciplinary integration. In this approach, disciplines are separate and distinct, but purposeful connections are made among them (Drake, 2007). For example, a teacher might create learning stations at the elementary level during a study on sharks and each station has something to do with sharks but stations are distinguished by subject area such as “Reading about Sharks” and “The History of Sharks” or “What do Sharks Eat?” The topic or theme is the same, but each discipline is easily recognizable within the instruction.

The third approach is interdisciplinary integration. Interdisciplinary curriculum makes the connections among disciplines more explicit and while the curriculum still

centers on a common topic, “the concepts or skills are emphasized across the subject areas rather than within them” (Drake, 2007, p. 36). For example, a unit might be structured to focus on research skills and this skill is developed across all disciplines. In the interdisciplinary approach, the disciplines are still somewhat separate, but not as much as they are in multidisciplinary integration. Additionally, in interdisciplinary integration, the focus is on a particular skill as the “common denominator” across the curriculum (Drake, 2007, p. 37).

Finally, the fourth integrative approach is transdisciplinary integration.

Transdisciplinary integration is focused on real-life situations and how they apply and are relevant to the learner. This approach focuses on real-life contexts that are problem-based and require the student to be both questioner and researcher (Drake, 2007). For example, a third-grade class is interested in growing their food in the raised garden beds on school grounds. However, previous classes have attempted to grow things in the raised beds, but everything gets eaten by the rabbits that live in the area. The third-grade teacher poses a question “What can we do to keep the rabbits out of our raised garden beds, so they will not eat our plants?” In this approach, the teacher has drawn upon student interest in utilizing the raised garden beds to grow plants. The starting point is not in any particular discipline, but skills from multiple disciplines will be needed to solve the problem. While each approach outlined by Drake (2007) is different, they are similar in that they all require the use of standards and assessments. However, once again, these methods are not grounded in empirical studies.

Once again, the question of whether or not these continuums would be the best fit for use in iSTEM Education is unclear as there is a lack of empirical studies supporting

that claim. Furthermore, the presentation of integration approaches on a continuum would lead one to believe that the most integrative method would be the most desirable; therefore their use may be more beneficial in trying to evaluate which method is best. These continuums could be useful in providing clarification on math and science integration to determine which is best, but they do not appear to be the best choice for describing and categorizing integrative methods used in iSTEM Education. The study described in chapter four of this dissertation in practice intends to categorize and compare integration methods, so it is clear that the continuum models for integration are not appropriate for use in that study.

*Categories of Integration*

Categorical integration is another model of considering integration discussed in the literature. These models provide descriptions of various ways in which subjects could be integrated. Table 6 provides an illustration of these models with further descriptions of each in the paragraphs that follow.

Table 6  
*Categories of Integration*

Author	Categories of Integration									
Fogarty (1991)	Fragmented	Connected	Nested	Sequenced	Shared	Webbed	Threaded	Integrated	Immersed	Networked
Davison et al. (1995)	Discipline Specific		Content Specific		Process		Methodological		Thematic	

Fogarty (1991) described ten categories for integration that and are intended for teachers to use when designing instruction. Each model is described by a type of *lens* as to how the curriculum would be viewed within the model. The model is as follows:

1. Fragmented (a periscope- a traditional way of curriculum design where disciplines are segregated),

2. Connected (opera glasses- a way of connecting topics/skills/concepts to each other within the same subject and building upon them over a period of time)
3. Nested (3D-glasses- making natural connections within a lesson such as studying cycles when focusing on the water cycle),
4. Sequenced (eyeglasses- a way of putting concepts together at the same time in the teaching schedule but are still taught separately),
5. Shared (binoculars- where two disciplines are brought together using concepts that overlap),
6. Webbed (telescope- uses conceptual themes such as patterns to be used as a theme for multiple disciplines),
7. Threaded (magnifying glass- uses big ideas to weave together multiple skills and disciplines and goes beyond individual subject content such as using questioning throughout),
8. Integrated (kaleidoscope- designing curriculum around overlapping concepts/skills using a cross-disciplinary approach),
9. Immersed (microscope- a way of integrating within the learner without outside intervention such as building upon student interest) and finally,
10. Networked (prism- provides multiple paths for investigation in areas of student interest) (Fogarty, 1991).

Again, while these models may be helpful for teachers to design instruction, they are not grounded in empirical studies portraying what teachers actually do in the classroom.

Another set of voices in the literature is Davison, Miller, and Metheny (1995) in their presentation of five types of integration specifically related to math and science.

These five methods include: (a) Discipline Specific Integration (b) Content Specific Integration (c) Process Integration (d) Methodological Integration and (e) Thematic Integration. The definitions of each, as presented by Davison et al. (1995), are included in Table 7. Again, like many of the previous authors of integrative models, these approaches are not grounded in studies of actual teachers' integrative practices; they are merely presented as options for integration.

Table 7  
*The Five Types of Science and Math Integration*  
 (Davison, Miller, and Metheny, 1995, p. 227)

Type of Integration	Definition
<i>Discipline Specific Integration</i>	“This approach involves an activity that includes two or more branches of mathematics or science. For example, discipline-specific integration might include activities involving algebra and geometry in mathematics activities infusing biology, chemistry, and physics in science”.
<i>Content Specific Integration</i>	“This approach involves choosing an existing curriculum objective from mathematics and one from science. An activity is planned which will involve instruction in each of these objectives. It is content specific because it conforms to the previously developed curriculum, infusing the objectives from each discipline”.
<i>Process Integration</i>	“This approach uses real-life activities in the classroom. By conducting experiments, collecting data, analyzing the data, and reporting results, students experience the processes of science and perform the needed mathematics”.
<i>Methodological Integration</i>	“This approach involves students investigating issues in both science and mathematics using related strategies such as inquiry, discovery, and the learning cycle.”
<i>Thematic Integration</i>	“This approach begins with a theme which then becomes the medium with which all the disciplines interact.”

For the study described in chapter four of this dissertation in practice, categorical integration models appeared to be a better choice as opposed to the continuum models as

the study focuses on categorizing and comparing the integration methods elementary teachers are using in their classroom rather than evaluating them. When deciding between the Davison model and the Fogarty model, there were a few characteristics of each model that influenced the decision. Neither model was grounded in empirical studies of what teachers actually do, though both models looked to categorize and compare as opposed to evaluating integration approaches. The Davison et al. (1995) model appeared to be much easier to work with as the criteria for each method of integration was clearly described and easy to follow. The Fogarty model is detailed and laid out nicely, but appeared to be too complex and cumbersome for the purposes of the study. Furthermore, while the Davison et al. (1995) model is focused on science and math integration, the ability to apply the integration approaches to all subjects is fairly easy, which lends itself well to looking at integration approaches used in iSTEM Education where many subjects could be integrated.

### **Summary**

A search of the literature into the integrative methods elementary teachers use when teaching iSTEM Education revealed few empirical studies. Hinde (2005) claimed infusion to be the most widely used method of integrative approaches among elementary teachers, though her interpretation of infusion “one subject area as the helper of another” (p. 106), would come close to Drake’s (2007) interpretation of fusion as an existing curriculum that already exists and a topic or idea is infused into it. Additionally, Czerniak et al. (1999), conducted a study in which they looked at the beliefs and intentions of teachers (elementary teachers included) to implement thematic units. In this study, Czerniak and colleagues stressed the importance of using a thematic integration approach

to teaching science and one of their conclusions was that “Teachers of lower grade levels have greater intentions to implement thematic units in their classrooms than teachers of upper-grade levels” (Czerniak et al., 1999, p. 139). Furthermore, some researchers suggest that elementary teachers use a thematic approach to teaching primary science and that the way in which elementary teachers implement thematic integration influences student learning (Waldrip & Knight, 2001).

Regardless of the integrative approach used in elementary classrooms, iSTEM Education requires that integration takes place. Furthermore, some have determined that each type of integration is advantageous in “different contexts and for different purposes...as long as it honors accountability mandates” (Drake, 2007). Through this review, it is clear that there are many options for integration and the degree of integration can fluctuate depending on the method chosen. Integrative methods are used to serve a variety of purposes, and the depth of integration may change depending on the end goal. For this study, the focus is not to evaluate which type of integration from which model is most effective, but rather to describe and compare the integrative practices that are currently taking place in the elementary classrooms when teaching STEM content. This may be used, in turn, to consider how to best provide iSTEM Education professional development to elementary teachers. In the following section, a review of the literature on effective teacher professional development in iSTEM Education at the elementary level is presented.

### **What is Effective Elementary Level STEM Professional Development?**

Professional development in iSTEM Education is critical for teachers, particularly in the areas of technology and engineering (Avery & Reeve, 2013). There are many ideas

regarding best practice in effective teacher professional development. Some of those ideas are directed towards using collaborative learning and creating professional learning communities (Wenger, 1999; Loucks-Horsley et al. 2010; Nickerson and Moriarty, 2005). Others emphasize the need for professional development to be focused on the real work of teachers (Loucks-Horsley et al., 2010). Others promote courses of study tied to practice as opposed to the traditional format of workshops (Garet et al., 2001).

Though there is little research that ties professional development to student learning, the literature does provide many ideas that show factors leading to successful teacher learning through professional development (Heller et al., 2012). For example, Roth and colleagues (2011) in their study on professional development practices implemented to improve student science learning using video analysis at the elementary level. After analyzing various professional development practices over the course of a year, authors found that science content knowledge increased for both teachers and students (Roth et al., 2011). Additionally, a study conducted by Fields and colleagues (2012) showed that students scored higher on science tests when their teachers participated in professional development with the same subject focus.

There is more work to be done in the area of professional development in iSTEM Education, as the current research regarding effective professional development in iSTEM Education is sparse. However, there are some researchers who have started to look at the specific and unique needs of professional development for teachers regarding iSTEM Education, particularly at the elementary level.

Avery and Reeve (2013) conducted a study focused on an iSTEM Education professional development experience and found that the workshops had a positive effect

on aiding teachers with connecting iSTEM Educational theories with teaching practices, which provided more enriched learning experiences for their students. The researchers presented six recommendations intended to be used by professional development designers when creating iSTEM Education specific professional development experiences including a) providing a supportive professional development environment b) providing an exemplar engineering design challenge c) providing training on managing group projects and evaluating student contributions d) considering standards-based pressures that impact STEM learning e) training teachers how to develop their own standards-based, engineering design challenges, and f) training teachers how to integrate STEM concepts into their instructional materials (Avery & Reeve, 2013). These recommendations are intended to be used as a framework for promoting quality iSTEM Education professional development and is applicable for use in all grade levels.

Hiebert (1999) suggested the best opportunities for teachers to learn new methods of teaching should follow four core features “a) ongoing (measured in years) collaboration of teachers for purposes of planning with b) the explicit goal of improving students’ achievement of clear learning goals, c) anchored by attention to students’ thinking, the curriculum, and pedagogy, with d) access to alternative ideas and methods and opportunities to observe these in action and to reflect on the reasons for their effectiveness...”( p. 15). The ongoing collaboration of teachers suggested by Hiebert (1999) falls in line with the idea of using collaborative learning communities which many researchers have also suggested (Wenger, 1999; Loucks-Horsley et al. 2010; Nickerson and Moriarty, 2005). Additionally, the focus on teacher reflection is a key element in transformational learning which may cause teachers to experience a paradigm shift in

their understanding of the material (Mezirow, 2000). However, while it would be beneficial to have professional development that spans over the course of years, the logistics of such a task provides its own set of challenges such as teacher attrition and funding.

Some researchers are concerned with the incoherence of current teacher professional development programs. Garet et al. (2001) stressed the ineffectiveness of the traditional professional development workshop format because they do not provide teachers with “sufficient time, activities, and content necessary for increasing teachers knowledge and fostering meaningful changes in their classroom practice” (p. 920). Another criticism by these authors is that teacher professional development activities tend to be disconnected from one another in that they utilize individual activities that do not form a coherent experience (Garet et al., 2001). Just as teachers need coherency in lesson planning to create a coherent storyline for students (Ramsey, 1993), a coherency in the development of teacher professional development experiences is also needed. Effective and coherent professional development programs should include clear goals that connect with activities, align with district and state standards and assessments, and provide opportunities to communicate with others (Garet et al., 2001).

In a literature review conducted for a three-year longitudinal study, Desimone et al. (2002) summarized that there have been some preliminary agreements regarding specific characteristics of high-quality professional development. These characteristics included a) a focus on content and how students learn content, b) active learning opportunities, c) links to high standards, d) opportunities for teachers to engage in leadership roles, e) extended duration and f) the collective participation of groups of

teachers from the same school, grade, or department (Desimone et al., 2002, p. 82). The study conducted by Desimone and colleagues (2002) examined the effects of professional development on teaching practice. They looked at over two hundred teachers over a three-year period in ten separate districts and examined how the features of professional development affected how teachers taught science and mathematics (Desimone et al., 2002). They concluded, "...professional development focused on specific teaching practices increased teachers' use of those practices in the classroom" (Desimone et al., 2002, p. 102). These findings help in defining the elements of highly effective teacher professional development, but there is still work to be done. Borko (2004) stressed:

We have much work to do and many questions to answer in order to provide high-quality professional development to all teachers. It will take many different types of inquiries and a vast array of research tools to generate the rich source of knowledge needed to achieve this goal. (p. 13)

Since background experiences in STEM areas may be lacking at the elementary level, teachers need to experience iSTEM Education first hand to learn how to teach it (Basista & Mathews, 2002). Additionally, teachers need access to successful implementation and models of iSTEM Education in action (Nadelson & Seifert, 2007). This is especially true for elementary teachers as most examples of effective iSTEM Education practices are targeted for middle and secondary teachers. Wang and colleagues state that elementary teachers need to have explicit examples of iSTEM Education and "New models of teaching must be developed if STEM integration is to lead to meaningful STEM learning, given that most teachers have not learned disciplinary content using STEM contexts, nor have they taught in this manner" (Wang et al., 2011, p. 2). The

research and development of these models are necessary to consider as teachers are more likely to be open to modifications to their teaching when they are provided with useful models (Levitt, 2002). Knowing the specific ideas where elementary teachers need professional development in iSTEM Education is important as Zhang and colleagues (2015) stated:

...effective pd should teach teachers what they need to know and help them deal with challenges arisen from practice. However, research on effective pd is largely disconnected from research on teacher knowledge... understanding of teacher knowledge provides a useful framework for considering teachers' needs for pd, which serves as a basis for designing effective pd. (p. 473)

Research specific to elementary iSTEM Education has some suggestions regarding indicators that make an iSTEM Education experience effective. According to Hanover (2012), best practices unique to iSTEM Education professional development draw heavily from general teacher development techniques; however, certain approaches are considered by experts to be most applicable to iSTEM Education teacher needs (Hanover, 2012). For example, Hanover (2012) suggested eight elements of effective STEM Professional Development which have been included in Figure 3.

- ❖ **Active** – Engage teachers in practicing concrete tasks related to teaching, assessment, and observation of learning.
- ❖ **Collaborative** – Include time for teachers to share ideas and practices.
- ❖ **Learner-centered** – Draw upon teachers' questions, inquiry, and experiences.
- ❖ **Student-centered** – Build on teachers' current work with students.
- ❖ **Relevant** – Address problems teachers experience in their classrooms.
- ❖ **Content-specific** – Develop teachers' knowledge and capacity to teach specific subject matter.
- ❖ **Pedagogy Focused** – Provide modeling, coaching, and problem-solving around specific areas of practice.
- ❖ **Appropriately Structured** – Plan a sufficient amount of time for teachers to participate in and process their professional development.

Figure 3  
*Elements of Effective STEM Professional Development*  
(Hanover, 2012, p. 19)

These eight specific features of effective iSTEM Education professional development are similar to what the field of education might determine as common practice for teacher professional development, but for teachers of iSTEM Education, these elements are especially important.

In the book *The STEM Road Map*, Johnson and Sondergeld (2015) cited the Core Conceptual Framework by Desimone (2009) as an effective framework for promoting professional development that improved teacher abilities. The framework includes five elements for increasing teacher quality, and they include “collective participation, active learning, coherence with policy, extended duration, and a focus on learning new skills in the context of building content knowledge” (Johnson & Sondergeld, 2015, p. 203). Collective participation in this context is referring to the practice of having teachers from the same building or district participate in professional development experiences together to have an additional support system in place. According to Johnson and Sondergeld (2015), “collective participation ensures more buy-in to the reform on the school level and provides much-needed support to improve the odds of achieving intended outcomes for teachers and students...” (p. 204). On that same note, coherence is essential in the professional development program as the goals of the experience must be situated within the school, state and district policies in regards to iSTEM Education (Johnson & Sondergeld, 2015). Active learning is the idea that teachers actively participate in the lessons they will be teaching their students by acting as the learner instead of the teacher. For example, rather than having teachers “sit and get” during a professional development program, active learning requires teachers to get up and experience first-hand the

thinking and skills required to engage in a lesson that they might teach in a class themselves. Duration is another element, and according to Johnson and Sondergeld (2015), much research has been done to determine that at least 80 hours of professional development must take place for a change in practice to occur. Finally, content knowledge must be included in the professional development program. This is especially critical for elementary teachers as most do not have a degree in specific content areas.

The National Academies of Sciences, Engineering, and Medicine recently presented a list of characteristics that is a combination of multiple researchers to develop a “consensus model” of effective professional development in their publication titled *Science Teachers’ Learning: Enhancing Opportunities, Creating Supportive Contexts* (2016). While it was noted that there were still gaps that required further research, they offered a model of effective professional development that takes the consensus model to the next step.

While there are multiple ideas regarding effective professional development, many are grounded in correlational studies as opposed to empirical studies and few provide insight on the outcomes of teacher learning. However, the ideas and research that has been conducted on the topic provide some insight on how effective professional development should be designed. Table 8 summarizes some of the characteristics previously presented in this review.

Table 8  
*Features of Effective Professional Development Summary*

Feature of Effective PD	Wenger (1999)	Loucks-Horsley et al. (2010)	Nickerson and Moriarty (2005)	Hiebert (1999)	Avery and Reeve (2013)	Garet et al. (2001)	Desimone et al. (2002)	NRC (2016)	Hanover (2012)
Coherence						X	X		
Collective Participation					X	X	X		
Clear goals						X			

Scaffolded Learning							X	
Collaborative Learning	X	X	X	X		X		X
Assessment						X	X	
Targeted Teaching Strategies								X
Reflection				X				X
Content specific							X	X
Learner centered								X
Extended time period				X			X	X
Supportive Environment					X			
Leadership opportunities							X	
Access to alternative ideas				X				
Addressing standards-based pressures						X	X	
Active learning opportunities							X	X
Professional Learning Communities	X	X	X					
Real work of teachers		X				X		X
Workshops						X		
Pedagogy focused (models and exemplars)				X	X			X

Most of the studies reviewed thus far have focused on face-to-face models of professional development; however, online professional development is becoming increasingly more common. Indeed, the evidence thus far suggests that online programs may be just as effective as more traditional PD program (Fishman et al., 2013). In the following section, a review of the literature focused on effective professional development deployed via an online format, specifically, is presented.

## **What are considerations for effective online iSTEM Education professional development?**

According to the National Center for Educational Statistics (Planty et al., 2009), online programs were uncommon at the turn of the century, but now nearly every institute of higher education offers them. An earlier report from the NCES, reported that in 2000-2001, 52 percent of institutes of higher education that had undergraduate programs also offered undergraduate opportunities through distance education courses (i.e. online courses) and 52 percent of institutions offering graduate programs also offered distance education for graduate level students (U.S. Department of Education NCES, 2003). According to Palloff and Pratt (2007), the belief that online education was only for the non-traditional adult student is no longer an accepted perception as people of all ages and stages of life are taking online courses for various reasons. Given the product of this dissertation in practice is an online professional development course on iSTEM Education for adult learners (teachers), it is necessary to take into account what is known about effective online professional development. Kearsley (2000) pointed out that the virtual classroom is a “unique social context, much different from that of a regular classroom” (p. 8). Just like all face-to-face classes are set up and implemented differently, so too are classes deployed via the internet.

While online courses vary in their design, many researchers have attempted to establish models, goals, and tenets by which to guide instructors to create and implement effective online courses. For example, Moore (1989) shared three kinds of interactivity that can affect how a student learns in an online course. These three types of interactivity are; (a) interaction with content, (b) interaction with instructors and (c) interaction with classmates. Moore stated that none of these types of interactions occur by themselves

within a course, but rather in a way where all three can occur simultaneously. Rourke and colleagues (2001) created a graphic representation of the relationship between these interactions called the ‘Community of Inquiry: Model of Online Learning’ and is included in Figure 4.

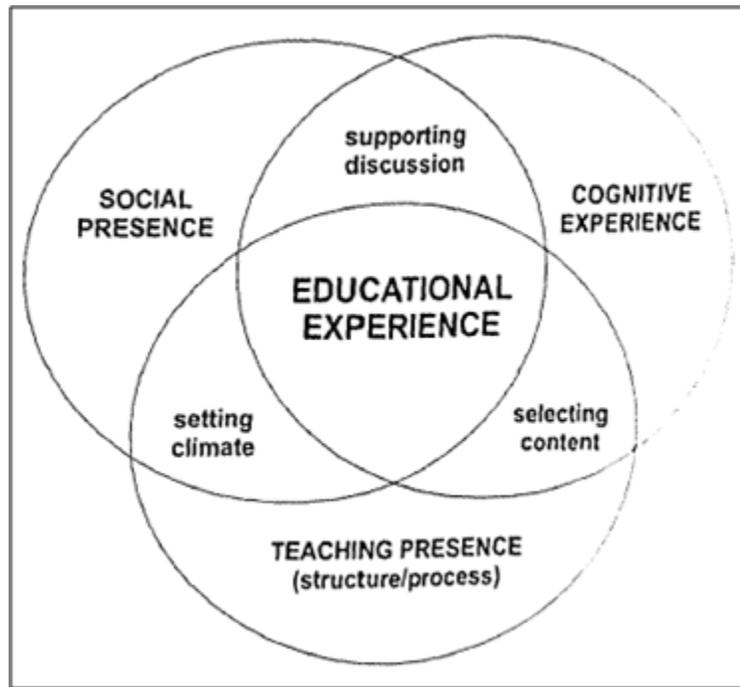


Figure 4  
*Community of Inquiry: Model of Online Learning*  
(Rourke et al. 2001)

Another perspective comes from Janicki and Liegle (2001), who developed a list of ten concepts they believed to be the best way to design web-based instruction. They are;“(a) Instructors acting as facilitators, (b) Use of a variety of presentation styles, (c) Multiple exercises, (d) Hands-on problems, (e) Learner control of pacing, (f) Frequent testing, (g) Clear feedback, (h) Consistent layout, (i) Clear navigation, and (j) Available help screens” (Janicki & Liegle, 2001, p. 62). Additionally, Gagne et al. (1992) presented nine events of learning which correlate to and address the conditions needed for learning:

1. Gain attention

2. Inform learners of objectives
3. Stimulate recall of prior learning
4. Present the content
5. Provide “learning guidance”
6. Elicit performance (practice)
7. Provide feedback
8. Assess performance and
9. Enhance retention and transfer to the job

Additionally, Payne (2004) provided four features supporting online methods for educators for reflection and interaction. These features include; “Providing both individual and group learning opportunities; Providing opportunities for feedback and for learner success; Designing all assignments, including exams, to be formative, to track and encourage learner progress and reflection; and providing maximum learner choice and support; ceding control of learning to the learner(s)” (Payne, 2004, p. 236).

While there are multiple perspectives on the many models for best practice in online course design and implementation, there are some areas that overlap. Such as the idea that instructors play the role of facilitator and provide clear and consistent feedback, as well as creating a course design that is learner-centered with many opportunities for collaboration with both peers and instructors. These ideas also overlap with the tenets of transformative learning theory. For example, transformative learning theory includes roles for both the instructor and the student. Instructors are to act as “co-learners” or facilitators in the process who help to establish a safe and welcoming environment for students to participate in dialogue and critical reflection. While this does not seem much

different from what one might do in a face-to-face teaching environment, in reality, it is quite unique. Palloff and Pratt (2007) stated:

The expected outcome of the transformative process in the online environment, than, is significantly different from that which might be experienced in a face-to-face class. To frame it simply, the results of the transformative learning process are the student's ability to stay focused on a position or idea or to achieve a shift in paradigm, thereby adopting a new view of the same idea. Students may be able to develop new ways of explaining their ideas, or they may be able to enhance or expand upon those ideas; they may also be able to reflect on how the process itself has affected them. (p. 190-191)

Transformative learning has a foundation in constructivism (Mezirow, 2000) and it has been established that "constructivism is a major feature of the online classroom" (Palloff & Pratt, 2007, p. 185). Participants in an online course have the unique opportunity to engage with course content and reflect on discussions at their own pace. Students can go back to revisit concepts that may have challenged them previously to clarify ideas and check for possible misconceptions. Students are also able to re-read course discussion threads in the created "communities" online and see "aha moments" of their own as well as their peers' (Palloff & Pratt, 2007). This practice in and of itself helps to promote transformative learning by fostering opportunities for students to engage in critical reflection of ideas they may have had when they began the course that may have since changed or become more developed over the course. This is a unique feature in online learning that may not be able to be replicated in a face-to-face course as students are verbally speaking and listening to each other rather than typing and reading.

