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An Analysis of Secondary Integrated STEM Lesson Plans: Common Characteristics, Learning Expectations and the Impact from the Teacher's Definition of I-STEM

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An Analysis of Secondary Integrated STEM Lesson Plans:
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and the Impact from the Teacher's Definition of I-STEM

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by

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Abstract

This qualitative study investigated teachers' understanding of their definition of I-STEM (Integrated STEM education), how those understandings manifested into lessons and associated lesson artifacts, how they assessed students in such lessons, and what factors or rationales supported their ability to conduct or not conduct I-STEM lessons. A survey was sent to the members of four professional organizations representing I-STEM disciplines to solicit their participation in this project. Ten teachers ranging from grades 9-12 participated in this study. Of those who responded, six teachers identified with National Science Teachers Association (NSTA), three teachers selected International Technology and Engineering Education Association (ITEEA), and one teacher claimed International STEM Education Association (ISEA). No teachers identified with National Council of Teachers of Mathematics. In addition to surveys, data were collected using interviews, email responses, and a review of lesson artifacts.

Three distinct factors emerged from this study. First, there was a lack of consistency among I-STEM disciplines, then, assessments of students was predominately focused on soft-skills, and finally, several participants shared three characteristics that seemed to define experiences for conducting what they believed were I-STEM lessons. Additionally teachers emphasized factors effecting implementation of I-STEM describing rationales enabling participants' to implement I-STEM lessons. Responses provided insight and revealed how teachers understood I-STEM definition, how they interpreted integration of the disciplines, and "why" they conducted I-STEM lessons. The majority of participants implemented I-STEM in the absence of an official school/district definition.

Assessments provided interesting results in this study. The majority of participants

identified expected outcomes or products based on their I-STEM definition and in their responses. However, the rubrics submitted measured or awarded points to various soft skills, such as teamwork and communication abilities. Participants discussed the implementation of I-STEM skills and knowledge, however, of the submitted rubrics, only a very criteria were presented that actually awarded points to students based on their understanding or growing in I-STEM knowledge or skills. Most points or grades were awarded based on the students' abilities to communicate either in a presentation or paper. Few points were awarded to the process of I-STEM or to the constructed products.

Acknowledgements

Several people made this process and completion of the dissertation possible. First, I would like to thank Dr. Stephen Burgin, committee chair, for agreeing to take on this responsibility, for providing time, feedback, and support. Your guidance throughout this process has been invaluable and has helped me grow as an educator. I look forward to our continued I-STEM conversations.

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May the Force be with you all. Always.

Dedication

Michelle Owens Hayward, I dedicate this edition of my dissertation to you. You are the only person, who truly understands my personal goals, my passion for education, and most importantly me. You are my love, my life. I fail to find words that grasp how truly grateful I am to you as you have supported me through this process and have ensured that I finish it.

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Introduction

For some time conversations about Science, Technology, Engineering, and Mathematics (STEM) shaped how several schools consider STEM as learning experiences (Lynch, Peters-Burton, & Ford, 2015) and their efforts to increase the number of students in the STEM fields (www.usnews.com/news/stem-index). The sense of urgency for U.S. schools to produce more students prepared to enter STEM related careers and fields have been addressed at both the national (www.whitehouse.gov, 2014; National Research Council, 2014; NRC, 2011) and state levels (National Governors Association, 2007). These conversations have caused some districts to redesign or even open new schools labeled as "STEM schools" (NRC, 2011; Researchers without Boarders, 2013).

As schools transform to or open as "STEM schools", the question arises as to what exactly STEM means. Currently, various understandings of STEM have established three models; selective, inclusive, and career and technical pathways (NRC, 2011) and are categorized depending on intent or focus of the school. A ranking system is already in place for STEM schools to be considered in the Top 500 schools based on students' Advance Placement math and science scores. These are described in the *US News and World Report* rankings (http://www.usnews.com/education/best-high-schools/national-rankings/stem). However, one has to question if Advance Placement scores are sufficient enough criteria to determine the "top" rankings for STEM programs, particularly if one is interested in the nature of instruction in those schools.