## Summary

This chapter aimed to clarify what is meant by integrating STEM, consider different ways in which STEM subjects can be integrated, and how professional development should be designed to support teachers in implementing iSTEM Education. The key insights gained from this literature review include the following ideas. Much work is being done to determine a standard definition of iSTEM Education and integration, but these definitions remain elusive. The integration of STEM content describes an overlapping of disciplinary ideas and practices through the use of pedagogical strategies such as problem or project based learning, including the engineering design process. While iSTEM Education requires some form of integration takes place, there are a variety of ways in which to integrate STEM content. However, more empirical studies of how elementary teachers are integrating STEM content in their classroom is needed to better understand their iSTEM Education teaching practices. Professional development for elementary teachers in iSTEM Education should provide opportunities for teachers to engage in experiences that promote and engages them in transformative learning, provide elementary specific models and samples of iSTEM Education in action, and allow for collaborative learning experiences. In the following chapter, I present a sampling of current professional development offerings for iSTEM Education, along with a critical discussion informed by the literature review.

## **CHAPTER THREE: PRACTITIONER SETTING FOR THE STUDY**

### **Introduction**

This chapter describes the practitioner setting for the dissertation-in-practice by providing an analysis of current course offerings on iSTEM Education. A critical review of current PD offerings will be used to identify gaps in current offerings that new PD courses might address.

#### **Status of Current Integrated STEM Education Offerings for Teachers**

The first step in learning about current professional development opportunities in iSTEM Education for elementary teachers began with an inquiry into the existing iSTEM Education courses offered for preservice and practicing teachers in general. The Google search engine was used with keywords such as “STEM Methods Course” and “STEM Education Course” and “STEM professional development courses.” Courses selected for inclusion had to fit the following criteria: (a) the course must be part of an institute of higher education or have an affiliation with a recognized educational organization (NSF, NASA, etc.), as opposed to an isolated freelance offering (i.e. courses provided by individual people via their personal website such as “The STEM Mom”), (b) if the course is offered by an institute of higher education, it must be part of a pre-service teacher development program or in-service teacher outreach program as opposed to STEM content courses offered through other academic areas and (c) information on the content of the course was made available (such as course descriptions and syllabi). A total of twenty courses were identified. Though some additional courses were found, only the title was offered with no other descriptive information regarding course content. It is important to note that new courses are continually being developed and employed in

iSTEM Education, so the results of this inquiry are only representative of the courses being offered at the time of this dissertation in practice being written.

A few limitations of this inquiry are important to note. First, offerings from places such as “The STEM Mom,” though available to teachers, were not included in this query. However, the idea that these offerings are grounded in research and are provided by qualified instructors is unclear, which is why they were not included in the search. Teachers would not be committed to a degree or certificate, but the quality and accuracy of such offerings may not result in the kind of transformative learning desired by those committed to the iSTEM Education movement. This is not to say that these offerings may not be beneficial, but rather that these offerings are provided by places that may not be accredited or recognized by the research community. Second, some districts may provide their own professional development opportunities for teachers in iSTEM that are not tied to a degree, but the contents of such offerings have not been made available for critique. For example, there are many businesses and organizations that offer teacher professional development in STEM Education that can be hired to come to a school and provide a workshop for a fee paid by the school district. Finally, it is understood that most of the courses included in this inquiry come from institutions of higher education which typically provide courses that would lead to a degree. This is good in the sense that pre-service teachers and those seeking higher degrees have multiple options available from which to choose, but it leaves in-service teachers who are only looking to gain professional development to improve their teaching without many options.

## **Results of Inquiry**

The results of this inquiry show that courses preparing teachers to teach iSTEM Education follow four main approaches: (a) ‘STEM’ as a suite of content courses (taught separately and/or integrated), (b) ‘STEM’ as a suite of disciplinary pedagogy courses (taught separately or with STEM embedded in another discipline, e.g., Science Methods and STEM Learning), (c) ‘STEM’ as a standalone methods course, and (d) ‘STEM’ as a suite of ‘STEM’ courses. While there are many other STEM type courses offered throughout the country by various institutions, I chose only to include in this synthesis those that were specifically intended to prepare teachers to teach iSTEM Education or those that appeared to be considered as such based on the course descriptions provided. In the sections that follow, I describe each type of iSTEM Education offering for teachers, provide illustrative examples, and provide a critique of each method.

### *‘STEM’ as a suite of content courses*

Some institutions use an approach to prepare teachers to teach iSTEM Education by offering a suite of content courses in each of the STEM disciplines. For example, the New York Institute of Technology (2016) has a set of courses included in their certificate of STEM Education focused on integrative teaching methods. However, the focus is on mathematics, science, and technology with no mention of engineering. The course description described developing problem-solving skills, but there was no description for the inclusion of engineering design in the course. Additionally, the other courses included in the STEM certificate were content courses, and these two issues are what led to its current classification in this review.

This approach may be considered beneficial in that a focus is given to developing teachers' content knowledge, which allows teachers to better understand the content they teach. According to Ball et. al. (2008):

Teachers must know the subject they teach. Indeed, there may be nothing more foundational to teacher competency. The reason is simple: Teachers who do not themselves know a subject well are not likely to have the knowledge they need to help students learn this content. (p. 404)

If teachers are to better facilitate student learning, then they must have a deep understanding of the subject matter they teach (Shulman, 1986).

However, this approach is problematic as it does not necessarily support subject matter knowledge for teaching and simply knowing a subject well does not mean one is able to teach it (Ball et al., 2008). Additionally, treating subjects separately fails to convey the integrated nature of iSTEM Education teaching and learning. In the initial query prior to this final dissertation in practice, some institutions offered STEM methods courses in this way. However, after nearly a year from the initial search, most of the institutions who previously fell into this category have changed and are no longer offering STEM methods courses in this manner. This change in inquiry results illustrates how quickly the iSTEM Education movement fluctuates as those committed to it learn more about iSTEM Education and how it should be taught. The few institutions fitting this course description can be found in Table 9.

Table 9  
*'STEM' as a suite of content course offerings*

Name of Course(s)	Institution	Delivery Method	Credential Earned	Certification Grade Band
Math, Science, and Technology 1 and 2	<a href="#">New York Institute of Technology</a>	Campus	Graduate Credit toward degree	K-12
2-part Methods course: 1. Elementary Science Instructional Strategies and STEM Learning 2. Elementary Math Instructional Strategies and STEM Learning	Texas A&M University (2015)  <i>*Course appears to be no longer offered</i>	Online	Graduate Credit	K-5

*'STEM' as a suite of disciplinary pedagogy courses*

Some institutions choose to prepare teachers in iSTEM Education by offering a suite of pedagogy courses that are taught separately or have STEM content embedded in another discipline. For example, Drake University (2016) offers a STEM Methods set of courses as part of a graduate degree program, but rather than one single course, they have split it into three classes. The first course is Engineering and Technological Design, the second is Nature of Science, Technology, and Engineering, and the third course is Mathematical Practices. All three classes are offered as face-to-face campus courses and are required to complete a “STEM” focus.

Additionally, not all “STEM” degrees or programs had courses specifically titled as STEM Methods courses but had degree programs that ended in a degree or certificate in STEM Education. For example, Wheelock College (2015) in Boston, Massachusetts has a thirty hour Master’s degree program titled “Masters of Science in Educational Studies with a focus on STEM.” These thirty credit hours are comprised of online courses such as “Teaching and Learning Elementary Science,” “Numbers and Operations,” and a

mix of other separate courses in teaching math and science. There were no courses provided in the program description (which had a breakdown of all required courses for the degree) with a title of STEM Methods or anything close to it, yet the focus of the degree was on STEM Education. Rider University (2016) also offers a graduate certificate in STEM Education, but the courses listed for completion are either all science courses (for a science-focused STEM certificate) or math courses (for a mathematics focused STEM certificate). There are no specific STEM methods courses listed as part of the certificate program, as is the case for other institutions listed in Table 10. The Project Manager for this STEM initiative was contacted to clarify if a STEM methods course was included and the response indicated that there is not a current STEM methods course within the program at this time, but that one is being developed to be deployed this fall.

When iSTEM Education is embedded within another methods course (e.g. math or science), iSTEM Education becomes a subset of the main discipline. This is a problem because rather than iSTEM Education being its own unique content and pedagogy, more emphasis is given to one particular discipline. This is similar to the critique of technology teachers when technology is embedded superficially into a science or math course. Technology becomes a tool for teaching science or math content as more emphasis is given to the science or math objectives (Williams, 2011). Similarly, when embedding iSTEM Education within a science methods course, iSTEM Education becomes a tool for teaching science content as more emphasis is given to the science discipline.

Table 10

*'STEM' as a suite of disciplinary pedagogy course offerings*

Name of Course(S)	Institution	Delivery Method	Credential Earned	Certification Grade Band
3-part Methods course: 1. Methods of Engineering and Technological Design 2. Inquiry and the Nature of Science, Technology, and Engineering 3. Mathematical Practices *No STEM methods course	<a href="#">Drake University</a>	Campus	Undergraduate and Graduate Credit towards degree	K-8, 5-8, K-12 Specialist
STEM Certificate comprised of: 5 courses in teaching and learning mathematics OR 5 courses in teaching and learning science *No STEM methods course	<a href="#">Rider University</a>	Online	Graduate Credit towards degree	K-8
Masters in STEM comprised of: 10 courses in mathematics, science, and general pedagogy *No STEM methods course	<a href="#">Wheelock College</a>	Online	Graduate Credit towards degree	1-6
STEM Minor comprised of: 6 courses of disciplinary pedagogy courses as well as Research Methods *No STEM methods course	<a href="#">University of Massachusetts</a>	Campus	Undergraduate Credit towards degree	7-12
STEM Endorsement comprised of: 1. Science Curriculum and Reform 2. Mathematics in the School Program 3. Instructional Tech, Design, and Assessment 4. Engineering Principles and Concepts for the Non-Engineer	<a href="#">Millersville University</a>	Online	Graduate Credit towards degree	K-12

*'STEM' as a standalone methods course*

Some institutions prepare teachers in iSTEM Education through providing courses specifically labeled as a STEM Methods course. For example, the NASA Endeavor STEM Education Project (2015) offers an online STEM methods course as part of a graduate certificate or Master's degree in STEM Education. This STEM Methods course is a required course within both the Certificate and the Master's degree option. Similarly, the University of Wisconsin-Stout (2015) and the University of Cincinnati

(2015) both offer online degrees that include a STEM Methods course. Additional institutions with similar course offerings are included in Table 11.

While the exact content covered within each course is not available, the overall idea of a methods course, specifically on iSTEM Education, stands out as being a step in the right direction for teaching teachers how to teach STEM content as its own subject. Kaufman and colleagues (2003) supported the idea of iSTEM Education being a subject of its own when they stated:

First, the STEM areas cannot be viewed as independent silos of content. For example, there cannot be a separate engineering curriculum and a technology curriculum. STEM should be viewed as a meta-discipline, the creation of a discipline based on the integration of other disciplines into a new whole. (p. 15)

Table 9 provides a summary of institutions who provide courses specifically labeled as STEM methods courses.

Table 11  
*'STEM' as a standalone methods course*

Name of Course(S)	Institution	Delivery Method	Credential Earned	Certification Grade Band
Methods of STEM Education	<a href="#">NASA/US Satellite/Columbia Teachers College/Adams State College (2015)</a>	Online	Graduate credit towards degree and/or certificate	All
STEM Methods 1 & 2	<a href="#">University of Kentucky (2014)</a>	Campus	Undergraduate credit towards degree	8-12
STEM Education Foundations	<a href="#">Old Dominion University (2014)</a>	Campus	Undergraduate and graduate credit towards degree	Unspecified
Integrative STEM Methods for Young Learners	<a href="#">The College of New Jersey (2015)</a>	Campus	Undergraduate credit toward degree	6-8
Perspectives of STEM Education	<a href="#">California State University (2015)</a>	Campus	Graduate credit toward degree	Unspecified

Issues in Integration of STEM	<a href="#">University of Wisconsin-Stout (2015)</a>	Online	Graduate Credit toward degree	6-12
Teaching STEM Methods	<a href="#">National University-California (2015)</a>	Campus	Undergraduate credit toward degree	K-8
Integrating STEM into Practice	<a href="#">University of Cincinnati (2015)</a>	Online	Graduate credit towards degree	K-8
Introduction to STEM Education	<a href="#">University of Arkansas (2015)</a>	Campus	Undergraduate credit toward degree	Early Childhood
STEM Curriculum and Methods, Elementary	<a href="#">Valley City State University</a>	Online	Graduate Credit toward degree	K-12
STEM I and 2 for Elementary Teaching	<a href="#">Marist</a>	Campus	Undergraduate credit toward degree	1-6

*‘STEM’ as a suite of ‘STEM’ courses*

Some institutions have taken notice of the need for more time to devote to iSTEM Education and have begun creating degrees and certificates in STEM Education that are comprised of multiple STEM courses that extend beyond a single methods course. For example, Virginia Tech Online offers a graduate certificate in STEM Education that is comprised of four separate STEM courses. There is no specific methods course labeled, but the courses appear to show an attempt being made to dig deeper into iSTEM Education beyond a single methods course in that they are providing courses related to iSTEM Education focused on foundations, pedagogy, trends, and issues. Additionally, the University of Texas- Austin offers a Master’s degree that has a STEM focus that is comprised of multiple courses in STEM Education. The STEM focus also requires nine credit hours in science content areas (Biology, Math, Physics, etc.). A summary of institutions fitting this category of course offerings can be found in Table 12.

As the push for iSTEM Education continues, it appears that a suite of courses focused on the key elements of iSTEM Education would be the most desired path.

Instructors and students would be able to take their time and dive into pertinent ideas and topics focused on iSTEM Education. Additionally, if iSTEM Education is considered its own subject, then the opportunity for teachers to take multiple content courses within iSTEM Education would help their content knowledge of the discipline as content courses can help teachers better understand the content they teach (Ball et al., 2008). However, as stated previously, just because one possesses a deep understanding of content, doesn't mean they will be able to teach it effectively (Ball et. al, 2008).

Table 12  
*'STEM' as a suite of 'STEM' courses*

STEM Certificate comprised of: 1. STEM Education Foundations 2. STEM Education Pedagogy 3. STEM Education Trends and Issues 4. Readings in Technology Education	<a href="#">Virginia Tech Online</a>	Online	Graduate credit towards a certificate	All
Master's STEM focus comprised of: 1. Knowing and Learning in STEM Ed 2. Curriculum History and Development in STEM Ed 3. Equity in STEM Ed. 4. Research on Teaching and Teaching Development in STEM Ed. 5. Systemic Reform in STEM Ed.	<a href="#">University of Texas- Austin</a>	Campus	Graduate credit towards degree	K-12

### Summary and Implications for Research and Practice

Within this chapter, I have presented a sampling of the current offerings for iSTEM Education professional development. The results of this inquiry suggest a lack of professional development opportunities that are specifically focused on teaching methods of iSTEM Education in the elementary classroom. Given the differences in teaching contexts of elementary teachers and middle/secondary teachers, what are the unique needs of elementary teachers regarding implementing iSTEM Education, and how can professional development be designed to best address those? Chapter four of the

Dissertation in Practice will outline the design of a study of elementary teachers' conceptions and design of iSTEM instruction. The findings of this study, presented in manuscript format in Chapter five serve to inform the design of a sample online elementary-specific professional development opportunity on iSTEM Education (Chapter six).

## **CHAPTER FOUR: CONTRIBUTION TO SCHOLARSHIP**

### **Introduction**

This chapter describes the scholarly contribution of the dissertation in practice, a research-based manuscript, by providing an in-depth description of the methodology. The findings of this study will shed light on the ways in which elementary teachers conceptualize iSTEM Education and are integrating STEM content into their instructional plans. These contributions are important first steps in addressing current gaps in the literature regarding elementary teachers' understanding and implementation of iSTEM Education and to identifying the unique professional development needs of elementary teachers regarding iSTEM Education.

### **Purpose of the Study**

We know very little about which types of integration elementary teachers are using in their instructional approaches to iSTEM Education, and therefore very little about the potentially unique needs of elementary teachers in terms of iSTEM PD. To contribute to the research on iSTEM Education at the elementary level, the proposed study identifies and explores the conceptualizations of elementary teachers regarding iSTEM Education and the extent to and methods by which they integrate STEM disciplines in their instructional planning. Based on the iSTEM framework (Honey et al., 2014), the following research questions will guide the study:

1. To what extent are elementary teachers' prepared to implement iSTEM Education?
  - a. What are elementary teachers' perceived levels of preparedness to implement iSTEM Education?

- b. What is the nature of iSTEM Education opportunities in which elementary teachers have participated?
2. In what ways do elementary teachers approach iSTEM Education in their lesson plans?
3. How do elementary teachers conceptualize iSTEM Education?
  - a. What learning goals do elementary teachers have for students as part of their iSTEM Education lessons?
  - b. What do teachers see as the benefits of students learning about iSTEM Education (outcomes)?
  - c. What is the nature and scope of teachers' integration of STEM disciplines?
  - d. What instructional designs, supports, and adjustments to the learning environment do teachers utilize when integrating STEM content?

### **Target Journal**

The target journal for disseminating the research results of this dissertation-in-practice is the *Journal of Research in STEM Education* (J-STEM). J-STEM is an international peer-reviewed publication for educators interested in and committed to Science, Technology, Engineering and Mathematics Education research. The journal is focused on “enhancing the quality of teaching and learning in the fields of science, technology, engineering, and mathematics (STEM) by making the results of rigorous research findings to the researchers, practitioners, and policy makers.” (J-STEM, 2017). The journal also publishes research articles that inform learning and teaching pursuits specifically in STEM Education, with particular emphasis on manuscripts that employ

rigorous research methods. J-STEM's target audiences include scholars, teachers, and policy makers. The guidelines for authors for the J-STEM Education are similar to other research journal requirements. Articles are not to be more than twenty-five pages in length and must follow the American Psychological Association's (APA) Publication Manual style. J-STEM focuses on research in STEM Education but also accepts articles from practitioners as they have a publication called *Pedagogical Innovations*.

J-STEM is an appropriate choice for disseminating the results of this dissertation-in-practice because the study conducted is a survey study of elementary teachers' ideas and experiences integrating STEM content into their teaching and uses rigorous qualitative research methods. The study design is described in the following sections.

## **Design of the Study**

### **Methodological Framework**

This qualitative study used an exploratory cross-sectional survey design to examine the variations in the ways elementary teachers conceptualize and design iSTEM Education instruction. A cross-sectional survey approach was appropriate for this study as I intended to reveal the conceptualizations and practices of elementary teachers regarding iSTEM Education at a single point in time (Creswell, 2013). An exploratory study was appropriate because of the lack of detailed preliminary research in this area and because I desired to show that further research is needed (Stake, 1995). The intent is to provide insight into teachers' conceptions that can inform further research in iSTEM Education, specifically in regards to the unique professional development needs of elementary teachers.

As a former elementary teacher who is familiar with and values iSTEM Education and integrative methods for teaching STEM content, it is important to clarify that I am pro-STEM and have an interest in helping the iSTEM Education movement progress. However, I have made a conscious effort to set aside preconceived ideas of what may emerge from the data to present the most organic and objective findings as possible. This was done by including multiple data sources (triangulation), having a peer and/or faculty member assist in the coding of data as peer review, and having a peer debriefer review the analyses.

### **Context of the Study**

#### ***Participants***

Participants in the study were required to hold a valid teaching license and be currently teaching in a K-5 elementary school. Participation was voluntary, and consent was secured in line with IRB. The participants for this study were collected using a convenience sample of Missouri elementary teachers with whom I had access to via personal acquaintance or via professional network. Additionally, snowball sampling was used to identify additional participants by allowing all participants to share the opportunity with other teachers in their network who may be interested in participating in the study. Since the intent of this study was to explore the unique professional development needs of elementary teachers, it did not make sense to only look at experts or exemplary teachers (e.g. illustrative case of best practices), so teachers from all experience levels were included in this study.

For this exploratory cross-sectional survey study, purposeful sampling (drawing from consenting teachers) was used to illustrate the different perspectives and practices of

elementary teachers' integrative methods of STEM content as well as the teaching experience and demographics of participants. Purposeful sampling is used when the researcher wants to show different perspectives on the issue (Creswell, 2012). The samples selected for this study illustrate the diversity of integrative methods among participating elementary teachers. Sampling was guided by methods typically used in selecting cases for case study research. The selection criteria of the samples for the example vignettes, as described by Stake (1995), included those that: (a) maximize what can be learned, (b) are easy to access (location and time) and (c) show balance and variety (p. 6). For example, samples selected were chosen based on those that help lead to better understanding of the diverse ways in which elementary teachers conceptualize STEM Education and the integrative and design approaches they use to teach STEM content. Balance and variety influenced sample selection as samples were chosen that represented a range of teacher experience and knowledge on STEM Education. A balanced representation between beginners and experts were included in considering sample selection as well as the potential variety in teacher conceptualization of STEM Education. As Stake (1995) stated, "Balance and variety are important; opportunity to learn is of primary importance" (p.6).

### ***Recruitment***

During the recruitment process, an audit trail was kept to provide documentation of all attempts to recruit teacher participants, as suggested by Creswell and Miller (2000). The audit trail was kept on a Microsoft Excel spreadsheet and included the date, the person contacted, and the location of the contact person (school, organization, etc.). The ad was distributed in the following ways:

- Posted on Facebook
- Sent via email to elementary teachers known by the researcher
- Paper copies passed out at multiple conferences to elementary teacher attendees
- Sent via email to principals and administrators throughout Missouri
- Sent to various STEM organization leaders throughout Missouri via email after locating them via a Google search
- Sent to MSTA regional directors via email and was then posted on the Missouri MSTA website.
- Sent via email to administrators for teacher organizations in Missouri, such as the Missouri chapter of the National Science Teacher Association.
- Distributed by other ‘gatekeepers’ to their contacts (e.g., professors emailing teachers in their PD programs, etc.)

Within the ad there was a request for the contacted persons to share the recruitment ad with other teachers whom they felt may be interested (snowball recruiting). Recruitment began on July 22<sup>nd</sup>, 2016 and lasted until October 18<sup>th</sup>, 2016. During the nearly three months of participant recruitment, multiple reminder emails were sent to previous contacts as participation was low.

There were many hurdles in getting elementary teachers to participate. Many teachers commented they would participate but then never followed through, even after reminders. Some teachers commented they were not a “STEM Teacher” so they didn’t feel they could participate. Other teachers mentioned they didn’t have a STEM lesson available and wouldn’t know where to find one. Still, some mentioned that they hadn’t written a formal lesson plan in “years” and didn’t have the time to write one up for

submission. While there are no specific rules dictating the sample size required for qualitative research, the sample size for this study was determined based upon the time allotted for the study and the resources available to me (Patton, 1990). For this study, the target sample size was 35-40 responses, however, the actual number of responses was twenty-nine. These twenty-nine teachers represent the population sample for this study.

All teacher participants in this study taught grades Kindergarten through 5<sup>th</sup> grade. 38% taught Kindergarten through second grade, while 62% taught third through fifth grade. 45% of teachers taught in an urban area while 55% taught in a rural area. 27% of teachers had 1-5 years teaching experience, 28% had 6-10, 28% had 11-15, and 17% had 16 or more years of teaching experience. In the following section, a description of the data collection procedure for this study is presented.