Statement of the Problem

STEM could be represented or interpreted in a variety of ways, particularly in the design of lessons, depending on a school or teacher's interpretation of the concept (NRC, 2009). What contributed to this situation was currently no agreed upon model of or definition for a STEM school (NRC, 2011), no agreed upon definition of STEM itself (Bybee, 2010), or even a clear definition for integrated STEM (called here I-STEM) (NRC, 2014). I-STEM was one of the ways frequently recommended to engage students in STEM learning. So, one of the challenges had been a broad interpretation of what STEM means and in what optimal ways a STEM school might operate from a curriculum perspective.

Some used the term STEM when referring to instruction involving any or all of the four STEM elements including, but not demanding formal integration of all four elements (Barakos, Lujan, & Strang, 2012). Heil, Pearson, and Burger, (2013) used the phrase "iSTEM" to represent lessons that were integrated with some or all of the STEM components and thus assisting students in making connections between the disciplines to enhance the learning experience (NAE & NRC, 2014; Heil, et al., 2013). The National Research Council (2014) expressed similar interpretations when they discussed the definition of integrated STEM. They wrote,

> Developing a precise definition of integrated STEM education proved to be a challenge for the committee because of the multiple ways such integration can occur. It may include different combinations of the STEM disciplines, emphasize one discipline more than another, be presented in a formal or informal setting, and involve a range of pedagogical strategies. For example, one model suggests that "integrative" STEM education must include technological or engineering design as a basis for creating connections to concepts and practices from mathematics or science or both . . . [T]he term *integrated* is used loosely and is typically not carefully distinguished from related terms such as *connected, unified*, *interdisciplinary*, *multidisciplinary*, *cross-disciplinary*, or *transdisciplinary*. Defining integrated STEM education is further complicated by the fact that connections can be reflected at more than one level at the same time: in the student's thinking or behavior, in the teacher's instruction, in the curriculum,

> between and among teachers themselves, or in larger units of the education system, such as the organization of an entire school (p.23).

Researchers, such as Nathan, Srisurichan, Walkington, Wolfgram, Williams, and Alibali (2013) found in their research positive outcomes in student learning from lessons involving STEM, such as transferring of knowledge, the linking of concepts across disciplines, and the promotion of collaboration and discussion with students. However, this team also reported that such effects on learning were “uneven” (p. 82) and inconsistent in the “high quality implementation” (p. 82) of STEM lessons. Therefore, according to Nathan, et. al, (2013), it appeared lesson-designing impacted the effectiveness of a student’s learning and outcomes. This raised some important points that I believed needed to researched, such as determining if there were patterns or shared characteristics of an integrated STEM lesson based on a teacher’s understanding of integrated STEM education, or if the teacher’s concept of integrated STEM influenced how information could be presented or how activities are conducted, or how teachers assessed their lesson outcomes as a result of their understanding of integrated STEM.

Despite not having an agreed upon a definition, schools were continuing with various opportunities for STEM education (Lynch, et al., 2015), integrated or otherwise. Time and research had been dedicated to identifying types of STEM schools (NRC, 2011; NRC, 2012), along with identifying characteristics associated with STEM schools (Researchers without Boarders, 2013). However, characteristics of integrated STEM lessons remained unclear. This question about the nature of integration had been the impetus for study reported here. How do teachers’ interpretations of integrated STEM become represented in actual lessons?

Purpose of the Study with Conceptual Framework

The purpose of this study was to gain a better understanding of how secondary (Grades 9-12) teachers’ 1) defined integrated STEM as an instructional perspective 2) perceived and/or understood how integrated STEM influenced components of an integrated STEM lesson, such as lesson plans, notes, handouts, Powerpoints, and videos; 3) reacted to I-STEM as it influences assessment design, and 4) determined what factors were addressed in their implementing an I-STEM lesson/activity.

Part 1 of the *Purpose* was designed to better understanding how teachers were defining and describing the concept of integrated STEM and that hoped to shed light on what influences impacted a teacher’s perception or definition of I-STEM, such as a school or district definition or if teachers were developing their own definitions.

Part 2 of the *Purpose* was an investigation of teachers’ perceptions about their understanding or definition of integrated STEM and how it was expressed throughout the I-STEM lesson/activity, like exploring what components were found in I-STEM lessons or activities. From the materials provided by the subjects, artifacts, responses and interviews were analyzed to determine if there are patterns or categories consistent amongst by the materials provided. Each artifact and statement made provided by the participant was assessed to determine how the teacher’s understanding of I-STEM manifested itself within the lesson planning, presentation, definition, and student handouts.

Part 3 of the *Purpose* targeted how students were assessed and/or how students were expected to demonstrate their understanding of expected outcomes based on the provided artifacts. Student work was not expected to be part of the artifacts submitted. Part 4 of the *Purpose* sought to better understand why a teacher may or may not conducted an I-STEM lesson by examining responses to determine any particular reason or reasons.

Theoretical Framework

I-STEM is still an emerging concept being implemented in schools and the classrooms, so there “is not single theoretical framework” (Lynch, Behrend, Burton, & Means, 2013, p. 4) that describes the impact or effectiveness of integration in a STEM setting. However, there are some concepts that are being employed within these experiences that are applicable to I-STEM that can establish a possible framework for such conversations.

Experiential and Situational Learning. Many researchers argued that experiential learning was essential to an integrated STEM lesson (Nathan, et al, 2013; Kolodner, Camp, Crismond, Fasse, Gray, Holbrook, Puntambekar, & Ryan, 2003; Mehalik, Doppelt, & Schunn, 2008; Fortus, Dershimer, Krajcik, Mars, & Mamlok-Naaman, 2004). Gilmore (2013) believed this improved STEM education and was the key to its success. She wrote, “Experiential Learning is the process of making meaning from direct experiences. Direct experiences include hands-on projects in which students are able to apply science, technology, engineering and mathematical skills to real life situations. Students are learning beyond core subjects when engaged in hands-on STEM experiential learning” (p. 1).

Coupled with experiential learning were two types of situational learning theories: Situated Learning (Lave & Wenger, 1991) and Situational Context Learning (SCL) (Bell, et al., 2013). Situated Learning had at its center a concept called “legitimate peripheral participation” (p. 29) where the learner became an active and full participant in one’s current setting. Similar to Lave and Wenger’s (1991) theory, the SLC also required a participation in the setting he or she belonged. Bell et. al., (2013), citing much of McLellan’s work (1996), claimed, “learning cannot be achieved or looked at separately from the context in which it occurs” (p. 350). Both resources illustrated the importance of emerging the participant within the setting in order to impact the learner.

Designing Lessons. How a teacher designed a lesson influenced the impact or effectiveness of expected learning outcomes and the experiences had by participating students (Wiggins & McTighe, 2005). Roehrig, Wang, Moore, and Park (2012) conducted a study where they understood integrated STEM as one of two models, content integration and context integration. For them, content integration focused on the "merging of content fields into a singular…activity or unit" (p. 35), while context integration focused on the "content of one discipline and [used] contexts from [other disciplines] to make the content more relevant" (p. 35). In their study they found "four structural approaches to planning for integrated STEM" (p. 37): Co-teaching, team teaching, team planning but individual implementation, and individual planning and implementation. Understanding various implementations occurred in instructional strategies, such as co-teaching, team teaching or individually taught, the planning of such a lesson was a deliberate process to ensure the lesson objectives align with activities and outcomes (Wiggins & McTighe, 2005).

To achieve true integration (Schmoker, 2011; Wiggins & McTyghe, 2005), teachers could use a popular method known as the "backwards design" (Wiggins & McTyghe, 2005, p. 3). This process guided a teacher to work through the three different stages of 1) identifying desired results, 2) determining the assessments and the evidence that is acceptable from the assessments, and 3) planning the instruction so students can have deliberate learning experiences.

While some teachers may prefer to develop integrated STEM lessons/activities on their own, commercially produced integrated STEM lessons for schools and teachers were available. Carter (2013) analyzed eleven commercially produced STEM curricula, including *The Infinity Project*, *Project Lead the Way*, and *Math Trailblazers*. His study concluded these commercially produced STEM curricula were not truly integrated. I wondered if they were perceived as appropriately integrated STEM curricula based on a teacher's own definition of integrated STEM or if selected and used for convenience. This study did not investigate teachers using prefabricated lessons, rather it investigated from select teachers lessons they believed were integrated STEM.