### ***Data Collection***

The data sources for this study were chosen in order to facilitate the process of triangulation so as not to rely on any one single form of data (Maxwell, 1996). The data collected include: (a) teacher surveys, (b) iSTEM Education lesson plans and (c) interviews. Each teacher participant was asked to complete an online survey and submit a lesson plan at the same time. Participants were instructed to submit lesson plans that were of their own creation or adaptations as opposed to a copied or scanned replica of a teacher's guide. A purposeful sample of five teachers was then selected for a phone interview, and all selected participants successfully completed the interview. The following section provides a detailed description and analysis of each data source.

### ***Data Analysis***

*Data Source #1: Teacher Surveys-*

Stage one of data collection for this study began with a Teacher Survey. The intent of this survey was to reveal the teachers' ideas regarding iSTEM Education, their level of teaching experience in general and specific to iSTEM Education, and the types of professional development experiences teachers have had related to iSTEM Education. The survey included demographics and questions that addressed the instructional resources they use and the professional development they have had specifically related to STEM Education. The teacher survey is included in the Appendices of this dissertation-in-practice. Responses to the survey questions assisted in determining where the teacher would fall on the beginner to expert continuum and was used to help select cases for the purposeful sample.

All teachers in the population sample completed a teacher survey using the Jotform online survey tool. Teacher participants were categorized into groups based on their responses to survey questions to provide insight on the range of experience and knowledge in iSTEM Education of the population sample. I then analyzed each survey by identifying which ones included the themes that best addressed the research questions for this study. The demographics of the population sample are presented in the following paragraphs.

The population sample had a range of total years teaching experience from one year to twenty-four years. Every grade level from Kindergarten through sixth grade is represented in the population sample. The majority of teachers placed themselves as a Beginner (20) on the iSTEM Education experience continuum. Three teachers placed themselves as Somewhat Experienced, and five teachers placed themselves as Experienced. Only one teacher placed themselves as Somewhat Advanced while no (0)

teachers placed themselves as Advanced. The placement of teacher participants on the iSTEM Education continuum was self-identified by the teachers and may not represent the participant's actual placement on the iSTEM Education continuum.

The number of professional development hours in iSTEM Education experienced by teachers over the past two years ranged from zero hours to one-hundred-twenty hours, with the majority of teachers (22) falling in the range of zero to twenty-five hours. These numbers are influenced by what the teacher participants consider to be representative of iSTEM Education professional development. For example, one teacher who was later interviewed reported that she experienced fifty hours of iSTEM Education professional development. However, when probed was revealed that she had considered her art integration professional development as iSTEM professional development as she believed in STEAM (adding "Art" to the STEM acronym), regardless of the fact that none of her professional development focused on any subject other than the arts (music, theatre, visual art, and dance).

Of the above professional development hours, the majority of teachers (23) reported that zero to twenty-five of those hours were elementary specific versus kindergarten through twelfth grade combined. Only six teachers reported twenty-six or more hours of elementary specific iSTEM professional development. Eight teachers reported being Not Satisfied with the quality of the iSTEM professional development they have experienced, while four reported being Somewhat Satisfied. The majority of teachers (13) reported being Satisfied while four teachers reported being Very Satisfied. The majority of teachers (13) reported being Not Satisfied with the availability of iSTEM

professional development while two teachers reported being Somewhat Satisfied. Twelve teachers reported being Satisfied while two teachers reported being Very Satisfied.

*Data Source #2: Lesson Plans-*

After completing the teacher survey, each participant was asked to submit an iSTEM lesson plan. Lesson plans are essential forms of data as they reflect outcomes teachers have for their instruction and were chosen for this study as there was a desire to learn more about teacher instructional practices (Sias et al., 2016). Lesson plan submission requirements were as follows a) the lesson must be a lesson the teacher has previously taught b) the lesson is written by the teacher (i.e. not a scanned copy of a lesson included in a curriculum book, though teachers may draw on lessons created by others) and c) the submission includes all additional items (worksheets, rubrics, etc.). While not all teachers may have experience in creating iSTEM lesson plans specifically, they all should have had experience with creating lesson plans for their classroom. These iSTEM Education lesson plans were intended to provide an example of the extent to which these teachers are integrating STEM content in their iSTEM Education lesson designs, and helped me determine which participants should be interviewed in Stage 2 of the data collection process.

In the Teacher Survey, teachers were asked where they got the lesson they were submitting. Two teachers submitted lessons that were provided to them by their district while the majority (17) said they adapted their lesson from other resources. Eight teachers reported they had created the lesson themselves while two reported having done something different (Other).

Another question in the Teacher Survey asked if teachers were required to teach the lesson they had submitted. Nine teachers reported the lesson they submitted was required by their school or district while the majority (19) reported their lesson was not required by their school or district. One teacher reported that their lesson was and was not required (the concept was required but not the specific lesson).

After careful review of the survey results, directed content analysis was conducted to determine the frequency of concepts and ideas that arose in the data (Petocz & Newbery, 2010) and to determine a purposeful sample to interview. Directed content analysis is a coding tool used when prior research about a phenomenon already exists but is incomplete or would benefit from further description (Hsieh and Shannon, 2005). Hsieh and Shannon (2005) described three types of content analysis; (a) conventional content analysis (b) directed content analysis and (c) summative content analysis as presented in Figure 6.

<i>Type of Content Analysis</i>	<i>Study Starts With</i>	<i>Timing of Defining Codes or Keywords</i>	<i>Source of Codes or Keywords</i>
Conventional content analysis	Observation	Codes are defined during data analysis	Codes are derived from data
Directed content analysis	Theory	Codes are defined before and during data analysis	Codes are derived from theory or relevant research findings
Summative content analysis	Keywords	Keywords are identified before and during data analysis	Keywords are derived from interest of researchers or review of literature

Figure 5  
*Major Coding Differences Among Three Approaches to Content Analyses*  
 (Hsieh and Shannon, 2005, p. 1286)

In this study the phenomenon to be expanded upon is integration, using Davison and colleague's (1995) research on the five types of integrative approaches.

Lessons were then sorted by integration methods following Davison and colleagues' (1995) five types of integration (a) Discipline Specific Integration, (b) Content Specific Integration, (c) Process Integration, (d) Methodological Integration and (e) Thematic Integration. I sorted each lesson based on the information provided in the lesson plan. A few issues arose as not all lessons included exactly the same elements as no general lesson plan template was provided. Teachers were allowed to submit lessons in whichever way they desired. I had to make assumptions at times as to what subjects were being used as no standards or objectives were explicitly written. Some lessons also claimed to include elements such as engineering, but upon further analysis, it was found that they did not.

The majority of the lessons submitted (14) fell into the category of No Integration; meaning the lesson was primarily one subject only. Two teachers submitted lesson plans that were Thematic Integration; meaning they had a theme (e.g., Pumpkins) and all content areas focused on that theme. Two teachers submitted lesson plans that were Methodological Integration; meaning they used inquiry, the learning cycle, discovery, etc. to build knowledge using science and math. Six teachers submitted lesson plans that were Process Integration; meaning they posed a problem and used science processes and math standards to find answers. Five teachers submitted lesson plans that were Content Specific Integration; meaning they used at least one standard from one subject and another standard from another subject. No teachers (0) submitted lessons that were Discipline Specific Integration; meaning they pulled standards/content from different fields in the same subject (i.e. Algebra and Geometry or Biology and Geology).

The content analysis revealed a rich sample with representations from various categories. Five teachers were chosen as the purposeful sample. This purposeful sample included a teacher from grades kindergarten, second, third, fourth, and fifth grade with a range of teaching experience from three to fifteen years. Integration methods used in iSTEM Education lesson plan submissions of the purposeful sample included Methodological Integration, Thematic Integration, Content Specific Integration, Process Specific Integration, and No Integration. These five participants all participated in a phone interview. Details of the Teacher Interviews are discussed in the following section.

*Data Source #3: Teacher Interviews-*

Five teachers were identified as potential samples for the example vignettes in Stage 1 of data collection. Stage two of data collection included Teacher Interviews. These interviews were conducted by phone, given the geographic distance between myself the researcher and participating teachers. The interview consisted of follow-up questions to the teacher survey and the iSTEM Education lesson plan. This interview allowed me to ask more specific questions regarding their responses to the survey and the lesson plan they submitted. This interview addressed the research questions and the framework for this study by Honey et al. (2014) by targeting areas specific to teachers' goals, implementation, design, and understanding of iSTEM Education. A semi-structured interview protocol is included in the Appendices of this dissertation in practice.

All interviews were transcribed for analysis, which began with open-coding of hard copies of the transcripts. A highlighter color was assigned for each of the research questions, and transcripts were examined line-by-line to identify excerpts relevant to each

question and assign codes. Intercoder agreement was established through analysis of a sample of data conducted by myself and a faculty member. Using the Teacher Interview responses to the question “Why is it important for students to learn STEM?” the faculty member and I used open coding for first-level coding and then directed content analysis with axial coding for second-level coding, to independently read and code themes by hand. These themes were both predetermined (integrative approaches in the iSTEM lesson plans) and those that emerged from the data (in all data sources). We then came together to compare codes and themes to check for intercoder agreement. Any differences were discussed, and changes in coding were made as agreed upon by coders.

Once coding was complete, codes for each research question were entered into an Excel workbook with a separate tab for each question/code set. Frequencies of codes across all five participants were noted to assess the prevalence of the codes across the entire data set. Codes were then grouped into categories based on similarities and themes that emerged. Themes were then examined in relation to the research questions, and the absence of particular themes was also noted. A sample research question and the themes that emerged/were found absent during coding are shown in Table 13 below.

Table 13  
*Example Themes by Research Question*

<b>Research Question</b>	<b>Categories of Codes</b>	<b>Major Themes Present</b>	<b>Notable Themes Absent</b>
<b><i>RQ1- How do elementary teachers conceptualize iSTEM Education?</i></b>	Category #1- Teacher Role in STEM Education Instruction	Questioning Modeling Facilitating	Teacher as designer of the learning experience
	Category #2- Nature of Student Activity in STEM Education	Exploration Building/Creating Collaboration	Student learning/ developing new understandings

	Problem-Solving/Trial and Error	
Category #3- What is Taught in STEM Education (Subject Matter)	*No consensus Using technology How things work Design process/skills Science is the core + other subjects	Technology not mentioned beyond use of instructional technology

### ***Sample Selection***

Once the surveys and lesson plans were analyzed and coded, I chose five participants from the population sample of teachers to interview to act as example vignettes for this study. Selection of these sample vignettes again pulled from case selection strategies in case study research. Creswell (2013) stated “For case study research, I would not include more than four or five case studies in a single study. This number should provide ample opportunity to identify themes of the cases as well as conduct cross-case theme analysis (p.157). For this study, five samples were chosen, which act as the foundation for the example vignettes for the study. These example vignettes aim to give the broadest representation of elementary teachers’ understanding, design, implementation and experience regarding iSTEM Education. These example vignettes are included in chapter five of this dissertation in practice.

### **Limitations, Assumptions, and Design Controls**

Limitations of this study include the small sample size of teacher participants. Additionally, teachers were self-selected, and it is possible that teachers who chose to participate in the study are biased and are more “pro-STEM” than their colleagues who were not involved in the study. Furthermore, the samples selected for this study represent a small sample limited to Missouri elementary schools. The conclusions made through

this study may not apply to all elementary teachers. However, I have purposefully selected a range of elementary teachers who represent those with limited to extensive backgrounds in iSTEM Education as well as a range of teaching experience in order to represent as many elementary teachers as possible. Additionally, to achieve external validity, I provide thick descriptions and detailed accounts of each sample included in this study. By including a continuum of teacher experience and knowledge in iSTEM Education and rich descriptions of each sample, it is my intent to enhance the applicability of this study for a variety of readers. While limitations exist for this study, I have taken measures to minimize personal bias and adhere to data collection protocols described in this study. These include 1) using a peer coder to validate the coding scheme and act as a peer debriefer 2) using multiple data sources for triangulation and 3) clarifying researcher bias prior to the study.

### **Summary**

It is my intent to examine the integrative practices of elementary teachers regarding iSTEM Education and how they conceptualize iSTEM Education instruction. This study will help the iSTEM Education community better understand the unique needs of elementary teachers, which will provide a clearer picture of how to provide high-quality professional development for elementary teachers in iSTEM Education.

Chapter five presents a manuscript to be submitted to the *Journal of Research in STEM Education*. This study informed the design of a sample online professional development course created for this dissertation in practice. Chapter six presents this course, along with an outline of the eight sequential modules. A rationale and connection to the research are also described along with modifications made based off the findings

from this study. This chapter also includes a description of how the sample online professional development course created for this study provides opportunities for participants to experience transformative learning in their understanding of iSTEM Education.

## **CHAPTER FIVE: SCHOLARLY MANUSCRIPT**

### **Elementary Teachers' Conceptions and Integration Methods of iSTEM Education:**

#### **An Exploratory Cross-Sectional Survey Study**

##### **Abstract**

Because elementary teachers are typically responsible for teaching all subjects, there is a unique opportunity for integrative approaches to teaching iSTEM Education at the elementary level (Becker & Park, 2011). However, there is a need for professional development if teachers are to be successful in teaching iSTEM Education (NRC, 2011), as elementary teachers may lack strong content knowledge in STEM disciplines (Ginns & Watters, 1995; Trygstad, 2013; Honey et al., 2014; Fulp, 2002; Ma, 1999; Hanover, 2012). Elementary teachers are prepared as generalists--they take few courses in STEM content, and experiences with iSTEM Education in their teacher preparation programs are rare (Fulp, 2002). Beyond the need for professional development related to STEM content knowledge, however, we know very little about the unique needs of elementary teachers regarding instructional approaches to iSTEM Education. This study examines and describes the ways in which elementary teachers conceptualize iSTEM Education and the integrative approaches they use when teaching STEM content, with the intent to inform the development of elementary specific iSTEM Education professional development.

## **Elementary Teachers' Conceptions and Integration Methods of iSTEM Education: An Exploratory Cross-Sectional Survey Study**

According to the President's Council of Advisors on Science and Technology (2010), "the success of the United States in the 21st century will depend on the ideas and skills of its population" (p. 5). Science, Technology, Engineering, and Mathematics (STEM) Education works to develop students who have the technical skill-set necessary to boost the United States back into the global economic competition (PCAST, 2010). While STEM Education lacks a formal, universally accepted definition, there is an overwhelming consensus regarding the importance of the need to develop STEM literate individuals. Trygstad (2013) stated "A new workforce of problem-solvers, innovators, and inventors who are self-reliant and able to think logically is one of the critical foundations that drive innovative capacity" (p. 1).

To address the need for STEM literate individuals, elementary teachers have been charged with building the foundation for this STEM workforce. However, there is little research that can inform the design of iSTEM professional development to address the unique challenges elementary teachers face when teaching iSTEM Education. The findings from the exploratory cross-sectional survey study intend to describe current conceptions and practices of elementary teachers in order to provide insight into the unique professional development needs of elementary teachers in iSTEM Education.

### **Review of Relevant Literature**

The present study is informed by literature related to defining STEM, integrating STEM, and preparing teachers to implement STEM.

#### *Defining STEM Education*

Despite the consensus among the education community regarding the importance of STEM Education, there isn't agreement on what STEM is. A simple search in the literature for STEM Education yields an array of varying definitions. Table 1 provides a few examples, though it is far from exhaustive.

Table 1  
*Comparison of STEM Education Definitions*

Author	Definition
Tsupros (2009)	“STEM Education is an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy” (p. 14).
The California STEM Learning Network (CSLN) (2015)	“STEM Education is an interdisciplinary and applied approach to teaching that is coupled with hands-on, problem-based learning.”
Sanders (2012)	“Integrative STEM education refers to technological/engineering design-based learning approaches that intentionally integrate the concepts and practices of science and/or mathematics education with the concepts and practices of technology and/or engineering education. Integrative STEM education may be enhanced through further integration with other school subjects, such as language arts, social studies, art, etc.” (p. 2).
The United States Department of Education (2007)	“Science, Technology, Engineering, and Mathematics education programs are defined as those primarily intended to provide support for, or to strengthen, science, technology, engineering, or mathematics (STEM) education at the elementary and secondary through postgraduate levels, including adult education” (p. 11).
Merrill (2009)	“A standards-based, meta-discipline residing at the school level where all teachers, especially science, technology, engineering, and mathematics (STEM) teachers, teach an integrated approach to teaching and learning, where discipline-specific content is not divided, but addressed and treated as one dynamic, fluid study” (as cited in Brown, 2012, p. 7).

Teaching Institute for Excellence in STEM (2015)	“STEM education is trans-disciplinary in nature offering students the ability to use project-based learning to address real-world issues that affect their family, their community and their world.”
The National Science and Technology Council (2013)	“Formal or informal (in school or out) education that is primarily focused on physical and natural sciences, technology, engineering, and mathematics disciplines, topics, or issues (including environmental science education or environmental stewardship)” (p. 54).
Gomez and Albrecht (2014)	“STEM pedagogy is rooted in interdisciplinary applied applications of knowledge. STEM Education is a philosophy designed around a cooperative effort to provide students with a comprehensive, meaningful, real-world learning experience” (p. 8).
Johnson et al. (2015)	“The teaching and learning of the content and practices of disciplinary knowledge which include science and/or mathematics through the integration of the practices of engineering and engineering design of relevant technologies” (p. 24).
Vasquez (2013)	“STEM education is an approach to learning that removes the traditional barriers separating the four disciplines (science, technology, engineering, and mathematics) and integrates them into real-world, rigorous, relevant learning experiences for students” (p. 4).
Wells and Ernst (2012)	“Integrative STEM Education is the application of technological/engineering design based approaches to intentionally teach content and practices of science and mathematics education concurrently with content and practices of technology/engineering education. Integrative STEM Education is equally applicable at the natural intersections of learning within the continuum of content areas, educational environments, and academic levels" (as cited in Virginia Tech., 2016).
Nadelson and Seifert (2017)	“We define integrated STEM as the seamless amalgamation of content and concepts from multiple STEM disciplines. The integration takes place in ways such that the knowledge and process of the specific STEM disciplines are considered simultaneously without regard to the discipline, but rather in the context of a problem, project, or task” (p. 221).

When comparing these definitions, several patterns emerge. First, STEM Education is conceptualized in three distinct ways-- as an approach to learning, as an approach to teaching, and as a philosophical stance toward education. Across these three distinctions, however, there are some commonalities. For example, the need for providing opportunities for students to apply their knowledge is prevalent among many definitions, as well as the focus on integration.

Integrative approaches are defined as “approaches that explore teaching and learning between/among any two or more of the STEM subject areas, and/or between a STEM subject and one or more other school subjects (Sanders, 2009, p. 21).” Proponents of iSTEM Education agree that an integrative approach is a key component of effective iSTEM Education instruction (Johnson et al., 2015; Nadelson et al., 2013); but there is no consensus among the education community regarding the method of integration (Means, 2008), and there are a variety of ways in which STEM content can be integrated (Becker & Park, 2011). Furthermore, there are varying depths by which STEM content can be integrated (Nathan et al., 2013) and there are empirical studies supporting the use of curriculum that promotes integrated STEM Education experiences (Wang, et al., 2011). The current literature, however, focuses primarily on the integration of math and science, rather than on integration across all STEM disciplines (Heil et al., 2013).

### *Preparing Elementary Teachers to Integrate STEM*

Elementary classrooms have different affordances for integration than secondary educators as there is flexibility in the elementary curriculum that can support new approaches for teaching iSTEM Education (Nadelson et al., 2013). Furthermore, elementary teachers are typically responsible for teaching all subjects, so there is a unique

opportunity for integrative approaches to teaching iSTEM Education at the elementary level (Becker & Park, 2011). Yet, there are few elementary specific iSTEM Education professional development opportunities (as opposed to specific to individual disciplines of STEM) (Hanover, 2012). Both research and professional development on iSTEM Education are often grouped together in a K12 bundle and don't distinguish between the levels of elementary or secondary education (Hanover, 2012) where the affordances for integration are quite different.

### *Need for the Study*

Though the elementary classroom presents unique affordances for iSTEM Education, we currently know very little about how elementary teachers conceptualize iSTEM, which types of integration elementary teachers are using in their instructional approaches to iSTEM Education, and the unique needs that elementary teachers may have when it comes to iSTEM Education professional development. Considering teacher beliefs and perceptions regarding integrative approaches among STEM content as teacher professional development programs work to develop teacher thinking and practice is important as both teacher attitudes and perceptions “drive classroom actions and influence the teacher change process” (Richardson, 1996, p. 102). To address the gaps in the literature revealed above, this study examines the conceptions and integrative practices of elementary teachers in iSTEM Education and explores difficulties elementary teachers face when teaching iSTEM Education that can shed light on their specific professional development needs.

### **Theoretical Framework Guiding the Study**

This study is framed by the iSTEM Education framework by Honey and colleagues in the report *STEM Integration in K-12 Education: Status, Prospects and an Agenda for Research* (2014). This framework includes four main features: (a) goals of integrated STEM Education, (b) outcomes of integrated STEM Education, (c) the nature and scope of integrated STEM Education, and (d) implementation of integrated STEM Education (p. 31). This framework is intended to provide researchers with the vocabulary to “identify, describe, and investigate specific integrative STEM initiatives...” (Honey et al., 2014, p. 31).

The present study also uses the integration approaches described by Davison, Miller, and Metheny (1995) as an analytical framework. Davison et al. (1995) described five types of integration specifically related to math and science. However, this framework can easily be applied to STEM disciplines more broadly. These five methods include: (a) Discipline Specific Integration (b) Content Specific Integration (c) Process Integration (d) Methodological Integration and (e) Thematic Integration. Like many integrative models, however, these approaches are not grounded in studies of actual teachers’ integrative practices but are merely presented as options for integration. Thus, the present study will provide an empirical test of the framework.

The study described in the following section is guided by the following research questions:

- 1) To what extent are elementary teachers’ prepared to implement iSTEM Education?
  - a) What are elementary teachers’ perceived levels of preparedness to implement iSTEM Education?

- b) What is the nature of iSTEM Education opportunities in which elementary teachers have participated?
- 2) In what ways do elementary teachers approach iSTEM Education in their lesson plans?
  - 3) How do elementary teachers conceptualize iSTEM Education?
    - a) What learning goals do elementary teachers have for students as part of their iSTEM Education lessons?
    - b) What do teachers see as the benefits of students learning about iSTEM Education (outcomes)?
    - c) What is the nature and scope of teachers' integration of STEM disciplines?
    - d) What instructional designs, supports, and adjustments to the learning environment do teachers utilize when integrating STEM content?

### **Methodology**

This qualitative study used an exploratory cross-sectional survey design to examine the variations in the ways elementary teachers conceptualize and design iSTEM Education instruction. A cross-sectional survey approach was appropriate for this study as I intended to reveal the conceptualizations and practices of elementary teachers regarding iSTEM Education at a single point in time (Creswell, 2013). An exploratory study was appropriate because of the lack of detailed preliminary research in this area and because I desired to show that further research is needed (Stake, 1995). The intent is to provide insight into teachers' conceptions that can inform further research in iSTEM

Education, specifically in regards to the unique professional development needs of elementary teachers.

### *Context of the Study*

#### *Participants*

Participants in this study were certified classroom elementary teachers in a Midwestern state. Participants were collected using a convenience sample and snowball sampling via email, social media, internet postings, and word of mouth. Twenty-nine teachers responded initially, submitting responses to the online survey (See Appendix A for the full survey) as well as an iSTEM Education lesson plan. The twenty-nine teacher participants in this study taught grades Kindergarten through 5<sup>th</sup> grade. 38% taught Kindergarten through second grade, while 62% taught third through fifth grade. 45% of teachers taught in an urban area while 55% taught in a rural area. 27% of teachers had 1-5 years teaching experience, 28% had 6-10, 28% had 11-15, and 17% had 16 or more years of teaching experience.

#### *Data Sources and Analysis*

The data collected included a survey, an iSTEM Education lesson plan, and an interview. Research questions 1 and 2 were answered by examining survey and lesson plan data for the entire sample, whereas research question 3 was answered by interviewing a purposeful subsample of participants in-depth.

#### *Survey*

Stage one of data collection for this study began with a Teacher Survey. The intent of this survey was to reveal the teachers' ideas regarding iSTEM Education, their level of teaching experience in general and specific to iSTEM Education, and the types of

professional development experiences teachers have had related to iSTEM Education. The survey included demographics and questions that addressed the instructional resources they use and the professional development they have had specifically related to STEM Education. Responses to the survey questions assisted in determining where the teacher would fall on the beginner to expert continuum and was used to help select cases for the purposeful sample.

All teachers in the population sample completed a teacher survey using the Jotform online survey tool. Teacher participants were categorized into groups based on their responses to survey questions to provide insight on the range of experience and knowledge in iSTEM Education of the population sample. I then analyzed each survey by identifying which ones included the themes that best addressed the research questions for this study. After careful review of the survey results, directed content analysis was conducted to determine the frequency of concepts and ideas that arose in the data (Petocz & Newbery, 2010) and to determine a purposeful sample to interview.

#### *iSTEM Education Lesson Plan*

Lesson plans are essential forms of data as they reflect outcomes teachers have for their instruction and were chosen for this study as there was a desire to learn more about teacher instructional practices (Sias et al., 2016). Lesson plan submission requirements were as follows a) the lesson must be a lesson the teacher has previously taught b) the lesson is written by the teacher (i.e. not a scanned copy of a lesson included in a curriculum book, though teachers may draw on lessons created by others) and c) the submission includes all additional items (worksheets, rubrics, etc.). While not all teachers may have experience in creating iSTEM lesson plans specifically, they all should have

had experience with creating lesson plans for their classroom. These iSTEM Education lesson plans were intended to provide an example of the extent to which these teachers are integrating STEM content in their iSTEM Education lesson designs, and helped determine which participants should be interviewed in Stage 2 of the data collection process.

Lessons were then sorted by integration methods following Davison and colleagues' (1995) five types of integration (a) Discipline Specific Integration, (b) Content Specific Integration, (c) Process Integration, (d) Methodological Integration and (e) Thematic Integration. Each lesson was sorted based on the information provided in the lesson plan. A few issues arose as not all lessons included exactly the same elements as no general lesson plan template was provided. Teachers were allowed to submit lessons in whichever way they desired. Assumptions were made at times as to what subjects were being used as no standards or objectives were explicitly written. Some lessons also claimed to include elements such as engineering, but upon further analysis, it was found that they did not.

### *Interviews*

Five teachers were chosen as the purposeful sample and all participated in a follow-up phone interview, allowing for further clarification of instructional choices as well as descriptions of conceptualizations and teaching practice. These teachers were chosen as they all used a different integrative approach in their iSTEM Education Lesson Plan and represented a range in multiple categories. In this manner, their responses could illustrate the range of ways in which teachers conceptualize iSTEM education across a

variety of integrative approaches. An overview of the purposeful sample is provided in Table 2.

Table 2  
*Overview of Purposeful Sample*

<b>Teacher</b>	<b>Grade</b>	<b>Rural/ Urban</b>	<b>Years of Teaching Experience</b>	<b>STEM Ed. Continuum</b>	<b>Hours of STEM pd</b>	<b>Satisfaction with STEM Pd Attended</b>	<b>Satisfaction with availability of STEM pd</b>
<i>Laura</i>	K	Rural	12	Beginner	0	Not Satisfied	Not Satisfied
<i>Mary</i>	2	Rural	3	Beginner	10	Satisfied	Satisfied
<i>Cassie</i>	3	Urban	12	Beginner	0	Not Satisfied	Not Satisfied
<i>Sidney</i>	4	Rural	6	Beginner	5	Somewhat Satisfied	Somewhat Satisfied
<i>Kim</i>	5	Urban	15	Somewhat Experienced	10	Satisfied	Satisfied

Integration methods used in iSTEM Education lesson plan submissions of the purposeful sample included Methodological Integration, Thematic Integration, Content Specific Integration, Process Specific Integration, and No Integration. This subset of teachers was chosen to better understand the range and types of integration used by elementary teachers when designing iSTEM Education instruction.

All interviews were transcribed for analysis, which began with open-coding of hard copies of the transcripts. A highlighter color was assigned for each of the research questions, and transcripts were examined line-by-line to identify excerpts relevant to each question and assign codes. Intercoder agreement was established through analysis of a sample of data conducted by myself and a peer debriefer. Using the Teacher Interview responses to the question “Why is it important for students to learn STEM?” the peer debriefer and I used open coding for first-level coding and then directed content analysis

with axial coding for second-level coding, to independently read and code themes by hand. These themes were both predetermined (integrative approaches in the iSTEM lesson plans) and those that emerged from the data (in all data sources). We then came together to compare codes and themes to check for intercoder agreement. Any differences were discussed, and changes in coding were made as agreed upon by coders.

Once coding was complete, codes for each research question were entered into an Excel workbook with a separate tab for each question/code set. Frequencies of codes across all five participants were noted to assess the prevalence of the codes across the entire data set. An example is provided in Figure 1.

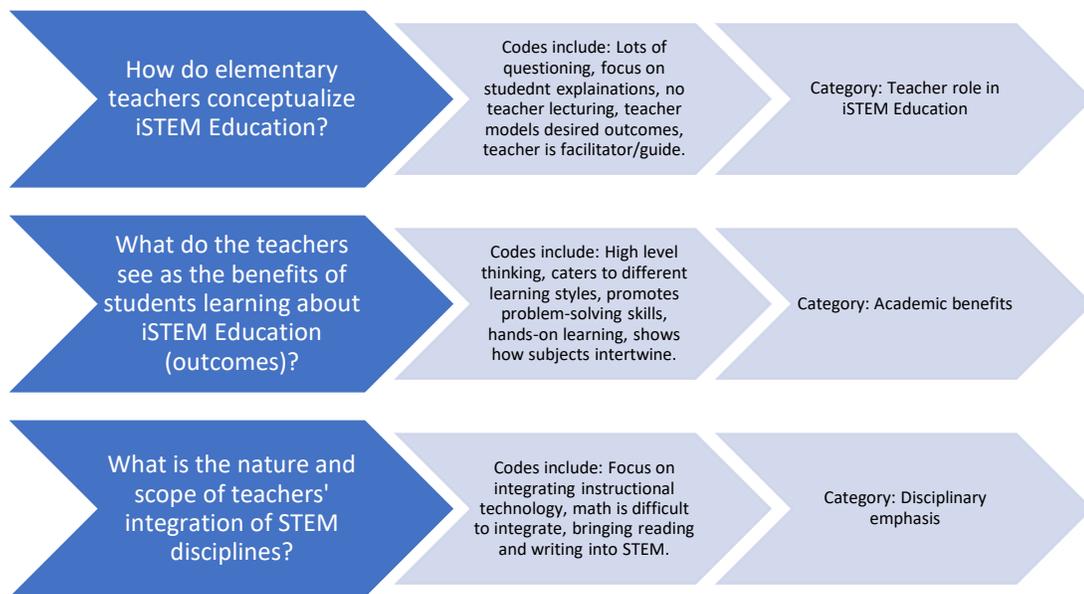


Figure 1  
*Illustration of Frequencies and Grouping*

Codes were then grouped into categories based on similarities and themes that emerged. Themes were then examined in relation to the research questions, and the absence of particular themes was also noted. An example is provided in Table 3.

Table 3  
*Example Themes by Research Question*

<b>Research Question</b>	<b>Categories of Codes</b>	<b>Major Themes Present</b>	<b>Notable Themes Absent</b>
<i>RQ1- How do elementary teachers conceptualize iSTEM Education?</i>	Category #1- Teacher Role in STEM Education Instruction	Questioning Modeling Facilitating	Teacher as designer of the learning experience
	Category #2- Nature of Student Activity in STEM Education	Exploration Building/Creating Collaboration Problem-Solving/Trial and Error	Student learning/developing new understandings
	Category #3- What is Taught in STEM Education (Subject Matter)	*No consensus Using technology How things work Design process/skills Science is the core + other subjects	Technology not mentioned beyond use of instructional technology

## **Results**

The results are presented in order of the research questions, beginning with information about elementary teachers' preparedness to implement iSTEM, the methods by which they approach STEM integration in their lessons, and how they conceptualize iSTEM education. Results should be interpreted within the limitations of this study, which include the small sample size of teacher participants. Teachers were self-selected, and it is possible that teachers who chose to participate in the study are biased and are more "pro-STEM" than their colleagues who were not involved in the study. Additionally, the sample is limited to elementary teachers in one state, and the findings of this study may not apply to all elementary teachers.

### **Experience Level with STEM**

First, teachers self-placed themselves on a STEM Education experience continuum describing their previous work in STEM Education that ranged from Beginner to Advanced. 69% identified as Beginners, 11% identified as Somewhat Experienced, 17% identified as Experienced, 3% identified as Somewhat Advanced, and 0% identified as Advanced. Placements on the continuum were intended to provide a ranking of teacher participants in regard to their current experience in STEM Education. These self-rankings were not necessarily made based on similar understandings of 'STEM Education', and some teacher participant placements did not necessarily match their actual level of experience, based on the analysis of their lesson and interview. During interviews, some teacher participants who identified themselves at a higher level of experience ended up indicating they would change their ranking to a lower level, as will be discussed in a later section of this manuscript. Regardless of the actual accuracy of continuum placements by teacher participants, these "rankings" allowed me to see where teachers thought they were on the STEM Education experience continuum, based on the way they conceptualized iSTEM Education when taking the survey.

### **Participation in STEM Professional Development**

Next, teachers reported on the hours of professional development they have experienced in the past two years related to STEM Education. 38% reported 0 hours, 38% reported 1-25 hours, 10% reported 26-50 hours, 4% reported 51-100 hours, and 10% reported more than 101 hours. Of the professional development hours reported, teachers identified the number of those hours that were elementary specific experiences versus those that were presented in a K12 bundle. 38% identified 0 hours of elementary specific STEM professional development, 41% identified 1-25 hours, 10% identified 26-50, 4%

identified 51-100, and 7% identified more than 101 hours of elementary specific professional development. See Figure 2 below.

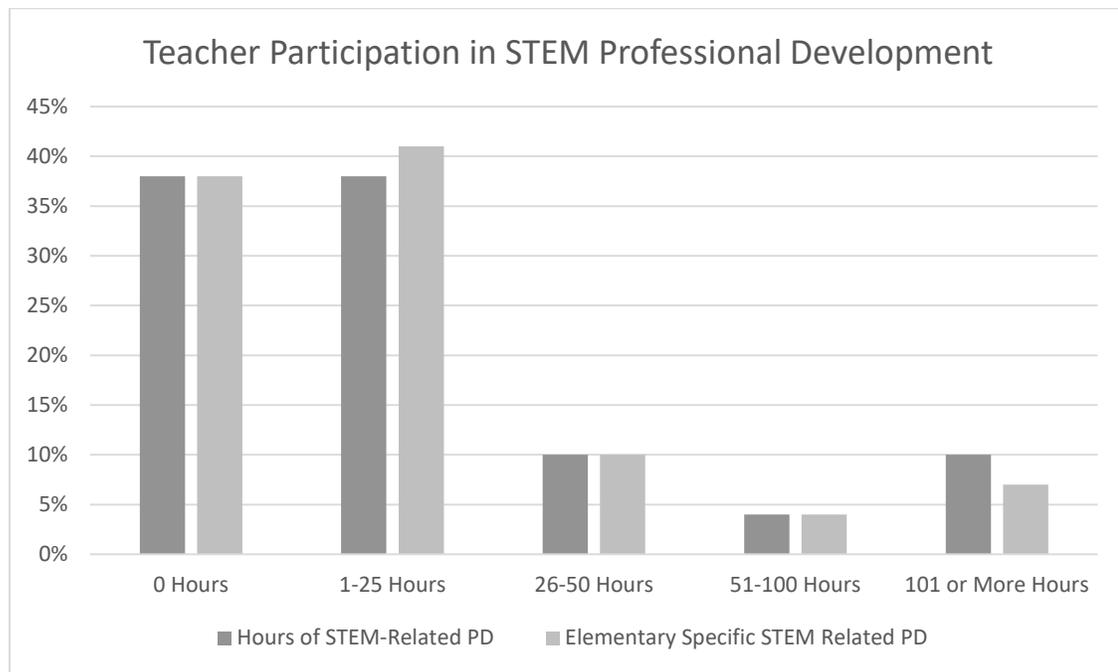


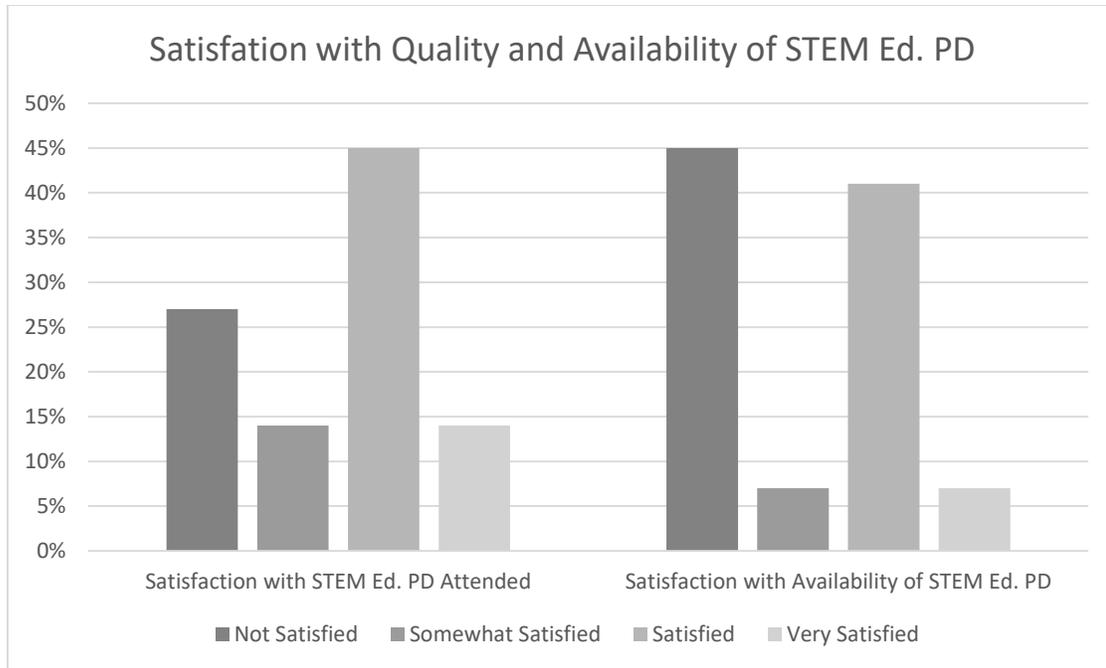
Figure 2  
*Teacher Participation in STEM Professional Development*

Figure 2 shows the majority of elementary teachers in this study have not participated in many hours of STEM related professional development. Some teachers who did report higher amounts of STEM-related professional developed, mentioned that they considered individual subject area professional development experiences (science, technology, or math professional development) as part of their hours of STEM-related professional development, even though the experience did not focus on integrated STEM Education. For example, teachers considered their experiences in technology training for elementary teachers through their district (using particular applications on an iPad) as STEM professional development. Those teachers who reported the highest number of

hours in STEM specific professional development, reported having attended a summer workshop specifically on STEM Education that spanned over a two week period.

Teachers were also asked to rate their satisfaction with the STEM Education professional development they had attended over the past two years. 27% were Not Satisfied, 14% were Somewhat Satisfied, 45% were Satisfied, and 14% were Very Satisfied. Some teachers indicated they were satisfied with the STEM Education professional development they had attended, even though they had reported attending zero hours of STEM Education specific professional development. Teachers who expressed this stance towards STEM Education professional development were generally not concerned with the fact they hadn't had any specific STEM professional development. They were either uninterested in receiving professional development in STEM Education or they expressed that they were unaware that they needed it.

Finally, teachers rated their satisfaction with the availability of STEM Education professional development. 45% were Not Satisfied, 7% were Somewhat Satisfied, 41% were Satisfied, and 7% were Very Satisfied. Some teachers indicated they could possibly get more STEM Education professional development from their district coordinators if they asked, but they were unaware of any opportunities that were readily available to them. Figure 3 below provides an overview of participant teachers' satisfaction with STEM Education professional development.



**Figure 3**  
*Teacher Satisfaction with Quality and Availability of STEM Ed. PD*

Figure 3 suggests that participants in this study were mostly satisfied (45%) with the STEM Education professional development they attended, but most (45%) were unsatisfied with its availability. While participants expressed a general satisfaction with the STEM Education professional development they had attended, the specific nature of those experiences are unclear. Interviews with a sample of participants was intended to provide more detailed information about teachers’ satisfaction with the quality and availability of STEM PD opportunities.

### **Teachers’ Approaches to Integrating STEM**

Analysis of teachers’ lessons revealed a wide variety of conceptions, and approaches to STEM education. Considering the Six Essential Features of Effective STEM Integration (Johnson et al., 2015), shown in Table 4, teachers in this study did not

include and were not primarily concerned with the majority of the features considered to be essential.

Table 4  
*Six Essential Features of Effective STEM Integration*  
(Johnson et al., 2015, p. 5)

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Feature 1	In order to engage students in meaningful learning and provide access to the content, integrated STEM learning environments include a motivating and engaging context. These contexts should be personally meaningful and allow for students to connect with the content.
Feature 2	In order to develop problem-solving abilities, creativity, and higher-order thinking skills, integrated STEM Education should include engineering design challenges of relevant technologies for compelling purposes. This can also include engineering thinking, technological progress, and reverse engineering of technologies.
Feature 3	STEM integration should allow for students to learn from failure and to redesign based on what is learned. This is one of the hallmarks of engineering thinking and should not be overlooked.
Feature 4	In order for learning to be meaningful and worth the time it takes to participate in project and problems-based learning challenges, integrated STEM Education should include standards-based mathematics and/or science objectives in the learning activities. In addition, real-world problems are interdisciplinary beyond just the STEM disciplines. This means that other disciplines, such as English/language arts and social studies, can be included as appropriate.
Feature 5	In order to provide students with opportunities to learn the standards-based content deeply, it is imperative that content be taught in a student-centered manner. Students need opportunities to grapple with the content and think for themselves in order to deepen their conceptual knowledge.
Feature 6	Integrated STEM learning environments should emphasize teamwork and communication abilities that are imperative for life in a 21st-century workforce.

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For example, meaningful learning and engaging contexts (feature 1) was either not included or was surface level. Engineering design challenges were almost missing entirely (feature 2) and explicit standards addressed in lessons (feature 4) specific to math

and science were weak or missing. Finally, most teachers did not focus on providing learning experiences where students had the opportunity to deepen their conceptual knowledge (feature 5). Teachers tended to address feature 3 (allowing mistakes) and feature 6 (collaboration) in their lesson plans.

An analysis of lessons using Davidson et al.'s framework also showed variation in how teachers integrated STEM. First, the majority of the lessons submitted from the population sample (48%) fell into the category of No Integration; meaning the lesson was primarily one subject only. For example, one teacher submitted a lesson plan with the goal of students being able to identify area and perimeter of a square and a rectangle using a formula. Math was the only subject represented.

The next largest proportion (21%) of teachers submitted lesson plans that were Process Integration; meaning they posed a problem and used science processes and math standards to find answers. For example, one teacher submitted a lesson plan that asked students construct a bridge out of toothpicks and gum drops. Students create and record multiple types of bridges, focusing on which shapes of bridges could hold the most weight. Students test and collect data to ultimately try and determine which shape bridge is best for holding the most weight.

The third largest proportion (17%) of teachers submitted lesson plans that used Content Specific Integration; meaning they used at least one standard from one subject and another standard from another subject. For example, one teacher submitted a lesson plan using one standard from science and one standard from math. This lesson had students investigating friction by pulling water bottles attached to spring scales across

various surfaces and calculating the averages of multiple pulls across each surface in Newtons.

The two smallest categories were Thematic Integration and Methodological Integration. Only 7% of teachers submitted lesson plans that used Thematic Integration; meaning all content areas focused on a theme. For example, one teacher used “pumpkins” as the theme of her lesson, and included activities such as estimating the number of pumpkin seeds inside the pumpkin, painting the pumpkin, and reading and writing stories about pumpkins. Only 7% of teachers submitted lesson plans that were Methodological Integration; meaning they used inquiry, the learning cycle, discovery, etc. to build knowledge using science and math. For example, one teacher submitted a lesson plan that used the 5E learning cycle where students used science, engineering, and math to learn about the water cycle. Students progressed through each learning sequence, engaging in activities that helped them discover how the water cycle works and then progressed into designing solutions to solve water pollution problems.

No teachers (0%) submitted lessons that were Discipline Specific Integration; meaning they pulled standards/content from different fields in the same subject (i.e. Algebra and Geometry or Biology and Geology). That is, teachers typically stuck to a specific topic within a discipline, as opposed to focusing on cross-cutting concepts within a discipline.

Interviews with the purposeful sample of teachers sheds light on the nature and scope of teachers’ integration within each category, the learning goals they defined for students, their perceived benefits of teaching STEM, and how they conceptualize and

enact STEM. These data are presented in the form of vignettes describing the teacher participants and the integrative approach their iSTEM Education Lesson Plans used.

***Thematic Integration – Laura***

Laura defined STEM Education as “...trying to combine science, technology engineering and math skills and concepts... and [students] learn how they are associated together and that they are introduced in a hands-on experience instead of just a teacher lecturing about the concepts.” Laura continued to comment about how she believed engineering was “how things come together” and she described science as something that “just happens.”

Laura described her goals for students when teaching a STEM lesson as primarily a way of keeping her students busy. She explained that she tries to keep her students “doing” all day. Laura describes another general goal for her classroom is trying to include technology because students do all of their tests with technology when they get to high school. Laura speaks about instructional technology use as something she and her grade level teacher colleagues try to incorporate more of, particularly iPads. She also commented that “...it [STEM] is something that was put on the backburner for reading and math...”

The biggest benefit Laura described for having students learn about STEM, was getting students to see how subjects went together. For example, Laura says “I think it is important that kids see how they [subjects], how those pieces are intertwined together. That we have to have an understanding of all of those to do any of those things well.” She also felt STEM would help her students to feel okay about making mistakes and to explain their thinking.

Laura submitted a lesson called “Pumpkins Galore” which she created herself that she was not required to teach. The objective of the lesson was for students “...to expose students to the different parts of a pumpkin, practice counting, and to explore different ways to use a pumpkin for fun”. Throughout the two-session lesson, students use pumpkins in a variety of activities to make predictions. Students record predictions and noticings on height, weight, color, buoyancy, etc. Students then guess and count the number of seeds in the pumpkin. An art extension is included as an option where students are able to paint or carve their pumpkin. Neither formative nor summative assessments are included in the lesson plan. Additionally, standards being addressed were not included in this lesson plan.

The lesson Laura submitted was classified as Thematic Integration as her lesson was focused on pumpkins and all activities revolved around the theme. Davison, Miller, and Methany (1995) described thematic integration as a way of integrating many subjects around a central topic or theme. Laura shared that she tried to structure her STEM lessons in a way that went along with whatever theme or time of the year was taking place, such as the pumpkin lesson because it was around Halloween. When asked how she came up with the idea for the lesson, Laura said that she always carves pumpkins with her class and that she thought this lesson would go beyond “play.”

Laura continued to describe how her STEM lessons were rarely ever planned out and that she just tries to connect ideas back to science or math as they come up. She shared her frustration with teaching science and that she has no curriculum or materials to use aside from a weekly reader she gets from a school book publishing company. She explains “I don’t feel like I am equipped well enough to put all of those pieces together regularly...in our building it [teaching science] is pretty much whatever the teacher chooses to teach and when they teach and how they teach it.” Laura shared that because she doesn’t have materials provided by her district, she relies heavily on Teachers Pay Teachers and other internet sites to find STEM lessons and ideas. Laura shared that her STEM lessons generally have an art or craft project included because that is what she likes.

Laura stated that she had a little bit of professional development in science but none specifically in STEM Education. She shared that she desires professional development on integration and how to make iSTEM Education lesson plans. Laura lamented that while she desires to know more about STEM Education, her building doesn’t focus much on STEM as it has taken a “backseat” to reading and math.

Figure 4  
*Thematic Integration- Laura*

#### ***No Integration-Mary***

Mary defined STEM Education as “... learning how to explore and build on things... create new things...taking a look at how things work... discovering things to learn concepts...a hands-on exploratory approach to learning...trying to solve a problem that has more than one answer...” Mary continued to describe how she felt engineering was a “creation process” and that it was different from science because science is the “core concepts” while engineering is taking those concepts and “creating something to solve a problem.”

Mary’s biggest goal for students when teaching iSTEM Education was to get students to be independent and to be okay with making mistakes. She described problem-solving as the biggest benefit she sees in teaching iSTEM Education. She stated, “I think it is important to teach them [students] that this is how you're going to have to figure something out because there isn’t always going to be an answer.”