Research Questions

I researched a select group of teachers who demonstrated an ability to write and implement integrated secondary science lessons and was interested determining if certain characteristics existed among their perceptions. The questions that guided this study were

1. How do secondary teachers (grades 9-12) of various STEM disciplines define the concept of I-STEM?
2. How does a select group of teachers defining I-STEM manifest their definition in elements or components related to a lesson or activity as gauged from a review of artifacts submitted?
3. How do select teachers who have designed and/or contributed I-STEM lessons assess student achievement?
4. What factors and/or rationales influence select teachers to conduct or not conduct an I-STEM activity or lesson?

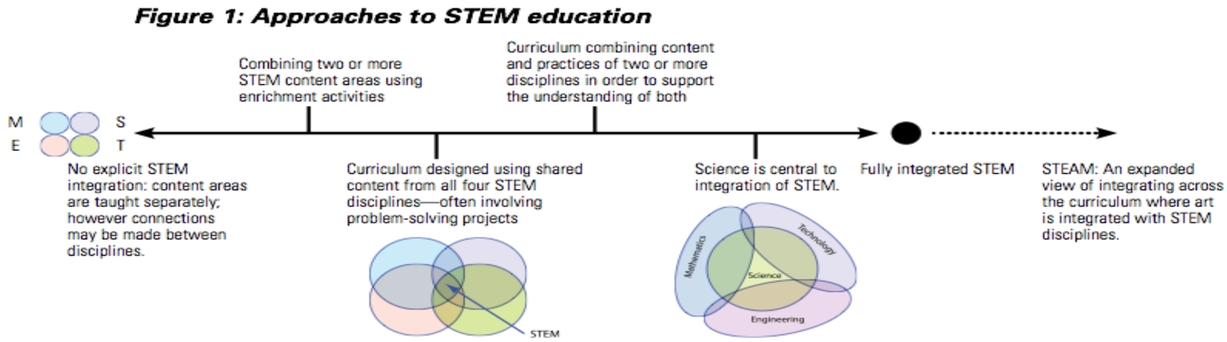
Brief Overview of Methodology

To get participants involved, an initial email was sent to area and regional representatives and organizations that represented each of the STEM disciplines, specifically the National Science Teachers Association (NSTA), the International STEM Education Association (ISEA), National Council of Teachers of Mathematics (NCTM), and International Technology and Engineering Educators Association (ITEEA). Each organization distributed my email with the survey and overview (Appendix A) on their list-serve. Subjects provided their best example of a secondary integrated STEM activity, which could have included a lesson plan, a textbook activity from a specified page number and book, PowerPoint slides, teacher notes/handouts, worksheets, laboratory activities, assessments (tests and quizzes), and brief summaries of expected outcomes and beliefs about how the lesson was an exemplar STEM lesson. The study was designed around a purposeful sampling technique called “snowball or chain sampling” (Merriam, 2009, p. 78). There was no maximum number of persons solicited or pieces of evidence collected, since it was based on a system of referrals. A goal of six responses was set as a minimum. Artifacts were collected for a three-week period or until it appeared the data collected began to be duplicated and repetitive and did not add new information to the collected data.

Artifacts, survey responses, and interviews collected in the study were analyzed primarily using a hybrid of open coding (Merriam, 2009). The analysis of typologies (Merriam, 2009, Hatch, 2002) for the studies two original groupings “Teachers who do conduct I-STEM lessons,” and “Teachers who DO NOT conduct I-STEM lessons”, did not have a separate analysis due to lack of data.

One category already identified for analysis was the Level of STEM Integration as based on Figure 1 description. This diagram captured the types of integration that may exist and may be submitted as part of a lesson or teacher description. As part of this study, I was interested in receiving artifacts that represented into the “fully integrated STEM,” however, it was unknown what exactly would be submitted and perceived as an I-STEM lesson. If a lesson/artifact were submitted that fell on either side of the continuum, then it would be classified and analyzed accordingly.

Figure 1: An overview of approaches to STEM education from Barakos, et al. 2012, p. 8.



Two items from this figure needed to be addressed. First, my study anticipated analyzing lessons and activities from a variety of disciplines; therefore, any discipline was considered central to the integration of STEM and not just science, as stated in the figure. Second, the concept of STEAM lessons/artifacts, the integration of the arts into STEM (Jolly, 2014), if submitted, was accepted and analyzed. This author would have accepted any lesson a subject considered an integrated STEAM lesson, however, if the arts were considered a central concept in which the lesson was designed around, it was rejected.

Assumptions

The design of this study was asking secondary teachers (grades 9-12) to volunteer and to provide artifacts related to their best example of an integrated STEM lesson. It was assumed their submissions were their most exemplar and representative example. Those who answered any questions via email or phone were assumed their answers were truthful.

Limitations on Generalizability

Surveys were sent to those who taught grades 9-12. These teachers were asked to submit artifacts they believed represented integrated STEM lessons. Results from this study were intended to aggregate data from teachers representing various science, technology, engineering, and mathematics organizations. All grade levels had self-reported representation. However, only three of the four disciplines were represented based on the subjects self-reported association. Mathematics was the only STEM discipline that did not have a self-reported representative.

Delimitations regarding Nature of Project

The extent of this study was limited to the number of participants who submitted responses. Therefore, it was not possible to guarantee a comprehensive evaluation of lessons representing teachers equally from across the United States. It was also not possible to guarantee the lessons submitted were from a diverse group of secondary teachers. Requests were sent asking teachers from all grade levels 9-12 to send artifacts relevant to their best integrated STEM lesson, however, not all grade levels had equal representation.

Chapter 2

Literature Review

"Now is the time to move beyond the slogan and make STEM literacy for all students an educational priority." Bybee, 2010b

Overview of STEM

Emergence of STEM. According to Sanders (2009), the National Science Foundation (NSF) in the 1990's began to use the acronym SMET, as "…shorthand, for 'science, mathematics, engineering, and technology'" (p. 20). Yet someone in NSF said SMET sounded too much like "smut"; STEM, therefore, became the acronym of choice (Sanders, 2009). The process to not only identify an appropriate acronym, but to identify what STEM is not as simple as it would appear.

STEM is a rather recent acronym (within the past two decades) that captures and quantifies science education. By the late 1980's to the early 1990's, there was a push to create new content standards (Deboer, 2000) across various educational communities (Sanders, 2009). Several versions of specific content standards were created and most were content specific, in the early versions. Sanders (2009) identified various organizations, such as the American Association for the Advancement of Science (AAAS) and its *Benchmarks for Science Literacy, Project 2061* (1994) and the National Research Council's (NRC) *National Science Education Standards (*NSES, 1994), and their attempts to create K-12 science content standards for basic science courses, such as biology, physics, chemistry and show interaction between fields. Other organizations, like International Technology Education Association (now called International Technology and Engineering Education Association, ITEEA) and National Council of Teachers of Mathematics (NCTM) produced their own content specific reformations and revisions. More recently, two resources were published directly impacting science, technology and engineering standards: *A Framework for K-12 Science Education: Practices, Crosscutting Concepts and Core Ideas* (2012) and the *Next Generation Science Standards* (Achieve, 2013). The very nature of design for these resources was to remove the silos surrounding the disciplines (Nathan, et al., 2013; Katehi, Pearson, & Feder, 2009,) and to exert a greater emphasis on integration of the four disciplines.

Need for STEM Education

STEM education's status was elevated to a critical in the *Rising Above the Gather Storm* publication (NRC, 2007). From this report it was clear there was a warning about the need to do things differently when it comes to preparing United States' students in the area of science, technology, engineering and mathematics. The committee wrote,

> Education in science, mathematics, and technology has become a focus of intense concern within the business and academic communities. The domestic and world economies depend more and more on science and engineering. But our primary and secondary schools do not seem able to produce enough students with the interest, motivation, knowledge, and skills they will need to compete and prosper in the emerging world (NRC, 2007, p. 94).