Mary submitted a lesson plan called “Properties of Matter” which she borrowed from a colleague who got it from Teachers Pay Teachers. The objective for students stated, “Students will describe and sort objects based on color, shape, size, and texture.” This lesson was structured as individual thirty-minute lessons that would span for six days. Activities included a nature walk, button sort, class discussion on matter, cracker sort, and the construction of a “Nature Friend” (a craft project using items found in nature to build a “friend” using a Styrofoam cup as the body).

The lesson Mary submitted was classified by the researcher as No Integration. The topic of Mary’s lesson is properties of matter, and all activities in the lesson are focused on the subject of science. Students participate in a variety of seemingly disconnected activities, and the final product of the lesson is a “Nature Friend” that is created out of a Styrofoam cup and items students found during a nature walk at the

beginning of the lesson. When Mary was asked about integrating STEM subjects in the interview, she stated “...I don’t want to say we have dropped out math...we talk about math within our STEM lessons but... I wouldn’t say it is 100%...they all kind of work together...not all of our lessons include all four of those things...”

Mary described the way she typically structures her STEM lessons as lasting about thirty minutes every afternoon for science and her lessons focused on students explaining and exploring. She continued that students typically are working together and “...have some sort of hands-on materials that they are manipulating and working with to create some sort of solution...”

Mary shared that she feels she has a wonderful support system when it comes to teaching STEM Education and specifically cited her grade level partner and other teachers in her building. She also mentioned that her building has different resources available for STEM Education as they have a membership to the National Science Teachers Association as well as a grant from the Missouri Partnership for Education Renewal (MPER). However, she commented that she does a lot of internet research and frequently uses Pinterest to find STEM lessons. Mary shared that while she would like to have professional development on teaching iSTEM Education, she was unsure as to how willing many of the other teachers in her building would be to try something new.

Figure 5

*No Integration- Mary*

#### ***Content Specific Integration- Cassie***

Cassie defined STEM Education as “...trying to integrate science into as many things as possible...so maybe reading, writing, science all in one... the technology piece like iPads and maybe research...using as much of the iPads and devices...” Cassie continued to admit that she had no idea what the “T” in STEM meant and that she “didn’t have a clue” as to what engineering would look like at the elementary level, but she thinks it would have something to do with designing and building.

Cassie’s main goal for teaching iSTEM Education is influenced by her school’s focus on integrating the expressive arts. She explains “...we are the arts integration school, so everything we do we try to hit as many areas as possible using art, music, drama, dance, even technology... our fine arts objectives or our learning objectives are the main things...” Cassie describes her view on the benefits of students learning about STEM as a way to promote higher-level thinking. She states “...it [STEM] is requiring them to think not just at the base level of input knowledge and just recall...it is all at the higher level of thinking. It really digs in and makes them really think.” Cassie also commented on how she believes that STEM Education can aid in encouraging students to have better behavior and be more productive.

Cassie submitted a lesson called “Lunes and Leaf Rubbings” which she got from a colleague who left their school many years ago. She was not aware of the original source, and she was not required to teach it. The objective of the lesson was “Students will experiment with writing lune poems (a form of Haiku poetry) based upon items found in nature.” The lesson spanned three sessions and connections to state standards included fine arts and communication arts standards.

The lesson Cassie submitted was classified as Content Specific Integration. Content Specific Integration is when a lesson includes one objective from one subject and

one objective from another. Davison, Miller, and Methany (1995) describe Content Specific Integration as using one objective from both math and science. However, in this study, a lesson could be categorized as Content Specific Integration if there were one objective from any two subjects included. In Cassie's case, her lesson included an objective from writing and another from art. When asked to describe her reasons for integrating the arts into her lesson, she stated "...we are the arts integration school so everything we do we try to hit as many areas as possible using art, music, drama, dance, even technology... we really kind of look at it like a big umbrella..." Additionally, Cassie described the difficulty she and others in her school experience when trying to integrate math into their art-focused curriculum because "math is so hard to integrate." Cassie emphasized that at her school science, technology and engineering are not a focus. She clarified that they do teach science but that it is not a focus for them.

Cassie described her typical lesson structure when teaching an iSTEM Education lesson as one that uses guided practice and "would definitely include a movement activity." Her lessons last about an hour and her job would be to model her expectations, so students knew what she expected of them. In the lesson Cassie submitted, she described how movement was integrated into her STEM lesson when her students go outside to observe leaves. She continues "...they get to basically imitate the leaves with their body. So they dance around, they float around, and they twirl. So they are basically observing the leaves and then doing things with their bodies to imitate that ..." Cassie also describes how she allows her students who are shy to use finger puppets to help them explain their thinking to their peers.

Cassie commented on how she feels she has a good amount of support for integrating and feels certain that if she went seeking for more STEM support that she would be able to get it. She cited her building art team (specialist teachers in art, music, drama, and dance) as the main source for helping her with integration, as well as the other teachers in her building. She described how helpful her district's science and math coordinators are and that she felt if she asked them for assistance then they would be very good about providing it. Her instructional resources for STEM are basically their buildings access to Science A-Z and the math and science curriculum provided by her district. When it comes to her resources that aid in her integration strategies, she explained "...I use Pinterest...we use Pinterest a lot to find ways that we can integrate as much as possible..."

Cassie shared that she was a bit apprehensive about how her building would react to any iSTEM Education professional development because it just wasn't a focus for them. She explains "...I'm not knocking STEM, but...again I think it is important so obviously, we have a need for pd, but...it is not something I feel like our building would focus on." Cassie stressed that perhaps individual teachers might go out and find STEM professional development and she might be interested to see what it would look like at the elementary level, but she really felt that she and the teachers at her building are solely focused on what they are doing at their building, which is focusing on the arts.

Figure 6

*Content Specific Integration- Cassie*

***Methodological Integration- Sidney***

Sidney defined STEM Education as "... taking science to a new more modern day level... the future careers and the future of our country and world is more based in science, technology, engineering, and mathematics...". She continues "...our kids are sadly too much in just rote memorization of basic scientific facts. So it is becoming more hands-on and real world applicable for solving problems within those fields." Sidney also described engineering as a building and design process and cited multiple careers where engineering design processes are used.

Sidney has many learning goals for her students when teaching a STEM lesson, but she comments on how her primary goals come from her state standards. She discusses the responsibility of public school teachers to stick close to their state standards. Her secondary goal, which she hits on multiple times throughout her phone interview, is focused on student retention. Sidney also has an overarching goal of getting students to be well-rounded and proficient at many different things. She sees this as both a goal and a benefit for having students learn STEM Education. Sidney focuses on the future needs of her students and how they will need to be "well-versed in multiple areas" to be good at most jobs. She describes the need for students to be problem solvers and to realize that students need to be able to create and implement their own ways to come up with a solution.

Sidney submitted a lesson plan called "Problem Solvers" which she adapted from a book called *Even More Picture Perfect Science* by Ansberry and Morgan (2010). Sidney was not required to teach this lesson. There were six different learning outcomes included in this lesson and five science and math Missouri Learning Standards. This lesson was structured as a 5E lesson that would span over five separate class periods, each lasting thirty to ninety minutes each day. A student assessment and modifications or accommodations were also included.

The lesson Sidney submitted was classified as Methodological Integration. Davison, Miller, and Methany (1995) essentially describe Methodological Integration as a method of integration that investigates issues, for example, in science and math using discovery, inquiry, and the learning cycle. There is a building of knowledge that occurs within the lesson as students progress. Sidney's lesson uses the 5E Learning Cycle (Engage, Explore, Explain, Extend, and Evaluate) and students are working to solve problems.

Sidney explained that her STEM lessons don't follow a typical structure, but she does have about two to three hours a week for teaching her "old-school" science lessons. Sidney utilizes Genius Hour and Makerspaces in both her classroom and her after-school club, while also using instant challenge task cards from Discovery Innovation. Sidney says her lesson structure depends on the activity. For example "...I do Makerspace in my classroom twice a week for about an hour each time...we started with task cards that are open ended... like create a robot...there is like 100 task cards that I got from our gifted teacher..." Sidney commented that she is trying to provide more opportunities for her students to engage in exploration and becoming a more student-centered educator.

Sidney stated that she didn't really feel like her district is providing her with any materials or resources to assist her with her STEM teaching as they aren't quite on board with STEM Education yet. Sidney remarked that her main source of STEM support comes from other teachers in her building, such as her grade level partners and the gifted teacher. Sidney described that she has taken the responsibility to write grants for money

needed to purchase STEM materials and that she uses various internet resources such as Google and YouTube for lessons and ideas. When asked about the areas she desired more professional development, Sidney had a lot to say. She explained that she would like more professional development in developing lessons and how to find resources that are free or affordable. She discussed her understanding of the importance of STEM Education but said she just doesn't know how to get it done by herself.

Figure 7

*Methodological Integration- Sidney*

***Process Specific Integration- Kim***

Kim defined STEM Education as "... Science, Technology, Engineering and Math education...I am lucky enough to teach in an arts integrated school so STEM would be more science, technology, engineering, art, and math integrated...so pulling those subjects into all parts of teaching." Kim explained the difference between engineering and science as engineering being "the study of how things are built and how things are made and created." She explained that she felt engineering was an aspect of science but was more "process related."

Kim's goals for students when teaching STEM begins with the objective for the lesson and the content being taught. She explained that if she was teaching a social studies lesson, then her primary objective would be that students had correct social studies content information. She stated that if say, technology was the focus of the lesson and the content was secondary, then she would be looking for mastery of the technology skill. Kim shared she felt STEM Education was beneficial for students because it helped them to be "well-rounded." She commented on how technology is changing "minute by minute" and how students need to be able to change with it. She also felt problem-solving, and collaboration skills were important benefits of students participating in STEM Education. Kim also commented on how she believes some students are more successful in STEM Education than others. As an example, she cited a student in her class who is "gifted" and "math minded" but is not necessarily creative. She says "...he is creative, but he is not a visual artist. He is not a great singer, he is not a great actor, but he is great with math and numbers and really good at problem-solving...so that helps."

Kim submitted a lesson plan called "Towering Towers" which she got from a colleague "many years ago." Kim was unsure of where the lesson originated, but she was not required to teach it. The goal of the lesson stated "As a team, you must only use the given materials, to build a tower that will support a ping-pong ball. Points are given for originality, neatness, height, and cost of materials". This lesson would take place during a single class session. There were no standards or objectives included in the lesson.

Kim's lesson was classified as Process Specific Integration. Davison, Miller, and Methany (1995) describe Process Specific Integration as an approach where students use real life activities to engage in science and math processes. Solving a problem is a part of process integration and Kim's lesson, while not exactly a real life problem, poses a problem for students to solve as a team. Students are expected to build a tower using only the materials provided and considering the cost of all materials used.

Kim explained the structure of her STEM lessons when she stated: "...depending on the lesson it is either, you know I will introduce the objective and then do a gradual

release of content”. She continued her description by saying she tends to incorporate a lot of technology into her teaching. She likes to use Schoology as a platform for paperless work and uses Google Apps, QR Codes, and other apps in her classroom as her students are all 1:1 with iPads. When asked how she integrates science, technology, engineering and math, Kim stated that she hadn’t taught science in about ten years as her school departmentalizes. She commented she tries to integrate math but “Math is one of the hardest subjects to use art integration.” She also commented on how she utilized other teachers, district coordinators, and the internet for help when developing her STEM lessons. Kim desired professional development in integration, specifically with the arts as she is at an arts school. She wants to be able to integrate STEM with the arts but would like it not to be “a chore or something extra...just make it kind of natural.”

Figure 8

*Process Specific Integration- Kim*

### **Discussion**

The purpose of this study was to examine and describe the ways in which elementary teachers conceptualize iSTEM Education and the integrative approaches they use when teaching STEM content, with the intent to inform the development of elementary specific iSTEM Education professional development. The findings of this study are discussed in light of the research questions in the sections that follow.

*To what extent are elementary teachers prepared to implement iSTEM Education?*

Teachers in this study were generally unprepared to implement iSTEM Education, as evident by the lack of STEM Education specific professional development attended as reported by teacher participants. This is not surprising considering that elementary teachers lack content knowledge in STEM content areas (Trygstad, 2013; Honey et al., 2014; Fulp, 2002; Ma, 1999; Hanover, 2012) and receive little preparation in these areas during their teacher preparation programs (Fulp, 2002).

An area that is surprising among the data, is how elementary teachers are seeking out iSTEM Education opportunities and materials on their own due to the lack of support in the area provided by their school or district. Some teachers are using their personal resources to learn how to teach iSTEM Education by writing grants and attending

conferences, while others rely solely on those experiences provided by their district or what they can find on the internet. Furthermore, the experiences provided by the districts related to iSTEM Education, tend to be focused on individual subject-specific resources with “STEM” iPad applications and websites to use to enhance a lesson. This plays into the idea that iSTEM Education, like technology (Williams, 2011), is being used as a tool to enhance other subjects, rather than a subject of its own.

To some in the study, iSTEM Education is just another “thing” that teachers are required to learn about, but has little effect on their daily teaching practice. However, to others, iSTEM Education is meaningful and they desire assistance in learning how to adjust and modify their teaching practice in a way that is reflective of effective iSTEM Education.

*In what ways do elementary teachers approach iSTEM Education in their lesson plans?*

Teachers in this study struggled with how to approach designing iSTEM Education lesson plans. Lesson plans were vague, underdeveloped, scattered, or inappropriate for teaching the desired objective. This is possibly indicative of how much time in general elementary teachers are spending on iSTEM Education. They aren’t devoting much time in the classroom to iSTEM Education so they aren’t taking the time it takes to develop quality iSTEM Education lessons. The reasons why could be numerous and each participant may fall into more than one category.

Perhaps teachers submitted these types of lesson plans because they didn’t have time to find anything else. Most teachers reported the lessons they submitted were pre-made so teachers weren’t developing them from scratch for this study. Many also

reported using websites where they could quickly find a lesson and use it in their classroom.

Perhaps teachers submitted these types of lesson plans because they truly don't know how to integrate and this was their best guess. It is interesting to consider how representative these lessons are of elementary teachers' understanding and ability to create iSTEM Education lessons. For example, teachers indicated that math was difficult to integrate and very few of them submitted lesson plans that integrated math. When teachers did try to integrate, some of their lessons included more standards and objectives than what would seem feasible for moving students towards mastery.

Finally, perhaps teachers submitted these types of lesson plans because they really did represent the way they conceptualized iSTEM Education at that particular moment. Teachers in this study focused on student engagement and making learning fun for their students so many of their lessons focused on being fun and engaging without a focus on content.

*How do elementary teachers conceptualize iSTEM Education?*

Teachers in this study appear to have general ideas regarding their role as the teacher when teaching iSTEM Education. Teachers see themselves as guides or facilitators and focus on making sure they give their students some independence in their learning. However, these ideas are underdeveloped, and there is a much larger emphasis on students being independent and self-guided than there is on content mastery.

Second, there is little consensus among teachers regarding what is or should be taught in iSTEM Education. Some teachers felt a STEM lesson had to include all four subjects represented in the acronym (science, technology, engineering, and math) while

others felt their STEM lesson could include all subjects. Additionally, the nature of the activities described by the teachers show differences in their overall approach to teaching iSTEM Education. For example, utilizing the teaching orientations as described by Magnusson, Krajcik, and Borko (1999), teachers showed multiple orientations to teaching iSTEM Education, but all of them fell into the categories of Activity Driven, Discovery, Project-based, and Guided Inquiry. Sidney and Cassie were primarily Activity Driven, though Cassie also had qualities of Discovery and Sidney had qualities of Project-based. Laura, Kim, and Mary were all primarily Guided Inquiry.

There is some consensus among teachers as to what students should be doing in iSTEM Education. Teachers expressed that students should be working with materials and participating in hands-on activities. Students should have opportunities to create, design, and build and their classroom environment should be such that students are okay with making mistakes.

Notably, teachers in this study differed in how they viewed technology as part of iSTEM Education. Teachers, for the most part, did not express ideas about technology in ways beyond using instructional technology (iPads and other electronic devices). Some teachers commented that they were aware that technology didn't have to be an electronic device. However, their representation of technology in their interviews and lesson plans expressed their dependency on electronic devices and "gadgets" to satisfy their technology integration. Most teachers used technology as a tool to enhance STEM lessons as opposed to focusing on specific technology skills or concepts.

Teachers also fluctuated on their understanding of the STEM acronym. Some understood the acronym to be STEM while others were adamant it was (or believed it

should be) STEAM, integrating the Arts into the acronym. Not surprisingly, another area of mismatch appears when comparing teachers' definitions of STEM Education. Just like the rest of the education community, there was no consensus among teachers in the study regarding what STEM Education is and is not. Teachers had ideas, but most were underdeveloped, misguided or incomplete.

*What learning goals do elementary teachers have for students as part of their iSTEM Education lessons?*

The primary goal teachers expressed for their iSTEM Education lessons was problem-solving. Teachers commented on how students needed to be able to be good problem solvers for future careers and everyday life. Teachers felt problem-solving was important, regardless of whether or not the problem was authentic or contrived. Teachers also had a strong desire to use iSTEM Education as a way to teach students to be independent and self-guided. Additionally, teachers placed a large amount of importance on using iSTEM Education to boost student communication skills through collaboration, team building, and sharing of ideas. Some teachers described their use of iSTEM Education lessons as primarily "ice breakers" or "fillers" when they had a little extra time to "do something fun." Teachers had no concern about meeting standards or objectives during these lessons but rather desired their students to get to know each other and learn to work together and share their ideas.

Building on the previous idea, few teachers had an overall concern about mastery of content or skills as a learning goal. Teachers were more concerned with collaboration and communication as opposed to specific learning objectives or better conceptual understanding of content. In fact, some teachers were more concerned with their lessons

being “fun” and “engaging” than they were on the content being discussed. They liked that iSTEM Education lessons that they had observed seemed fun and engaging for kids, so that was their primary reason for using them. Finally, while some teachers included some elements of engineering practices in their lessons and descriptions of iSTEM Education, most were underdeveloped. For example, the idea of making models and prototypes was the primary way of including engineering in a lesson. The idea was that as long as students were making building or making a model, they were engaging in engineering. Teachers had some understanding of what engineering entails but it was surface level and not necessarily representative of what engineers actually do.

*What do the teachers see as the benefits of students learning about STEM (outcomes)?*

Overall, teachers had very little to share regarding their thoughts on how iSTEM Education would be beneficial for their students. Most of them expressed they had heard about it and felt it was important but just didn’t feel like they knew enough about it to really have much of an opinion beyond their surface level understanding of iSTEM Education. However, teachers tended to somewhat agree on the idea of there being academic benefits to students learning about and participating in iSTEM Education. Teachers also expressed that engaging in iSTEM Education enhanced retention. Teachers discussed how student engagement in iSTEM Education aided students in retaining information that they would be able to recall and apply later, be it later that school year or more long-term such as later in life. Teachers focused on potential jobs that might require skills promoted in iSTEM Education. For example, teachers expressed that iSTEM Education helps students become well-rounded or well-versed in multiple areas, making them capable of doing more than one thing. Teachers felt this was an important skill-set

for students to have, to be good at more than one thing, because jobs now and in the future will demand that capability.

Last, some teachers felt a benefit to teaching iSTEM Education was because it was more engaging for students and therefore aided in behavior management. Teachers shared how they had students who had difficulty sitting still or behaving through more traditional methods of teaching but using more “STEM-based” lessons helped these students to be more engaged and produce better quality work.

*What is the nature and scope of teachers' integration of STEM disciplines?*

When it comes to integration, the number one area of concern for teachers was math. Teachers expressed that they felt math was the most difficult subject to truly integrate and struggled to figure out how to do so in their classrooms. Some felt like math was perhaps one of those subjects that had times when the concepts just needed to be taught separately, such as memorizing multiplication facts. Some teachers shared they would have counting or numbers involved in a math lesson, but there really weren't any explicit math concepts being taught.

Considering the *Six Essential Features of Effective STEM Integration* (Johnson et al., 2015), teachers in this study were primarily focused on feature three and feature six. Feature three indicated that effective STEM integration provides opportunities for students to make and learn from mistakes. Teachers in this study indicated they desired for their students to be able to make mistakes and tried to create a classroom environment that was conducive for students to take risks in their learning. Feature six emphasizes teamwork and collaboration, which many teachers emphasized as being an important reason for teaching iSTEM lessons.

Many teachers commented that they don't specifically teach iSTEM Education on a regular basis because they are not in a school or district where iSTEM Education is a particular focus. Because of this, they say they don't really have much in the way of professional development offerings and therefore lack the knowledge and skills they need to be able to integrate and teach iSTEM Education. All teachers commented on their focus of integrating reading and writing in everything they teach. While there was nearly universal agreement that subjects should not be taught in isolation, the degree to which integration should take place and what subjects should be integrated was unclear.

Finally, teachers revealed that very little time was devoted to iSTEM education in a typical school day. Some teachers had separate STEM times during the day or after school clubs that focused on iSTEM Education. However, most teachers did not teach iSTEM Education consistently or as a normal part of their typical school day.

*What instructional Designs, supports, and adjustments to the learning environment do teachers utilize when integrating STEM?*

When it comes to iSTEM Education supports, teachers relied heavily on the internet and technological applications. Websites such as Pinterest and Teachers Pay Teachers were cited by all teacher participants as places they go to find iSTEM Education lessons. Additionally, applications such as Google Apps and Twitter were cited as iSTEM Education supports as well.

Aside from the technology supports for iSTEM Education teachers also indicated they relied heavily on teachers in their own building for support. Colleagues in their building who are either grade level partners, other classroom teachers in their building, or specialist teachers were all referenced as sources for iSTEM Education supports from

participating teachers. No teachers mentioned having any iSTEM Education specific professional development, materials, or resources provided for them by their district for iSTEM Education. Teachers lack access to quality iSTEM Education specific resources and when they did find some they felt was worthwhile, they had to take it upon themselves to attain it (i.e. pay for it out of their own pocket, spend their free time at home working on a grant to get materials, etc.).

Considering the elementary teachers' unique opportunity to integrate (Becker & Park, 2011), a surprising finding of this study is that teachers' lessons were primarily one subject only and many lacked components such as standards and objectives. While this may be an artifact of the shorthand of 'lesson plans', nonetheless the majority of lessons fell into the category of "No Integration" within Davison and colleagues' framework (1995). While it appears this is somewhat related to how teachers conceptualize STEM, it might also reflect lack of knowledge for how to integrate, or constraints of their mandated curriculum. For example, Cassie discussed the difficulty of integrating math and Sidney brought up the limited time devoted to STEM in the day.

### **Implications**

The results of this study illustrate that there is much work to be done in helping teachers create quality iSTEM Education lesson plans that integrate in a way that is reflective of the Essential Features of Effective iSTEM Education Integration. Despite highlighting teachers' enthusiasm and interest in iSTEM, the examples presented in this study revealed a multitude of common difficulties elementary teachers faced regarding their conceptualization and implementation of iSTEM Education. These common difficulties have implications for the design of professional development opportunities for

elementary teachers in iSTEM Education. I have identified the common elementary teacher difficulties when attempting to integrate iSTEM Education along with specific recommendations for professional development in Table 5.

Table 5  
*Teacher Difficulties Identified and Recommendations for Professional Development*

<b>Identified Common Teacher Difficulties</b>	<b>Recommendations for Professional Development</b>
Teachers have general ideas regarding their role when teaching iSTEM Education, but these ideas are underdeveloped.	Teachers need to engage in discussions and view videos of iSTEM Education in action to get a more clear idea of the teacher and student roles in iSTEM Education.
Teachers struggle to decide what is or should be taught in iSTEM Education and get stuck on the subjects represented in the STEM acronym.	Teachers need to engage in activities and discussions aimed at illustrating what should be taught within iSTEM Education.
Teachers struggle with determining what iSTEM Education looks like at the elementary level.	Teachers need to see images of iSTEM Education and at the elementary level through videos and sample lesson plans.
Teachers saw technology in iSTEM Education primarily as using electronic gadgets.	Teachers need to consider different ways technology can be integrated to not only enhance other subjects but to build technological skills specifically.
Teachers saw iSTEM Education as something targeted primarily for gifted students or those who were good at math.	Teachers need to engage in activities and discussions that challenge this misconception to develop an understanding of STEM for all.
Teachers struggled to define iSTEM Education beyond knowing the subjects represented in the STEM acronym.	Teachers need to examine, compare, contrast, and develop their own definitions of iSTEM Education.
Teachers expressed their primary goal for iSTEM Education lessons was for problem-solving.	Teachers need to engage in activities and discussions on problem-solving strategies and to identify the various types and how they work in engineering.
Teachers use iSTEM lessons as ‘ice breakers’ or for team building activities. Not focused on mastery of content or skills.	Teachers need to engage in lesson plan analysis tasks to aid in learning how to develop iSTEM lesson plans that have a purpose and are focused on content.
Teachers had some idea about what engineering is in general but lacked knowledge on what it would look like at the elementary level.	Teachers need to engage in an analysis of various engineering design cycles and see images of what engineering what look like at the elementary level.
Teachers struggled to understand the benefits of iSTEM Education beyond future job skills and behavior management.	Teachers need to engage in activities where they are exposed to positive and negative rationales for iSTEM Education to allow them to develop an understanding of the benefits of iSTEM Education.
Teachers struggled with integrating subjects, particularly math, beyond surface level and nearly all expressed great desire to have professional development in integration.	Teachers need to engage in activities and discussion focused on integration methods of various subjects in iSTEM Education, particularly math.

Teachers struggled to identify quality resources for teaching iSTEM Education lessons and depended on websites such as Pinterest and Teachers Pay Teachers.	Teacher need to critique lessons and units of iSTEM Education to learn how to determine quality iSTEM Education lessons.
Teachers struggled with the idea of creating their own iSTEM Education lesson plans but expressed the desire to learn.	Teachers need to create iSTEM Education lessons and units with guidance that are applicable to the grade level they teach.
Teachers struggled to find professional development in elementary iSTEM Education as their schools and/or districts did not have a STEM focus.	Teachers need an online course so all teachers, regardless of location, have access to iSTEM Education professional development.

Based on the common teacher difficulties identified above, professional development providers will have a clearer understanding of the unique professional development needs for elementary teachers in iSTEM Education. Furthermore, the identification of these common difficulties may inform the design of new professional development programs and experiences that specifically address and support the needs of elementary teachers in their pursuit towards teaching quality iSTEM Education in their classrooms. These professional development experiences are vital if elementary teachers are to be expected to teach iSTEM Education (NRC, 2011).

In order to move the field forward, future studies should focus on the way in which elementary teachers integrate content in their teaching practice in general, as well as in regard to iSTEM Education specifically. Next, future studies should attempt to work towards identifying best practices and methodologies for teaching iSTEM Education at the elementary level. Finally, future studies should investigate the effectiveness of the professional development experiences provided for elementary teachers in iSTEM Education.

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## **CHAPTER SIX: CONTRIBUTION TO PRACTICE**

### **Introduction**

Elementary teachers have the unique opportunity of engaging young students in iSTEM Education experiences at an early age when they are most likely to develop their perception of STEM (NRC, 2011). The teaching of iSTEM Education at the elementary level also has the ability to capitalize on student curiosity and enthusiasm for exploring STEM concepts (Nadelson, 2013). However, one of the biggest barriers to igniting this curiosity and enthusiasm is the lack of teacher preparedness in teaching STEM concepts (Nadelson, 2013). The need for professional development in iSTEM Education specifically for elementary teachers is critical if the U.S. wishes to attain its goal of producing a skilled workforce in STEM areas. This dissertation in practice will contribute insights into the design of effective iSTEM Education professional development for elementary teachers as well as provide a package of resources that may be used in future professional development experiences. In this manner, it contributes both to the practice of elementary teachers and teacher educators/professional developers. Plans for reaching these two audiences are outlined below.

### **Plan for Dissemination of Practitioner Contribution**

As a foundation for the study described in chapter four of this dissertation in practice, I have created a sample online professional development course that is grounded in the current literature in the areas of online education and iSTEM Education. The final product of this dissertation in practice used the sample professional development course I previously created, as a foundation and then critiques and revisions were made to reflect the findings of the study described in chapter four of this dissertation in practice.

## **Current Course Design and Rationale**

When making decisions regarding the design of the iSTEM Education sample online professional development course for elementary teachers, there were challenges due to the lack of solid consensus regarding best practice on the topic. Because there is an absence of agreement on even the definition of what iSTEM Education is and is not, trying to pick and choose the material that would be most important for elementary teachers to know and be able to do after a short eight-week online professional development course was based on the researcher's judgment. Value choices had to be made by the researcher regarding the concepts and materials used in the sample online professional development course due to the lack of research in the area of iSTEM Education teacher professional development specifically for elementary teachers. These judgments were validated after seeking professional advice from other science educators regarding the content and design of the sample online professional development course.

The goals of this eight-week professional development opportunity are for participating teachers to be able to; (a) define iSTEM Education based on material presented in class and individual reflection and research, (b) describe, compare, and implement a variety of instructional and assessment strategies, which will enable students to learn science, technology, engineering, and math, (c) identify a variety of resources for effective instruction in iSTEM Education, (d) develop lessons based on reform-based and 21<sup>st</sup> Century recommendations (i.e., constructivism, inquiry, engineering design, and science literacy). Teachers will show evidence of this through the completion of an integrated lesson plan that meaningfully integrates at least two essential STEM subjects.

## **Structure of Sample Online Professional Development Course**

The sample online professional development course is structured using the Blackboard course management system. The sample online professional development course would run on a regular schedule with asynchronous activities to accommodate the needs of the schedules of participating teachers. There would be common due dates for assignments, but there will be no instances of students and teacher needing to be in the same place at the same time. Specific dates would be determined once the course went live. Modules are distributed through the Blackboard platform, and all assignments and discussion responses are submitted via Blackboard as well.

Weekly topics for this eight-week sample online professional development course include; (a) Overview and Class Introductions/What is iSTEM Education, (b) Why iSTEM Education?, (c) STEM Misconceptions and STEM for All, (d) Integration, (e) Engineering, (f) iSTEM Education Unit Analysis, (g) Putting it All Together, and (h) Integrated Lesson Plans. A more in-depth description of topics to be included in each module are provided in the following sections of this dissertation in practice.

Assignments for the online professional development course include, but are not limited to, weekly discussion board postings, Wiki postings, reflection papers, article reviews, document analysis tasks and the final iSTEM Education lesson plan. Each online professional development course module requires teachers to spend five to seven hours of time per week to complete. This includes the module itself, activities, readings, class discussions and any other assignments or tasks included in the module.

<p><b>Module #1:</b> Title of Module</p> <p><b>Objective:</b> After module completion, students will be able to...</p> <p><b>Pre- Test (First Week Only):</b> At the beginning of the online professional development course students will be asked to complete a pre-test to assess their understanding of STEM Education prior to completing the modules. This test will be multiple-choice, and points will be awarded for completion.</p> <p><b>Background:</b> Information required for teachers to complete tasks will be included here. Discussion topics and big ideas will be presented. In this section, I will speak to students by way of text and will point them towards various online materials that will help them to understand the material being covered.</p> <p><b>Resources:</b> Resources presented and discussed in the Background section will be included here.</p> <p><b>Toolbox:</b> This will be a section dedicated to introducing new tools/instruments for students to investigate and experience.</p> <p><b>Task:</b> Each module will have a list of tasks in which students are to complete as part of the learning experience for the module. Rubrics will be included for applicable assignments while other assignments will be awarded points for completion.</p> <p><b>Readings:</b> Each week students will be assigned readings. These readings are to be completed prior to the start of the next module. There will also be optional readings included throughout the background section, and readings included for students who need further development on topics not specifically addressed in the module.</p> <p><b>Course Discussion:</b> Each week (unless otherwise specified) students will be given discussion questions to be completed within the online professional development course discussion board. Discussion topics may be from the weekly readings or the material presented in a module. Students are to make an initial post and then respond to at least two of their peers. A discussion rubric will be included so students fully understand the course discussion expectations and points will be awarded accordingly.</p> <p><b>Synthesis:</b> At the end of each module I will include a synthesis of the material covered. There will be a checklist that includes all action items from the module, as well as any assignment due dates. Extra material, resources, and tutorials will also be included here should students desire to take their learning deeper.</p> <p><b>Post-Test (Last Week Only):</b> At the end of the online professional development course students will be asked to complete a second multiple-choice test to assess their learning of the material covered. Points will be awarded for completion.</p> <p><b>References:</b> Each module will contain references to work and materials used within the module.</p>
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Figure 14  
*Sample of Module Format*

The design of the online professional development course created for this dissertation in practice is grounded in the theory of transformative learning as well as the best practices established through research on online education. For example, Janicki & Liegle (2001) called for online courses to have a consistent layout. This sample online

professional development course was designed using modules for each week's lesson, and a consistent layout was used in the presentation of each module. Modules follow a common structure, as shown in Figure 14. Exercises and materials were also labeled in a similar manner throughout the sample online professional development course.

Janicki & Liegle (2001) also called for multiple exercises and a variety of presentation styles. Videos, readings, curriculum materials and a variety of other formats were used to present ideas and concepts to participants in the sample online professional development course. Formative assessment opportunities were included throughout each module via quizzes, discussion prompts, and various activities as well which follow another recommendation by Janicki & Liegle (2001). Instructions for navigation and tutorials and links for technical help were also available (see Figure 15), and the facilitator was available to help with any technical issues that may impede the learning process for participants. These were also design choices made in following the recommendations of Janicki & Liegle (2001) and transformative learning theory.

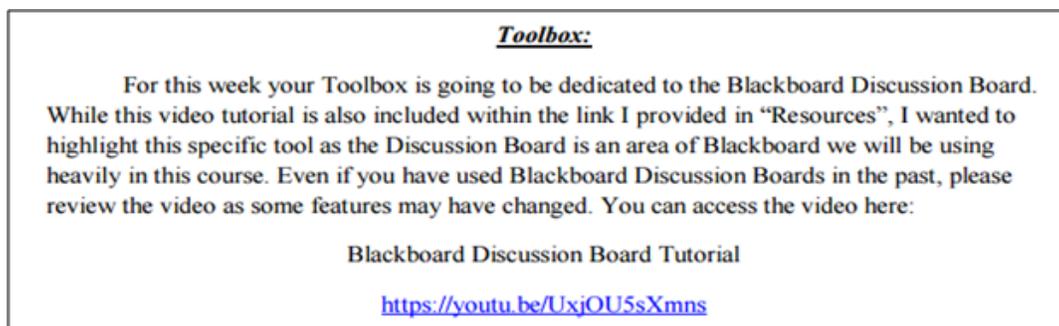


Figure 15  
*Sample Module Help*

While many assume that communication among students and instructors in an online course would be minimal due to the lack of social presence, Walther (1994) argued that rather than being impersonal, computer-mediated communication is often

'hyper-personal' (Walther, 1994). To foster transformative learning, it is essential to provide opportunities for students to engage in discourse where they feel safe and can participate in discussions based on questions posed by the instructor (Palloff & Pratt, 2007). Included in the sample online professional development course are multiple spaces for participants to engage in discussion and to participate in critical reflection. The first area provided is a discussion board where participants respond to carefully formed discussion questions and engage in discourse with their peers (see Figure 16). The second space is a Wiki where students have the ability to communicate with one another on a variety of subjects in a way that gives them more flexibility to share resources and get feedback from their peers (see Figure 17). These spaces also provide opportunities for teachers to wrestle with ideas that may have caused a disorienting dilemma (the first phase of transformative learning) (Mezirow, 2012). The discussion board in particular provides a space for teachers to progress through some of the beginning phases of transformative learning such as self-examination of their feelings/thoughts, critically evaluating their assumptions, recognizing that they are discontent with what they know and seek to share their discontent with others, and exploring new options for ideas or actions (Mezirow, 2012).

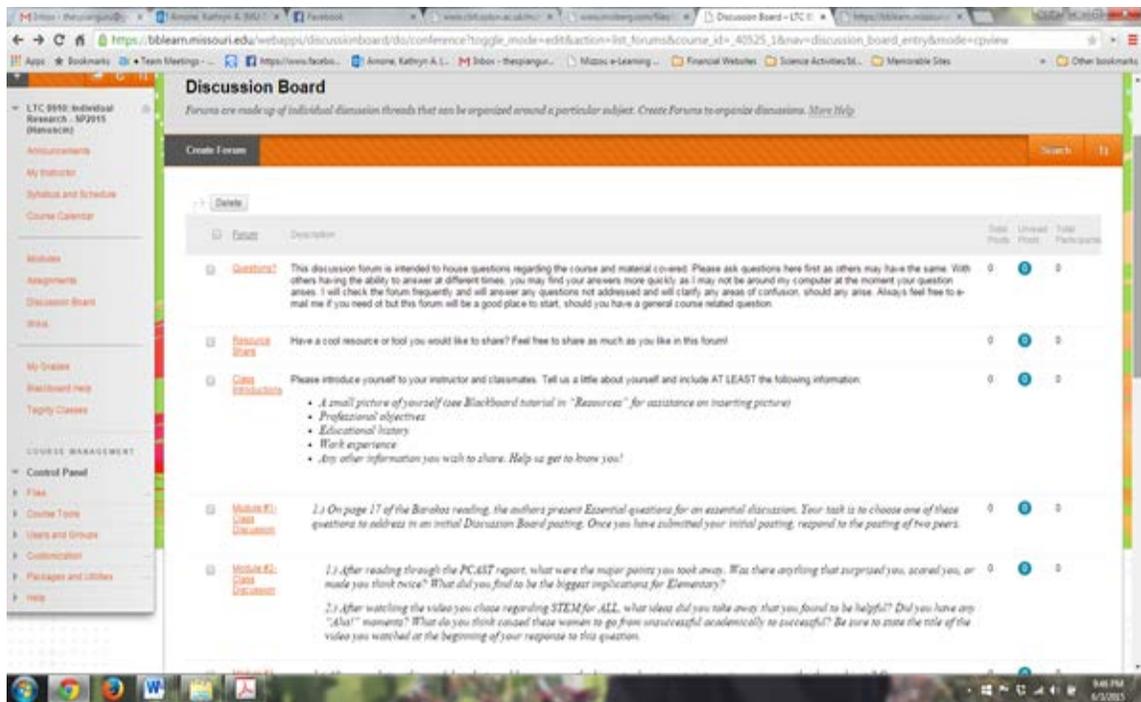


Figure 16  
*Online Professional Development Course Discussion Board Sample*

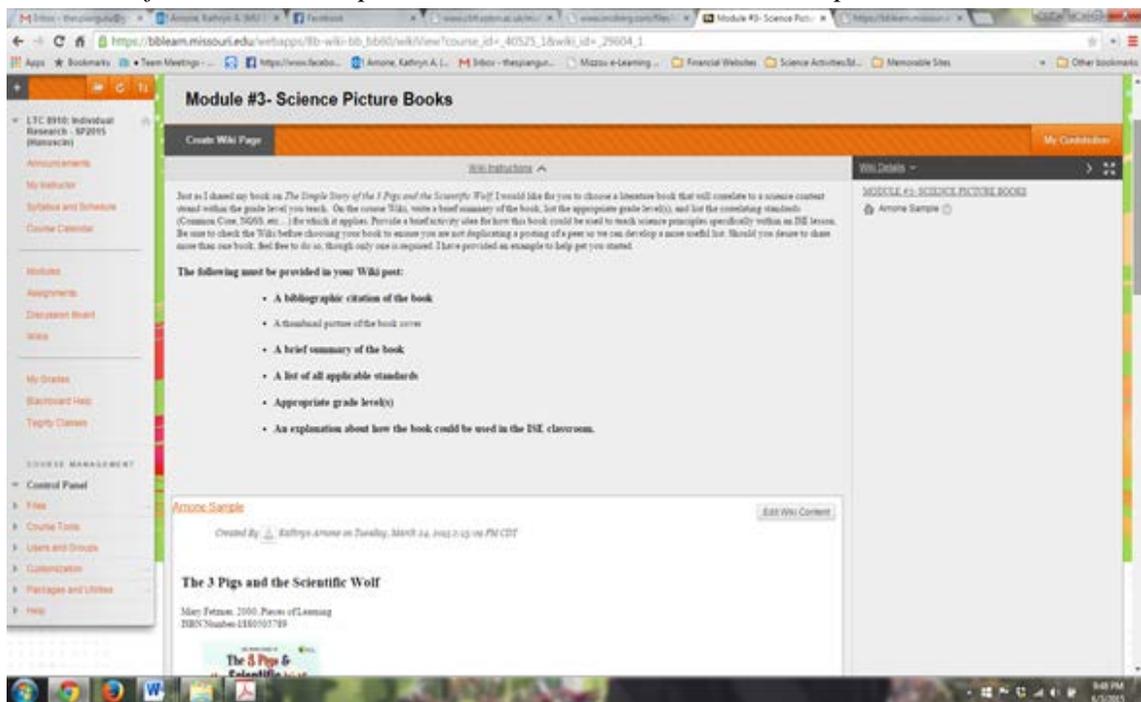


Figure 17  
*Online Professional Development Course Wiki Sample*

Through the discussion board, students address their thoughts and opinions to questions posed and each post is responded to by peers. The researcher's/teacher's job is to act as a facilitator in these forums so as not to impede on students' willingness to speak their mind. Feedback will be given following the tenets of transformative learning theory to ensure that participants feel that their contribution has been valued (Palloff & Pratt, 2007) thus encouraging them to continue to communicate and reflect. Feedback will also be given when exercise submissions are graded, and formative assessment probes are analyzed.

Interaction among students through discussion seems to be one of the most influential features of an online course (Swan *et al.*, 2000). Because discussion can occur at all different times, specifically referring to asynchronous courses, the ability for an instructor to actively control the conversation is nearly impossible. This is both a positive and negative feature, blessing and a curse, in that it forces the instructor to allow for a more student-guided learning experience but also opens up the opportunity for conversations to digress or go off topic. However, even though this structure is primarily student-guided, the instructor is still available and active in watching the discussion to ensure it is productive and can jump into the discussion if necessary. Wells (1992) discussed the idea that subjects that involve discussion, brainstorming, and reflection are best suited for online courses, that these discussions can be significant learning experiences for all learners. This is partly because, in online discussions, all students have the opportunity to have their voices heard, and no one student can dominate the conversation. Also, the online discussion allows students the opportunity to reflect on the postings of their peers before and after posting their contribution (Swan, 2001). Within

the sample online professional development course, there is a significant focus on student discussion in both the discussion board and the Wiki.

While there are multiple opportunities for social interactions within the sample online professional development course, major projects, and graded assignments are designed to be completed independently, using the knowledge and experience gained throughout the process. This design was implemented due to research that has been done by those who have investigated online collaborative learning experiences who found collaborative group projects to be unsuccessful for students (Sturgill, Martin & Gay, 1999; Hawisher & Pemberton, 1997). Group work also tends to be time-consuming and may involve a reduction of topics covered, however, some argue a positive to collaborative learning be that group work helps students to develop problem-solving skills as they would in the real world (Cooper et al., 1990). Finally, Swan (2001) raised the issue that collaborative learning itself may not mesh well with asynchronous course formats but that it is possible that perhaps we just haven't found the most effective ways to support such experiences. Finally, all modules, assignments, discussions and readings are included with the intent to provide opportunities for teachers to experience transformative learning. While not all teachers will experience transformative learning, those who do will do so in different ways and at different times (Mezirow, 2012). The purpose of this online sample professional development course is not to force transformative learning on teachers, but rather to provide as many opportunities for teachers to experience transformative learning as possible.

## **Overview of Module Contents**

The content of each sample online professional development course module was guided by the conceptual framework for this dissertation in practice, the *Descriptive Framework Showing General Features and Subcomponents of Integrated STEM Education* (Honey, Pearson, & Schweingruber, 2014). Each module provides participants with big ideas thought to be necessary for effective iSTEM Education instruction.

### ***Module 1***

In the module titled *Overview and Class Introductions/What is iSTEM Education?* students will have an opportunity to meet their peers and familiarize themselves with how the course is going to function. To ensure students have the opportunity to engage in adequate content in the first module, students will reflect on their experience with iSTEM Education, engage in activities to discover the meaning of iSTEM Education, and look at how iSTEM Education is presently being portrayed in the news.

### ***Module 2***

The next module is called *Why iSTEM Education?* This module provides teachers with the opportunity to think about why iSTEM Education is important. Teachers engage in discussions and activities that raise ideas about the rationales and benefits tied to iSTEM Education. Teachers get a short glimpse into the current policy and analysis in iSTEM Education to get just the amount of policy and reform information they need to build their foundational knowledge of iSTEM Education.

### ***Module 3***

The next module is called *STEM Misconceptions and STEM for All*. This module had to be broken into two separate topics due to course time limitations. Ideally, these

two topics would get modules of their own. However, in this module teachers engage in activities that challenge their ideas of iSTEM Education to try and reveal and address their misconceptions. The next half of the module is dedicated to a discussion on the diversity and equity issue in iSTEM Education. Teachers discuss why they should be focused on making iSTEM Education accessible to all of their students and raises awareness for underrepresented populations in iSTEM Education and the STEM fields.

#### ***Module 4***

The next module is called *Integration*. This module is used to gain an understanding of how teachers are integrating content in their classrooms and help them learn to do so in a way more suited for iSTEM Education. Teachers engage in discussions with each other regarding how they integrate in their classrooms and analyze lesson plans and articles to see how many different ways integration can occur and which ones they think would work best for iSTEM Education. This module will help teachers be able to recognize the variety of different integrative approaches available and to reflect on their current practice to see if their approach to integration could be modified to enhance their iSTEM Education instruction. Teachers have the opportunity to critique a video of a math and science integrated lesson taught by their instructor for the purpose of seeing what integration might look like in the iSTEM Education elementary classroom.

#### ***Module 5***

The next module is called *Engineering*. This module engages teachers in considering what engineering might look like at the elementary level. Engineering design and problem-based learning are covered as many elementary teachers did not receive training in engineering during their teacher professional development programs.

Professional development in engineering is important if engineering is to be recognized as an important part of science, technology, and math education (Bybee, Loucks-Horsley, 2000). These professional development opportunities should aim towards helping teachers develop the necessary skills to encourage and engage students with engineering design (Brophy et al., 2007). This module aims to address the development of these skills and engages teacher in logic problems with the intent of illustrating the different ways problem-solving skills can be addressed in the classroom and how those relate to engineering.

### ***Module 6***

The next module is called *iSTEM Education Unit Analysis*. This module is designed to give teachers a support for analyzing and identifying iSTEM Education lessons and units to use in their classrooms. Teachers engage in an analysis of a provided iSTEM Education unit to analyze using a provided assessment tool. Teachers are then required to use the same tool on one of their own units to find areas where they could make a current unit they already have in practice, more closely aligned with the basic tenants of iSTEM Education.

### ***Module 7***

The final instructional module is called *Putting it All Together: iSTEM Education Lesson Planning*. This module includes guidance in lesson planning for iSTEM Education using research-based methods such as the 5E Learning Cycle (Bybee et al., 2006) and Conceptual Storylines (Ramsey, 1993). Assessments for iSTEM Education is also included using both formative and summative assessment strategies. Teachers also receive a template for creating their iSTEM Education lesson plan that includes guiding

notes throughout to help support them as they progress through the creation process. This module helps teachers to pull everything together that they have learned from the course to design a lesson that would reflect the big ideas of iSTEM Education.

### ***Module 8***

The last module for the course is called *Integrated Lesson Plans*. This module does not include instructional content but is focused on providing feedback on final lesson plans submitted by teachers by their peers and instructor. Teachers are then asked to make any modifications to their final lesson plan based on feedback before final submission on the last day of the online professional development course. Through discussion and feedback from peers and the instructor, teachers can leave the online professional development course with a lesson that is ready to be implemented in their classroom and used as a model for current lesson planning for iSTEM Education in their classroom. A final reflection paper will also provide one last opportunity for teachers to engage in critical reflection on their teaching practice during the online professional development course.

### ***Transformative Learning***

As previously stated, the sample online professional development course was developed with the intention of providing participants with the opportunity to experience transformative learning in their understanding of iSTEM Education. For example, an activity included in one of the learning modules asks teachers to create a three-column chart with the three headings Science, Engineering, and Math. Teachers use a color-coded scheme to represent the similarities and differences of each discipline. Once the charts are complete, teachers are asked to examine their comparisons of the three major

disciplines in iSTEM Education. Teachers should start to see that while there are characteristics specific to each discipline, there is a lot of overlap. This overlap is what they should be looking for when determining ways to integrate material. Once they have discovered the overlaps, they need to determine how they can create a learning experience for students that will give them the opportunity to represent their understanding of the content. At the end of this module, teachers are asked to reflect critically on how they see these subjects working together in their own classrooms. This process is reflective of transformative learning as teachers have the opportunity to experience a variety of the ten phases of transformative learning (Mezirow,2012) (though every teacher will experience them differently) as well as critically reflecting on their own practice.