This concern continued to be perpetuated when the United States was compared to other nations in areas of math and science in different international assessments. A recent Program for International Student Assessment (PISA) reports (2012) the U.S. was lower than 17 other nations in science literacy (National Center for Educational Statistics, 2013). National Research Council (2011a) cites a 2010 National Assessment of Educational Progress (NAEP) report where nearly "75 percent of U.S. 8^{th} graders are not proficient in mathematics" (p. 3) upon completion of 8^{th} grade. This decline in math and science proficiency was, unfortunately, further intensified between subpopulations like gender and poverty (NRC, 2011a; Drew 2012). This ongoing trend of decline of the American education system when compared to international educational programs raised concerns about the future of the American economy (NRC, 2007). NRC (2011a) cited several earlier reports linking the impact on America K-12 STEM education on "continued scientific leadership and economic growth" (p. 3). One such solution to a positive impact on the economy and scientific leadership was to increase the number of persons proficient in mathematics, technology skills, and problem-solving skills. However, gaps still remained between jobs and persons qualified for highly technical positions.

The interest in the STEM field had grown so quickly and was so pervasive that Sanders (2009) suggested we entered a period of "STEMania" (p. 20). This mania was most likely being fueled by reports warning how the U.S. was falling behind several industrial nations in math and science, such as the PISA report (2014) mentioned above, and by the *Rising Above the Gathering Storm* publication (NRC, 2007). For many, educators and politicians alike, the solution to improving our educational status in key certain areas was to establish a STEM school or a STEM curriculum in an existing school focusing more clearly the STEM disciplines of on science, technology, engineering, and mathematics (National Governors Association, 2007; Researchers without Boarders, 2013).

Another reaction to this crisis was to direct fiscal resources to programs and curriculum containing a STEM label (Herschback, 2011), which focused on various levels of integration regarding the disciplines of science, technology, engineering and mathematics. This was seen in the design of various schools or pathways dedicated to STEM, which was addressed below.

I did not want to imply the concept of integrated STEM had been vacant in previous decades. Salinger and Zuga (2009) identified "interest in education involving the study of STEM subjects began in the colonial era" (p. 4). They went on to note the federally funded career and technology education (CTE) due to the Vocational Education Act of 1917. Bybee

(2010) also argued a community of STEM existed before the term STEM was coined. He wrote, "The STEM community responded vigorously to produce the Sputnik-spurred education reforms of the 1960's" (p. 996). The point being here was regardless of the decade, STEM concepts and disciplines were valued and supported in the educational community, even if they were not seen as unified or integrated ideas.

Defining Integrated STEM. What may have started as a simple change from "SMET" to STEM in order to make it more clearly understood has evolved, "and yet…remains a source of ambiguity" (Sanders, p. 20); it was even more so with the concept of integrated STEM (NRC, 2014). As described previously, the idea of integrated STEM could be thought of as something that was taught in one classroom or across classes or event the spectrum of grades if so designed in a school (NRC, 2014). The one notion that seemed to emerge and gave it its ethos was the interdisciplinary-ness of the four concepts, which some had also called a multidisciplinary approach. Kelley (2010), citing Mallon & Burton (2005), kept each discipline separate and applied by different individuals from the different disciplines. It appeared the one goal most could agree upon, as Sanders (2009) pointed out, was a central theme that addressed the "inherent connections among science, mathematics, …technology" (Sanders, 2009, p. 23) and engineering.

This idea of connecting concepts across the disciplines was supported by the "STEM integration that spans the design and natural sciences" (Nathan, Srisurichan, Walkington, Wolfgram, Williams, & Alibali, 2013, p. 82), where design was understood as the combining of technology and engineering and natural sciences was math and science. This philosophy, according to Nathan, et. al, 2013, citing Sanders and Wells, 2006-2011, was the driving force behind Virginia Tech's integrative STEM program, which later became known as the Purposeful

Design and Inquiry (PD&I) method (Carter, 2013, Hayward & McComas, 2014). This style of learning was defined by Wells and Earnst (2012/2015) as a pedagogical approach that taught "content and practices of science and mathematics education through the content and practices of technology/engineering education…[and was] applicable at the natural intersections of learning within the continuum of content areas…" (http://www.soe.vt.edu/istemed/).

As higher education institutions were beginning to address the needs for students to graduate in STEM fields (NRC, 2007), so to were high school (grades 9-12) programs. Four different models or pathways for STEM experiences in the secondary grades began to emerge over the past decade (NRC, 2011a; NRC, 2011b).