### **Identifying Common Teacher Difficulties**

Along with providing a revised sample online professional development course, an additional product of this dissertation in practice is a description of common teacher difficulties. These difficulties were determined based on the data collected for the study described in chapter four of this dissertation in practice. The common teacher difficulties identified in this study are included in Table 19.

Table 19  
*Identified Common Teacher Difficulties*

<b>Identified Common Teacher Difficulties</b>
Teachers have general ideas regarding their role when teaching iSTEM Education, but these ideas are underdeveloped.
Teachers struggle to decide what is or should be taught in iSTEM Education and get stuck on the subjects represented in the STEM acronym.
Teachers struggle with determining what iSTEM Education looks like at the elementary level.
Teachers saw technology in iSTEM Education primarily as using electronic gadgets.
Teachers saw iSTEM Education as something targeted primarily for gifted students or those who were good at math.
Teachers struggled to define iSTEM Education beyond knowing the Subjects represented in the STEM acronym.

Teachers expressed their primary goal for iSTEM Education lessons was for problem-solving.
Teachers use iSTEM lessons as ‘ice breakers’ or for team building activities. Not focused on mastery of content or skills.
Teachers had some idea about what engineering is in general but lacked knowledge on what it would look like at the elementary level.
Teachers struggled to understand the benefits of iSTEM Education beyond future job skills and behavior management.
Teachers struggled with integrating subjects, particularly math, beyond surface level and nearly all expressed great desire to have professional development in integration.
Teachers struggled to identify quality resources for teaching iSTEM Education lessons and depended on websites such as Pinterest and Teachers Pay Teachers.
Teachers struggled with the idea of creating their own iSTEM Education lesson plans but expressed the desire to learn.
Teachers struggled to find professional development in elementary iSTEM Education as their schools and/or districts did not have a STEM focus.

Identifying these common teacher difficulties for elementary teachers is an important step towards identifying the unique needs of elementary teachers in regards to iSTEM Education professional development. This information can help those providing professional development experiences to elementary teachers by helping them anticipate the challenges their participants may face. Accordingly, these common difficulties are addressed within the revised sample online professional development course. The primary professional development needs for the elementary teachers in the study described in chapter four of this dissertation in practice are elaborated upon below.

- a) *Teachers need to have a better understanding of their role during iSTEM lessons.* What should they be doing and how is it different from their current teaching practice? Teachers in the study provided only vague descriptions of their role as ‘facilitators,’ without a clear link to specific actions they should be taking to support student learning of iSTEM.
- b) *Teachers need a better understanding of what iSTEM Education is and what should be taught at the elementary level.* Does teaching iSTEM Education mean the teacher only teaches Science, Technology,

Engineering, and Math? What happens to the rest of the subjects? What if they don't feel comfortable teaching science or engineering?

- c) *Teachers need examples of iSTEM Education in action that are specifically created for elementary grades.* Teachers need anchor lessons to critique and lesson templates that help walk them through the planning of an iSTEM Education lesson. What does quality iSTEM Education look like at the elementary level and how do they plan lessons that are successful?
- d) *Teachers need clarification about the technology in iSTEM Education.* Does the technology part of iSTEM Education refer to iPads and computers and electronic gadgets only? What about the technology that is the result of engineering? Do they need to spend a lot of money on new technologies to be able to teach iSTEM Education?
- e) *Teachers need a deeper understanding of the diversity and Equity issues in iSTEM Education and the STEM fields.* Teachers need to be aware that iSTEM Education is for all students, not just the “smart” kids. Additionally, teachers need to be made aware of the phenomena of underrepresented populations who are losing interest in STEM fields at an early age and learning of ways to keep this from happening on such a large scale. In what ways can teachers assist in keeping girls and minorities interested in STEM fields?
- f) *Teachers need training in how to teach engineering education.* What does engineering look like at the elementary level and how do they teach it

without adding another subject to their already overloaded schedules?

How are they supposed to teach engineering if they have never had any training to learn how? Why is it important that they teach engineering at the elementary level?

- g) *Teachers need assistance in developing iSTEM Education lesson plans that are focused on learning STEM content.* What should an iSTEM Education lesson plan look like? How do they ensure they are choosing lessons that would qualify as an iSTEM Education lesson? How do they determine what is quality iSTEM Education and what is not?
- h) *Teachers need help understanding why iSTEM Education is important and how it is beneficial to them and their students.* Why should they care about it and how is it going to affect their students in both the short term and the long term? What educational reforms have occurred that show that iSTEM Education is best practice?
- i) *Teachers need training in integrating subjects in a way that goes beyond surface level.* How do they integrate math in a way that explicitly teaches math content and not just as a tool to enhance another subject? What is the best method of integration for iSTEM Education? Is their only one way to integrate? How is integrating subjects going to help to ensure all teaching responsibilities (standards/objectives) are being met?
- j) *Teachers need access to iSTEM Education professional development that is accessible from urban and rural locations that can be experienced on their own time.* How can they access quality iSTEM Education

professional development when their buildings or districts don't have it as a focus? How do they bring iSTEM Education into their classroom when they don't have funding for materials and must use their own time and money to obtain resources and professional development?

It is clear that elementary teachers need access to specific elementary level iSTEM Education professional development and resources if they are to be expected to teach iSTEM Education effectively. It is my intent that the outcomes of this study and sample online professional development course will address this need. In the sections that follow, I describe how I have revised the design of the online professional development course to better meet the teacher needs identified in my study.

### **Revisions to the Online PD Course Design to Address Teachers' Needs**

The first goal for the final sample online professional development course design, the identification of common teacher difficulties and professional development needs, is to provide a model for others to build upon when working to provide the very best online professional development in iSTEM Education for elementary teachers as possible. All three contributions described above reflect what I learned about elementary teachers' classroom practice and conceptions of iSTEM Education. The Table 20 describes how the final revised sample professional development course addresses common teacher difficulties identified in the study.

Table 20  
*Teacher Difficulties Identified and Addressed in Course*

<b>Identified Common Teacher Difficulties</b>	<b>How Issue is Addressed in Sample Professional Development Course</b>
Teachers have general ideas regarding their role when teaching iSTEM Education, but these ideas are underdeveloped.	Teachers engage in discussion and view videos of iSTEM Education in action to get a more clear idea of the teacher and student roles in iSTEM Education.

Teachers struggle to decide what is or should be taught in iSTEM Education and get stuck on the subjects represented in the STEM acronym.	Teachers engage in multiple activities and discussions aimed at illustrating what should be taught within iSTEM Education, particularly a “STEM” acronym web search and discussion.
Teachers struggle with determining what iSTEM Education looks like at the elementary level.	Teachers view multiple videos, and lesson plans aimed at providing teachers with images of iSTEM Education and all are at the elementary level.
Teachers saw technology in iSTEM Education primarily as using electronic gadgets.	Teachers consider different ways technology can be integrated to not only enhance other subjects but to build technological skills specifically.
Teachers saw iSTEM Education as something targeted primarily for gifted students or those who were good at math.	Teachers engage in multiple videos, articles, activities, and discussions aimed at challenging this misconception and encouraging awareness.
Teachers struggled to define iSTEM Education beyond knowing the subjects represented in the STEM acronym.	Teachers examine, compare, contrast, and develop their own definitions of iSTEM Education based on the videos, articles, and discussions they hold in the course.
Teachers expressed their primary goal for iSTEM Education lessons was for problem-solving.	Teachers engage in logic problems with the intent to make their problem-solving strategies explicit and to identify the various types of problem-solving and how they work in engineering.
Teachers use iSTEM lessons as ‘ice breakers’ or for team building activities. Not focused on mastery of content or skills.	Teachers engage in lesson plan analysis tasks and activities for developing iSTEM lesson plans that have a purpose and are focused on content.
Teachers had some idea about what engineering is in general but lacked knowledge on what it would look like at the elementary level.	Teachers engage in an analysis of various engineering design cycles and investigate engineering units specifically for the elementary level.
Teachers struggled to understand the benefits of iSTEM Education beyond future job skills and behavior management.	Teachers engage in an activity where they are exposed to positive rationales for iSTEM Education and read documents that describe the benefits of iSTEM Education.
Teachers struggled with integrating subjects, particularly math, beyond surface level and nearly all expressed great desire to have professional development in integration.	Teachers engage in an entire module dedicated to integration methods of various subjects with videos, activities, and readings.
Teachers struggled to identify quality resources for teaching iSTEM Education lessons and depended on websites such as Pinterest and Teachers Pay Teachers.	Teachers critique lessons and units of iSTEM Education utilizing a provided assessment tool. Teachers also engage in activities, readings, and discussions on the topic.
Teachers struggled with the idea of creating their own iSTEM Education lesson plans but expressed the desire to learn.	Teachers create, with assistance, an iSTEM Education lesson plan on a topic of their choice as their final project.
Teachers struggled to find professional development in elementary iSTEM Education as their schools and/or districts did not have a STEM focus.	The course itself is an online course that would be made available, so many of these teachers in rural areas would have access to iSTEM Education professional development.

The outcome of the study described in chapter four of this dissertation in practice has provided an opportunity for me to critically examine the design for the sample online

professional development course through the use of an evaluative checklist. Sample questions from this evaluative checklist include “Do the activities I have chosen address the common teacher difficulties noted in my study” and “Does the overall design of the course reflect the unique professional development needs of elementary teachers as evidenced by my data?” Upon completing this evaluative checklist, I found areas for growth in my design, as well as areas that were executed well. See the completed evaluation checklist in the appendices of this dissertation in practice.

A description of the revisions to the original sample online professional development course design is included in the next section of this dissertation in practice as I became more aware, after analyzing my data, of the specific needs elementary teachers had regarding iSTEM Education professional development. A rationale for why the changes were made and how they will contribute to the overall effectiveness and/or applicability of the sample online professional development course is provided below.

Based on the results of the study described in chapter four of this dissertation in practice, revisions were made to the sample online professional development course. These revisions were made with the intent for the final product to be as relevant and beneficial to the elementary teachers for which it was created. These revisions were informed by the results of the previously mentioned study and address the most common identified difficulties elementary teachers have regarding iSTEM Education.

The first revision made to the course was a general reorganization and refocus of course modules. Based on the results of the study described in chapter four of this dissertation in practice, revisions were needed to the focus of each module. Originally there were modules dedicated to the history and policy and analysis of iSTEM Education.

While this is important information, based on the results of the study it was determined there were more important areas where teachers needed professional development. This module was basically scrapped, though some of the information and an activity was included in the “Why iSTEM Education” module. The original course also included a focus on 21<sup>st</sup>-century learners. This concept was blended into another module, therefore allowing an entire module to be dedicated to engineering. Modules that included information primarily on the Nature of STEM, STEM literacy, and the Next Generation Science Standards were condensed and blended into other modules to make room for modules on misconceptions of iSTEM Education and an entire module on analyzing iSTEM Education lessons and units. A restructuring of the order of modules was also completed to make the flow of the course more organized. A comparison of module topics from the original sample online professional development course and the final revised online professional development course is included in Table 21.

Table 21  
*Comparison of Original and Revised Course Module Topics*

<b>Original Course Modules</b>	<b>Revised Course Modules</b>
<b>Module #1:</b> <i>Overview and Class Introductions</i>	<b>Module #1:</b> <i>Overview and Class Introductions/What is iSTEM Education?</i>
<b>Module #2:</b> <i>History of iSTEM Education and Policy Analysis</i>	<b>Module #2:</b> <i>Why iSTEM Education?</i>
<b>Module #3:</b> <i>What is iSTEM Education?/Nature of STEM and STEM Literacy</i>	<b>Module #3:</b> <i>STEM Misconceptions and STEM for All</i>
<b>Module #4:</b> <i>Integration</i>	<b>Module #4:</b> <i>Integration</i>
<b>Module #5:</b> <i>Engineering and 21<sup>st</sup> Century Skills</i>	<b>Module #5:</b> <i>Engineering</i>
<b>Module #6:</b> <i>iSTEM Education and Standards</i>	<b>Module #6:</b> <i>iSTEM Education Unit Analysis</i>
<b>Module #7:</b> <i>Putting it All Together: iSTEM Education Lesson Planning</i>	<b>Module #7:</b> <i>Putting it All Together: iSTEM Education Lesson Planning</i>

After completing the general module revisions, a modification of each modules' content was then completed. A description of each module and its contents will be described in the paragraphs that follow.

*Module #1: Overview and Class Introductions/What is iSTEM Education?*

Teachers begin this module getting acquainted with the Blackboard site and their peers. After completing a few housekeeping tasks, teachers engage in content focused on the question "What is iSTEM Education?" In the original first module, no content was included. Teachers spent the entire first module doing tasks focused on getting acquainted and familiarizing themselves with the course management system. However, it was pointed out to me by a colleague that having no content during this first course module was similar to not teaching content during the first week of school. It was clear this adjustment needed to be made, so the revised course module includes both introductory information and tasks as well as content information and tasks. Teachers first complete a pre-test to measure where they are currently in their iSTEM Education knowledge. In the final module, teachers will take a post-test so a measurement of growth may be determined at the end of the course. Teachers then complete a few tasks such as reading the syllabus (if they hadn't already done so), creating their student profile, and introducing themselves on the course discussion board. In order to determine where teachers fell on the iSTEM Education experience continuum, teachers are asked to write a "STEM Autobiography" where they describe their experience so far in iSTEM Education. Teachers then engage in a search of definitions of STEM via the Google

search engine site and then analyze the definitions to find similarities and differences. Teachers then come up with their definition of iSTEM Education based on the evidence they found, the articles they read, and the discussions they engaged in with their peers. Teachers are then asked to find current events related to STEM in the news and engage in a discussion about how the media represents iSTEM Education and if they think it is an accurate representation or not. Teachers repeat their previous Google search except for this time they are looking for the variations of the STEM acronym. Teachers create a two-column chart that includes the acronym, the acronym's location, and the link to where they found the acronym in one column, and the meaning of the acronym in the other. Teachers then provide a summary and short reflection on their findings. Finally, teachers engage in a "What is iSTEM Education?" survey to evaluate their understanding of the course material. Teachers are assigned readings that are to be read prior to the next module and to engage in discussion questions on the discussion board.

### *Module #2: Why iSTEM Education?*

The content of this module was chosen based on the data that indicated the need for teachers to understand why iSTEM Education was important. Some teachers in the study had heard about iSTEM Education but were not concerned about it nor did they feel they needed to spend the time to learn about it. This module aimed to inform teachers of the need for iSTEM Education and the rationale for bringing it into their classroom. Teachers begin this module by doing a quick-write where they identify the reasons they currently feel iSTEM Education is important. Next, teachers engage in a "STEM Rationale" sort, where teachers examine and analyze iSTEM Education rationales that were both found in literature as well as actual rationales expressed by teachers in the

study described in chapter four of this dissertation in practice. Teachers sorted these rationales into whichever way they felt the rationales were best classified. Then, teachers discussed with their peers via the discussion board the way they sorted their rationales and who benefits within each rationale or category. Upon completing this task, teachers are asked to read and analyze a policy document that provides in-depth detail into the federal rationales for emphasizing iSTEM Education. Finally, teachers submit their first reflection paper over the material in this module. Teachers are assigned readings that are to be read prior to the next module and to engage in discussion question on the discussion board.

*Module #3: STEM Misconceptions and STEM for All*

The contents of this module was informed by the data illustrating the need for teachers to be able to identify lessons and units that promote the ideals of iSTEM Education and those that are “masked” as iSTEM Education lessons that lack content. Teachers begin this module with a quick survey where they determine if certain described activities would be considered representative of iSTEM Education or not. Upon completion, teachers read through a section of the module discussing the need to avoid the “STEM Dog and Pony Show.” In an attempt to bring a personal touch to the course, an example from a school where I previously had taught was used to illustrate what happened when teachers and administrators get stuck on the “look” of iSTEM Education and how the staff recognized the issue and made change. Teachers then take a bit of a turn in focus and choose one out of a selection of videos to view about women who went into STEM careers and the journey it took to get them there. The purpose of the rest of this module is to connect to the need expressed in the findings from the study described

in chapter four of this dissertation in practice, to make teachers aware of the diversity and equity issues in iSTEM Education. Teachers then read an anecdote from my teaching experience, again to try and add some personality to the course, about a time when I realized I had not been as culturally aware in my teaching as I should have been and how it inspired me to make change to be a more culturally responsive teacher. Teachers then read and respond to an article about equity in STEM and complete a quick survey over the material in the module. Then teachers make a practice posting on the course Wiki site to prepare them for the Wiki posting assignment that will be included in the next few modules. Finally, teachers are assigned readings that are to be read prior to the next module and to engage in discussion questions on the discussion board.

#### *Module #4: Integration*

The content of this module was chosen based on the data that indicated the need for teachers to learn how to integrate subjects and the different methods available to them to do so, specifically related to iSTEM Education. Teachers begin the module by viewing a video on STEM integration in K-12 education and then examine a few different methods of integration. A conversation on integrating math, with a video on math and science integration, is also included based on the data that revealed that math was an area teachers felt was the hardest to integrate. Teachers then complete a three column t-chart comparing the characteristics of engineering, math, and science. This activity asks them to think about characteristics of these three subjects and to compare areas that are different and those they may have in common. For example, a teacher might say that questioning is part of science and then realize that questioning is part of engineering and also part of mathematics. They would put questioning in all three columns, and at the

end, they would review their chart to find all the areas of overlap among the three subjects. Teachers then read about integrating science and math with other subjects and view a selection of videos. These videos touch on the need represented in the study outlined in chapter four of this dissertation in practice, for teachers to see images of integration and iSTEM Education in action. Teachers then choose a science lesson out of a selection provided to them and complete an article review where they specify the kind of integration being used and the subjects being integrated. Teachers then read and watch videos on integrating technology and engineering and the differences between science and engineering. Teachers then engage in a conversation via the discussion board regarding their thoughts about whether or not a lesson must include all of the subjects represented in the STEM acronym to be considered a STEM lesson. Teachers examine STEM lessons and use those lessons as justifications for the stances they take on the discussion board. This activity addresses the need expressed in the study described in chapter four of this dissertation in practice, for teachers to understand how integration might look with iSTEM Education. Teachers are then asked to engage in a video critique of me teaching an iSTEM Education lesson. Because I struggled to find a video of what I felt was a solid representation of iSTEM Education in action at the elementary level, I decided to use a non-perfect video of my own teaching and allow teachers to critique the areas they saw needed work. I thought this practice would be more beneficial as opposed to showing them one that was “perfect.” By asking teachers to think critically about what was going well in the lesson and what could be improved, I felt like it engaged teachers in a deeper level of thinking and possibly gave them an opportunity to experience transformative learning as far as what they understood iSTEM Education to “look” like

up to this point in the class. Next, teachers participate in a discussion about integrating literacy and make their first postings on the course Wiki of tradebooks they have found that could be used in teaching iSTEM Education. I provided a sample post to give them guidance and teachers will submit a new book to share every week for the next few modules. Finally, teachers are assigned readings that are to be read prior to the next module and to engage in discussion questions on the discussion board.

#### *Module #5: Engineering*

The contents of this module were informed by the data illustrating the need for teachers to have training in how engineering could look at the elementary level. This module began with a description of what engineering looks like within the Next Generation Science Standards. They are presented with the engineering design process shared in Appendix I of the Next Generation Science Standards and are then asked to conduct a Google and Google Image search of the engineering design process. Their task is to find two to three different representations of the engineering design process and then to critique each visual representation. Teachers are then asked to provide a statement regarding which representation they would commit to using or if they would use a new modified version they created themselves after their research. A summary of their rationale for choosing the design process they did was also assigned. Following this assignment is a short discussion and video on 21<sup>st</sup> Century Skills. Next, teachers engage in a conversation about the different types of problem-solving skills that people use when tackling a problem. These are the early skills required prior to engaging students in engineering design challenges. I chose to start with this concept as opposed to jumping right in to engineering design challenges because the data from the study described in

chapter four of this dissertation in practice revealed that elementary teachers felt intimidated by the thought of teaching engineering and I didn't want to overwhelm them, especially the teachers who fall in the "Beginner" range for the iSTEM Education experience continuum. Teachers are then asked to engage in a series of online logic problems and are instructed to write down the strategies they use when trying to solve the problem. Upon completion of the logic problems, teachers are asked to write an analysis and reflection of the experience, focusing on the problem-solving skills they used throughout the experience and how they could use these skills to incorporate engineering practices into their elementary classroom. Now that teachers have some background on basic problem-solving strategies, they are asked to investigate one iSTEM Education unit that is provided for them that integrates engineering through an engineering design challenge. Teachers then read through a description of the engineering practices from the Next Generation Science Standards to illustrate that engineering is so much more than just building things, as that was a common misconception that arose in the data from the study described in chapter four of this dissertation in practice. For the final engineering task, teachers engage in a survey called "Is it Engineering?" where they determine if described experiences are engineering or not. Finally, teachers are assigned their wiki posting and readings that are to be completed prior to the next module and to engage in discussion questions on the discussion board.

#### *Module #6: iSTEM Education Unit Analysis*

This module is part of a two-module series that aims to address the major need revealed by the study described in chapter four of this dissertation in practice. That need is to train teachers to create and modify iSTEM Education lesson plans. This first module

in the series is focused on getting teachers to analyze iSTEM Education units that are already created and practicing using a tool created to assess the quality of in iSTEM Education unit or lesson sequence. The first task for teachers asks them to think about the way they determine if a lesson is of quality. It can be on any subject, and they are asked to go beyond structure and formatting of the lesson. What do they require in a lesson before they allow it into their classroom? Teachers create a quick tool that they would use to evaluate a lesson using the criteria they require to have in a lesson. After submitting this tool, teachers read an anecdote from my personal teaching experience where I fell for a perceived “image” of iSTEM Education and the thought processes I went through before and after the lesson. Teachers are then given an assessment tool to use for assessing iSTEM Education units and are tasked with evaluating an iSTEM Education unit that is provided for them and to provide a justification of their evaluation. Teachers are then required to choose one of their own units and put it up against the evaluation tool to see areas where they could potentially enhance their unit to better reflect the characteristics of iSTEM Education. Teachers then engage in a brainstorming session for their final project, which is an iSTEM Education lesson (or lesson sequence). They may choose to work on the unit they analyzed in this module, or they may choose something different, but this is a chance for them to consider which of their units they want to start with in creating an iSTEM Education lesson or unit. Finally, teachers are assigned their wiki posting and readings that are to be completed prior to the next module and to engage in discussion questions on the discussion board.

*Module #7: Putting it All Together: iSTEM Education Lesson Planning*

This module is the second in a series targeted at helping teachers to develop their own iSTEM Education lesson plans. This module begins with an introduction to the 5E Learning Cycle. Resources are provided for teachers to explore including links to a further description as well as videos of elementary level 5E lessons in action. Next teachers engage in an exercise focused on conceptual storylines which ask teachers to analyze three separate lesson sequences. Teachers then discuss and view a video on assessment in iSTEM Education and look at the assessment strategies that tend to work well for assessing iSTEM Education lessons. Teachers are then introduced to the template they will be using for their final iSTEM Education lesson plan. This template is the skeleton of an iSTEM Education lesson that provides guidance in filling out each section. Questions for teachers to consider as they plan are included, and extra support is provided in the template (another chart included for those who need to have ideas broken down smaller to visualize) for those teachers who need additional assistance. There is no assigned readings or discussion for this module as teachers are given time to work on their iSTEM Education lesson plans.

*Module #8: iSTEM Education Integrated Lesson Plan*

During the final module of this online professional development course, teachers get the opportunity to post their iSTEM Education lesson plans to the discussion board for the purposes of receiving feedback from their peers on their work. Teachers post their lessons and then provide critical, constructive feedback on the lessons of their peers. Teachers then spend the majority of their time during this part of the module, making revisions to their lessons and getting them ready for final submission. Teachers complete a final reflection paper over their experience in the course and complete a post-test for the

purpose of aiding in determining their growth since the beginning of the online professional development course.

Upon completing this course, teachers are able to walk away with a sample iSTEM Education lesson plan they can use to help guide them in creating iSTEM Education lesson plans in their classroom. While this sample online professional development course will not produce teachers with mastery in iSTEM Education, it will produce teachers who are better informed and better prepared to tackle the challenge of bringing iSTEM Education to their students.

### **Resources for Supporting Elementary iSTEM Education PD**

The second goal for the final sample online professional development course design was to provide a package of resources used within the course. Such resources include activities, readings, and links to online resources. Activities and links are included to provide ideas on how to address specific concepts included in the final online professional development course. The resource package can be found in Appendix D of this dissertation in practice.

### **Contribution and Significance to Practitioner Community**

The target audiences for the practitioner product of this dissertation in practice, described above, are both elementary teachers and professional development designers. Elementary teachers will benefit from this work as it may enhance professional development experiences in iSTEM Education for elementary teachers by providing a more clear illustration of their unique needs when teaching STEM content. Professional development providers will benefit from this work as it will provide a starting point, or model, for addressing the unique professional needs of elementary educators as it is

grounded in literature and the study described in chapter four of this dissertation in practice. Both elementary teachers and professional development providers may benefit in the future from the exemplar lesson plans that will be produced by actual elementary teachers who take the course as they may be used as exemplar or sample lessons.

The major contribution to the practitioner community for this dissertation in practice is the final sample online professional development course that is grounded in the literature and reflects the findings of the study in chapter four of this dissertation in practice. This sample online professional development course may serve as a model for others who desire to provide elementary teachers with the specific and unique iSTEM Education professional development they need.

Beyond the scope of this dissertation in practice, there is potential for the University of Missouri's e-Learning program to house and implement the finalized version of the sample online professional development course to elementary teachers. This would be particularly beneficial to elementary teachers in the Columbia Public School District as they are allowed to take one course per year through e-Learning at no charge. By providing this sample online professional development course to e-Learning, the need for a no cost online professional development course in iSTEM Education specifically for elementary teachers not tied to a degree is met.

**APPENDIX A**  
**Survey Questions**

***Demographics***

Name:

Email:

Phone Number:

School/District:

Total years of Teaching Experience:

Grade Levels Taught:

1. Where would you place yourself on a STEM Education experience continuum (check one)

Beginner   Somewhat Experienced   Experienced   Somewhat Advanced   Advanced

2. Number of hours of PD completed in past 2 years (estimate) related to STEM:

3. How many of those hours were elementary-specific versus K12?

4. Overall, how would you rate your satisfaction with the **quality** of the STEM PD experiences you've participated in?

5. Overall, how would you rate your satisfaction with the **availability** of STEM PD experiences for you to attend?

6. Which of the following best describes the lesson you are submitting (Check one):

I created this lesson myself

I adapted this lesson from other resources to fit my needs

I was provided this lesson by my school or district

Other (please explain in text box below)

7. Is the lesson you are submitting a lesson required by your school or district (check one)?

Yes

No

8. Have you taught this lesson before?

Yes

No

## APPENDIX B

### Semi-Structured Interview Protocol

*Questions for interview appear below. Main question from Survey appears first in bold and interview questions to follow up appear in normal text. Italicized text includes the researcher's purpose in asking each probing question.*

**1. What does STEM education mean to you?** *(How do they define STEM?)*

In your survey, you said \_\_\_\_\_. Tell me more about that.

What does the 'T' mean? *(Do they view this as instructional technology?)*

What is engineering, and how is it different than science? *(Do they have a basic understanding of engineering practices? Do they see a difference between science and engineering?)*

**2. Why is it important for students to learn STEM?** *(How much do they value STEM Education?)*

In your survey, you said \_\_\_\_\_. Tell me more about that.

Are some students more successful in STEM than others? Explain why you think so. *(Do they think STEM Ed is only for the gifted?)*

Can you give me an example of this in your own classroom? *(Are all students capable of being successful in STEM or only certain students with specific abilities?)*

**3. If I walked into your classroom, and you were teaching a "STEM" lesson, what would I see?**

You described a lesson in which \_\_\_\_\_. What makes this a "STEM" lesson? *(How does the lesson they described fit with their understanding of STEM?)*

What would you be doing? What would students be doing? *(How is what they are doing different than traditional methods?)*

What are your goals for students in this, or other STEM lessons? *(Do they have independent objectives for each discipline or one overarching goal? Content objectives? Skills?)*

How do you integrate S, T, E, and M together? *(Is it surface-level or in-depth integration? Is one particular discipline foregrounded?)*

Would the lesson include more than just S, T, E, and M? Explain. *(Do all areas have to be included in the same lesson?)*

**4. What kinds of instructional resources do you use when planning your iSTEM lessons?**

In the survey, you mentioned your lesson came from \_\_\_\_\_. Tell me more about that resource.

Are you required to use this resource *(District mandated curriculum?)*

What support systems do you have available to you when planning these lessons? *(STEM Specialist in building, colleague collaboration, professional learning communities, etc.)*

How do you typically structure your iSTEM lessons? (*Do they use 5E, how long do they typically last, etc.*).

**5. What kinds of professional development have you had related to STEM?**

In the survey you mentioned \_\_\_\_\_. Tell me more about that.

In the survey, you mentioned your pd experiences were/were not specific to elementary teachers. Can you describe their focus (*middle secondary, content, etc.*)?

What kinds of things did you do? (*Discipline specific or STEM?*)

What have you implemented in your classroom as a result? (*Did the pd enact change in their teaching?*)

Was this required, or optional to attend? How did you hear about these opportunities? (*Did they seek out opportunities for pd or were they participating due to obligation?*)

Are there other things you're doing outside of workshops, such as collaborating with others in your school? (*Do they depend solely on professional development workshops/programs or do they utilize collaboration with others, readings, etc.?*)

**6. Did you find these professional development experiences beneficial? Why or why not?**

In the survey you mentioned these professional development experiences were/were not beneficial. Tell me more about that.

You also mentioned in the survey that you could use more professional development in \_\_\_\_\_. Can you tell me more about that? (*What areas do they feel weak, what specific aspects of STEM Education do they desire more training in?*)

Do you think this need is specific to you or do you think it would apply to other elementary teachers? Can you explain why you think this? (*Is this an issue specialized to this individual or is it more broad, such as bad school situation vs. typical methods of teacher training issues?*)

**APPENDIX C**  
**Course Evaluation Checklist**

**1. Do the activities I have chosen address the common teacher difficulties noted in my study?**

Check one: Yes  No  Somewhat

**Strengths:**

All of the identified common teacher difficulties were addressed in some way in the sample online professional development course.

**Weaknesses:**

While all identified common teacher difficulties were addressed in the online sample professional development course, some were not addressed to the depth that would be most beneficial to the teacher due to time limitations. An eight week course will not allow for mastery of all concepts delivered.

**Suggested revisions/actions:**

Revisions could include extending the length of the course so more concepts could be covered or concepts currently included could be covered more in depth. Another option would be to have a series of these methods courses. This course would be the foundational course and then the next course could go more in depth into some of the concepts that were only touched in this course.

**2. Are the activities I have chosen appropriate in addressing teacher difficulties for all levels on the experience and knowledge of iSTEM Education continuum?**

Check one: Yes  No  Somewhat

**Strengths:**

Each activity is designed to allow for varying levels of ability. Regardless of where a teacher is in their knowledge, they will have the opportunity to learn something. Each teacher will vary in their growth and will reach different levels of understanding but that is to be expected.

**Weaknesses:**

There is a lot to this course and it could be very demanding for some teachers, especially the ones at the very beginning side of the iSTEM Education continuum.

**Suggested revisions/actions:**

As the instructor I will need to be cognizant of students who are beginners so I may offer extra assistance. Possibly providing additional office hours or providing extensions to due dates for these students would be helpful. I will need to have extra activities and resources to provide students who are struggling more than others as well as students who need to be challenged more.

**3. Do learning activities provide opportunities for participants to experience transformative learning?**

Check one: Yes \_\_\_\_\_ No \_\_\_\_\_ Somewhat X \_\_\_\_\_

**Strengths:**

Modules are all designed to encourage transformative learning.

**Weaknesses:**

Not all activities included in the course are activities that would promote transformative learning.

**Suggested revisions/actions:**

Replacing some of the activities that do not do a good job promoting transformative learning would be a good revision. While the modules all together provide for transformative learning opportunities, individual activities could be evaluated and revised to do a better job of this.

**4. Does the overall design of the course reflect the unique professional development needs of elementary teachers as evidenced by my data?**

Check one: Yes X \_\_\_\_\_ No \_\_\_\_\_ Somewhat \_\_\_\_\_

**Strengths:**

Teachers everywhere will have access as it is designed to be a 100% online course. Teachers in rural areas will be able to get professional development in something they may not otherwise be able.

**Weaknesses:**

There are still gray areas in some of the content in the course (foundational definition of iSTEM Education and integration) that causes confusion.

**Suggested revisions/actions:**

Continued research into these two areas will be vital so changes can be made in the course to reflect the current research in those areas.

**5. Do the revisions to the sample online professional development course reflect the findings of my study?**

Check one: Yes\_\_\_\_\_ No\_\_\_\_\_ Somewhat\_\_\_\_\_

**Strengths:**

Each module and activity was designed with the results from the study in mind. An overhaul of the original course took place as I determined teachers needed different things than what had originally been put in place. I believe it definitely reflects the findings of my study.

**Weaknesses:**

While I feel the revisions reflect the findings of my study as far as what teachers need, it is unclear as to how effective some of the activities are as I haven't gotten to test them out yet. I feel like they are all great but one wouldn't know until they try them to know for sure.

**Suggested revisions/actions:**

It would be nice to have a test run of the course so I could make revisions based on the feedback I received. That way the course would be set up to run more smoothly.

**Comments:**

Overall, I think the course design is reflective of the results from my study. However, I recognize that it is not perfect. It will need continuous revision as iSTEM Education research continues. It is my intent to keep it updated and to continue to make it better as more information and ideas are revealed.

## Appendix D Resource Package

### Module #1: Overview, Class Introductions, and What is STEM?

#### Assignments-

- ✚ Pre-Test
- ✚ STEM Education Autobiography
- ✚ Defining STEM Google Search
- ✚ STEM in the News
- ✚ STEM Acronym Google Search 2 Column Chart
- ✚ What is iSTEM Education Survey

#### Readings-

- ✚ Brown, R., Brown, J., Reardon, K., & Merrill, C. (2011). Understanding STEM: Current Perceptions. *Technology and Engineering Teacher*, 70(6), 5-9.
- ✚ Bybee, R. W. (2010). Advancing STEM Education: A 2020 Vision. *Technology and Engineering Teacher*, 70(1), 30-35.

#### Discussion Questions-

- ✚ *If you were asked to provide your own definition of iSTEM Education, what would your answer be? In your post, provide YOUR definition of iSTEM Education and provide justification as to why you feel your definition is accurate.*
- ✚ *How do you feel STEM Education is being portrayed in the media and/or society? You have looked through various articles but what about television or the radio? After researching and experiencing this course module, do you think that representation is accurate? Why or why not?*

### Module #2: Why iSTEM Education

#### Assignments-

- ✚ Why is iSTEM Education Important Quickwrite
- ✚ STEM Rationale Card Sort
- ✚ STEM Rationale Discussion Board Post
- ✚ Policy Analysis- Rising Above the Gathering Storm Reading and Analysis
- ✚ Reflection Paper #1

#### Links-

- ✚ Video #1: ASEE- STEM Education Legislation History  
[https://www.youtube.com/watch?v=ielbwZ\\_Xvbw](https://www.youtube.com/watch?v=ielbwZ_Xvbw)
- ✚ Video #2: Congressman Chris Collins (New York)  
<https://www.youtube.com/watch?v=arpWhcqagWQ>
- ✚ Video #3: Congresswoman Elizabeth Esty (Connecticut)  
<https://www.youtube.com/watch?v=arpWhcqagWQ>
- ✚ Video #4: Congressman Lamar Smith (Texas)  
<https://www.youtube.com/watch?v=5bQHBYBkrSfo>
- ✚ Video #5: Congressman Joe Courtney (Connecticut)  
<https://www.c-span.org/video/?c4543404/rep-joe-courtney-stem-education-amendment-esea>

- ✚ Video #6: [Congressman Joe Kennedy \(Massachusetts\)](https://www.youtube.com/watch?v=WHciC96IGP0)  
<https://www.youtube.com/watch?v=WHciC96IGP0>

#### Readings-

- ✚ Sanders, M. E. (2008). Stem, stem education, stemmania.
- ✚ Gay, G. (2002). Preparing for culturally responsive teaching. *Journal of teacher education*, 53(2), 106-116.

#### Discussion Questions-

- ✚ Consider what you have learned so far about iSTEM Education. If someone asked you the question “Why iSTEM Education? Is it worth the trouble?” what would you say? I want you to think about how you would vocalize what you have learned and what you presently think in a way that you could explain it relatively quickly (like in an elevator conversation). What would you say?
- ✚ Consider the readings you were to have read prior to this module. How do Brown, et al. (2011) and Bybee (2010) define iSTEM Education and what rationales do they give for emphasizing iSTEM Education? Are their definitions and rationales similar or different to the ones you found in the policy document you read for Exercise 2D? How?

### **Module #3: STEM Misconceptions and STEM For All**

#### Assignments-

- ✚ Is it STEM? Survey
- ✚ ISE for All Videos
- ✚ Diversity in STEM Videos
- ✚ Equity in STEM Education Article Response
- ✚ Module #3 Survey
- ✚ Class Wiki Post

#### Links-

- ✚ Video #1- Dr. Ronie Ellington- The Future of STEM Education  
<http://youtu.be/7Hb0vkdzaWg>
- ✚ Video #2- Dr. Maggie Pocock- STEM for ALL  
<http://youtu.be/wvBdCjUGKP0>
- ✚ Video #3- The Future of STEM Depends on Diversity  
<https://youtu.be/-v8aDo4dV3Q>
- ✚ Video #4- Girls in STEM: A New Generation of Women in Science  
[https://youtu.be/Q\\_11rwb4vEc](https://youtu.be/Q_11rwb4vEc)
- ✚ Video #5- Change the Numbers: Equity, Diversity, and Inclusivity in STEM  
<https://youtu.be/63xTTYWEQ8>

#### Exercise Readings-

- ✚ Toglia, T. V. (2013). Gender equity issues in CTE and STEM education. *Tech Directions*, 72(7), 14.
- ✚ Dentith, A. (2008). Smart girls, hard-working girls but not yet self-assured girls: The limits of gender equity politics. *Canadian Journal of Education*, 31(1), 145.

#### Readings-

- ✚ Davison, D. M., Miller, K. W., & Metheny, D. L. (1995). What does integration of science and mathematics really mean?. *School Science and Mathematics*, 95(5), 226-230.

- ✚ Spires, H. A., Kerkhoff, S. N., & Graham, A. C. (2016). Disciplinary literacy and inquiry: Teaching for deeper content learning. *Journal of Adolescent & Adult Literacy*, 60(2), 151-161.

#### Discussion Questions-

- ✚ *In what ways do you feel you are a Culturally Responsive Teacher? In what ways do you feel like you can improve? Are there any areas you desire to improve regarding culturally responsive teaching or diversity and equity in iSTEM Education?*
- ✚ *What were your thoughts regarding the description of the elementary STEM school and the examples I shared. Were there any areas where you thought you saw iSTEM Education but perhaps it was incomplete? Was there anything you connected with or felt was especially interesting? Share your thoughts.*

### Module #4: Integration

#### Assignments-

- ✚ STEM Integration in K-12 Education Video
- ✚ What is engineering? Math? Science? 3 Column T-Chart
- ✚ Integrating Science Article Review
- ✚ Exercise 4D- Methods of Integration Comparison Discussion Post
- ✚ Critique images of STEM Education- Arnone Teaching Parachutes Video and Paper
- ✚ Wiki Posting

#### Links-

- ✚ Video #1- STEM Integration in K-12 Education  
<http://youtu.be/AIPJ48simtE>
- ✚ Video #2- Maths and Science Integration  
<https://www.youtube.com/watch?v=VDKDOILGvYU&feature=youtu.be&list=P LzBQynYYTjJMkObZON5LPP9vL0b-mW6-M>
- ✚ Video #3- Connecting Other Subjects to Inquiry  
<http://www.learner.org/workshops/inquiry/videos.html>
- ✚ Video #4- Animal Patterns: Integrating Science, Math, and Art  
<https://www.teachingchannel.org/videos/teaching-patterns>
- ✚ Video #5- Annenberg Learner  
<http://www.learner.org/workshops/lala/workshop7.html>
- ✚ Video #6- The Difference Between Science and Engineering  
<http://www.eie.org/eie-curriculum/resources/difference-between-science-and-engineering>
- ✚ Video #7- What the Research Says  
<http://www.eie.org/eie-curriculum/resources/what-research-says>
- ✚ STEMPact Lesson Plans  
<http://stempact.org/For-Educators/Resource-Library/Lessons-k5>
- ✚ Video #8- Critique Images of STEM  
[https://youtu.be/b\\_ILPYX3TTw](https://youtu.be/b_ILPYX3TTw)

#### Exercise Readings-

- ✚ Moss, Barbara. (2005). *Making a case and a place for effective content area literacy instruction in the elementary grades.*

<http://teachersites.schoolworld.com/webpages/dspucci/files/expository%20text1.pdf>

#### Readings-

- ✚ Kirkley, J. (2003). Principles for teaching problem solving. *USA: PLATO Learning Inc.*
- ✚ Moore, T. J., Glancy, A. W., Tank, K. M., Kersten, J. A., Smith, K. A., & Stohlmann, M. S. (2014). A framework for quality K-12 engineering education: Research and development. *Journal of Pre-College Engineering Education Research (J-PEER)*, 4(1), 2.

#### Discussion Questions-

- ✚ Which integrative method presented in this module would you consider the best suited for teaching iSTEM Education? Why? Are there any you feel would be a poor choice for teaching iSTEM Education? Why? Which method would you say was most prevalent in the STEMPact lessons from Exercise 4D you investigated? What are your thoughts on integration in iSTEM Education at this point?
- ✚ Share a condensed version of your video critique from this module with your peers (as a post not an attachment) and share your thoughts on the critiques of others

### **Module #5: Engineering**

#### Assignments-

- ✚ Engineering Design Process Analysis
- ✚ Logic Problems
- ✚ Logic Problem Analysis and Reflection
- ✚ Investigate at least ONE PictureSTEM unit overview
- ✚ Is it Engineering?
- ✚ Wiki Posting

#### Links-

- ✚ Next Generation Science Standards-Appendix I  
[http://www.nextgenscience.org/sites/ngss/files/Appendix%20I%20-%20Engineering%20Design%20in%20NGSS%20-%20FINAL\\_V2.pdf](http://www.nextgenscience.org/sites/ngss/files/Appendix%20I%20-%20Engineering%20Design%20in%20NGSS%20-%20FINAL_V2.pdf)
- ✚ Video #1- STEM Education: Developing 21<sup>st</sup> Century Problem Solvers  
<http://youtu.be/Xi2Qm87kC7o>
- ✚ The Three Jugs Problem  
<http://www.cut-the-knot.org/water.shtml>
- ✚ Tower of Hanoi  
<https://www.mathsisfun.com/games/towerofhanoi.html>
- ✚ Entrapment  
<http://www.theproblemsite.com/games/entrapment.asp>
- ✚ Trio Match  
[http://www.theproblemsite.com/games/trio\\_match.asp](http://www.theproblemsite.com/games/trio_match.asp)
- ✚ Cheater Hangman  
[http://www.theproblemsite.com/games/hangmanvariation.asp#.U\\_n1t2PQBCU](http://www.theproblemsite.com/games/hangmanvariation.asp#.U_n1t2PQBCU)
- ✚ Wolf, Sheep, & Cabbage  
<http://www.novelgames.com/flashgames/game.php?id=53&l=e>

- ✚ PictureSTEM Website  
<http://picturestem.org/>

#### Readings-

- ✚ Augustine, N. R., Barrett, C., Cassell, G., Grasmick, N., Holliday, C., & Jackson, S. A. (2010). Rising above the gathering storm, revisited: Rapidly approaching category 5. *Washington, DC: National Academy of Sciences, National Academy of Engineering, Institute of Medicine.*
- ✚ International Technology Education Association. (2009). The overlooked STEM imperatives: Technology and engineering.

#### Discussion Questions-

- ✚ *One of the objections to integrating engineering is that it leaves less time for science and math, which some people contend as more fundamental fields of study. Do you agree with this position? Why or why not?*
- ✚ *How do you think using the process we used with the logic problems would help to develop your students' problem solving strategies and prepare them for engineering design challenges?*

### **Module #6: iSTEM Education Unit Analysis**

#### Assignments-

- ✚ Lesson Plan Analysis Tool
- ✚ iSTEM Education Unit Analysis Assessment
- ✚ iSTEM Education Unit Analysis Assessment Justification
- ✚ iSTEM Education Chosen Unit Analysis Assessment and Justification
- ✚ iSTEM Education Lesson Plan Brainstorming
- ✚ Final Wiki Posting

#### Readings-

- ✚ Bybee, R. (2014). The BSCS 5E Instructional Model: Personal Reflections and Contemporary Implications. *Science and Children*, April, 10-13.
- ✚ National Education Association. (2010). Preparing 21st Century students for a global society. *National Education Association.*

#### Discussion Questions-

- ✚ *As you start brainstorming possible topics for your final project, what topics are you considering? What subjects are you thinking about integrating? Are there any areas where you are having difficulty? Post your idea and ask any questions you may have as your peers may be able to help.*
- ✚ *After working through the curriculum analysis task, what would you consider to be teacher supports that would be critical to be included in any elementary iSTEM Education curriculum? What elements would you like to see included that would make you feel more confident in teaching iSTEM Education? What kind of outside supports do you think you need to be successful?*

### **Module #7: Putting It All Together**

#### Assignments-

- ✚ Read and Explore Material on the 5E Learning Cycle
- ✚ Conceptual Storyline Task
- ✚ Watch and take notes on “STEM Education- Planning and Assessing.”

#### Links-

- ✚ NASA 5E Learning Cycle Overview  
<http://www.nasa.gov/audience/foreducators/nasaclips/5eteachingmodels/>
- ✚ 5E Instructional Model: BSCS  
<https://bscs.org/bscs-5e-instructional-model>
- ✚ Video #1- Exploring the Space That Air Takes Up-1<sup>st</sup> Grade 5E Lesson  
<https://www.teachingchannel.org/videos/first-grade-science>
- ✚ Video #2- Conservation of Mass in Matter-5<sup>th</sup> Grade 5E Lesson  
[https://www.youtube.com/watch?v=OaCNJ\\_5inBY&feature=youtu.be](https://www.youtube.com/watch?v=OaCNJ_5inBY&feature=youtu.be)
- ✚ Video #3- STEM Education- Planning and Assessing  
<https://www.youtube.com/watch?v=84D5yLu3Wh0&feature=youtu.be>

#### **Module #8: Integrated Lesson Plan**

##### Assignments-

- ✚ Post Integrated ISE Lesson Plan with Summary on the Discussion Board.
- ✚ Provide Critical Feedback on at least one ISE Lesson
- ✚ Post-Test

##### Discussion Questions-

- ✚ *Post your Final ISE Lesson Plan Rough draft to the discussion board with a summary/description of the lesson and any questions you would like to ask your peers regarding improvements.*
- ✚ *Read and provide constructive feedback to at least one peer by replying to their posting of their Final ISE Lesson Plan.*

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## VITA

Kathryn “Annie” Arnone was born in Columbia, Missouri, on April 8<sup>th</sup>, 1985. After graduating from Fulton Public High School in Fulton, Missouri in 2003, Kathryn attended the University of Missouri in Columbia, Missouri. Between 2003 and 2007, Kathryn studied elementary education, receiving a Bachelor’s degree in Elementary Education with a minor in Design and Technical Theater. In 2008, Kathryn was accepted into the University of Missouri’s Fellows program where she completed her Master’s degree in Curriculum and Instruction and her first year of teaching at Robert E. Lee Expressive Arts Elementary School at the same time. Upon graduation, Kathryn was hired as a classroom teacher for the Columbia Public School district where she taught third grade at Robert E. Lee Expressive Arts elementary school, first grade at Mary Paxton Keeley elementary school, and fifth grade at Thomas Hart Benton STEM elementary school. While teaching fifth grade in 2011, Kathryn was accepted as a fellow in the NASA Endeavor STEM Project, where she received a graduate certificate in STEM Education from Columbia Teacher’s College. In 2012, Kathryn left the classroom and began her doctoral studies, completing a graduate certificate in Online Education in 2014 and her Doctor of Education degree in 2017 in Learning, Teaching, and Curriculum with an emphasis in Elementary STEM Education.