Professional Organizations Definition of I-STEM. How various professional organizations understood and address I-STEM may impact how a teacher, who was associated with an organization, defined I-STEM. Researching each of the four professional organizations websites, I discovered which of them did and did not have a working definition of I-STEM for their members.

National Council of Teachers of Mathematics (NCTM) did not appear to have a definition for I-STEM on their website. Based on the information found on NCTM's website (http://www.nctm.org) their focus was primarily math education and not I-STEM education. However, it did appear they recognized some degree of relationship of mathematics to other disciplines in STEM and had several artifacts related to STEM, such as the organization's support of funding for STEM activities, as was seen in the letter of support for to Congress to continue providing funds for such activities (http://www.nctm.org). The organization was also soliciting articles for a future publication regarding how teachers used mathematics in STEM contexts.

The International STEM Education Association (ISEA) stated on their website (http://www.isea-stem.org/#!about/cipy) it was interested in "[bridging] the connection between all areas of STEM, to show the hands-on application to math and science through real-world, engaging, and fun activities" (www.isea-stem.org). Their goal was "to establish a professional association that supports STEM Educators in the K-12 classroom and promote STEM Education as the foundational cornerstone of innovation and excellence in educational experiences that are imperative for success in the technological world of today and tomorrow" (www.isea-stem.org). Maverick, the one participant who identified with ISEA, designed a lesson using scientific investigation pedagogy with physics concepts.

ITEEA has posted on their website (http://www.iteea.org/About.aspx) a definition for Integrative STEM education.

> Integrative STEM Education is operationally defined as "the application of technological/engineering design based pedagogical approaches to *intentionally* teach content and practices of science and mathematics education through the content and practices of technology/engineering education. Integrative STEM Education is equally applicable at the natural intersections of learning within the continuum of content areas, educational environments, and academic levels" (Wells & Ernst, 2012/2015).

As could be seen from their definition, this organization made a deliberate effort to integrate STEM disciplines with the engineering design process. This was the only organization to explicitly defined I-STEM.

I-STEM Schools and Pathways

The context in which teachers operated and instructed could influence the production of I-STEM lessons/activities (Barakos, et al., 2012; NRC, 2014). This study was designed to survey teachers from a variety of STEM disciplines, but it was unknown which of the school contexts they would be found. Each participant was asked to identify a school pathway the most represented them in the survey (Appendix 2) and the data was analyzed to determine if patterns or correlations existed with the artifacts provided and the school associated with. Research did identify some schools and pathways based on I-STEM and STEM disciplines. The National Research Council in 2011 published two resources that helped classify or categorize four types of schools (NRC, 2011b) based on specific criteria (NRC, 2011a) found within a that school setting. Table 2-1 summarizes four types of schools, along with select criteria associated with that school.

Table 2-1

Types of STEM Schools with Criteria unique to each school

Selective STEM School	Organized around one or more of the STEM Disciplines School population is low Select students talented and highly interested in STEM disciplines.
Inclusive STEM Focused School	Organized around one or more of the STEM discipline, but have no selection criteria Seek to serve a broader population Wishes to provide underrepresented subpopulations with access to STEM
STEM Focused Career and Technical Education	Typically found in a high school setting Can be placed in a regional center, CTE programs, or career academies
STEM Education in Non-STEM-Focused Schools	Found in a more traditional school setting Typically does not have a STEM focus, but does provide courses in various STEM disciplines, such as Accelerated Program (AP) Courses

Designing Integrated STEM Experiences

Principals of Integrated STEM Lesson. Creating an integrated STEM lesson must entail some distinguishable forms, qualities or characteristics. Wiggins and McTighe (2005) described conditions needed maximize learning experiences that highlighted the need for appropriate planning and when implemented paralleled several qualities identified by NRC (2014) that were considered necessary "implications for the design of approaches to integrated STEM education" (p.89).

NRC (2014) emphasized strategies that built knowledge and skills "within and across disciplines" (p. 89). From the research, they found the following four principles related to the "design of integrated STEM learning experiences" (p. 89). They were

1. Making integration explicit (p. 89),
2. Attending to students' disciplinary knowledge (p. 91),
3. Attending to the social aspects of learning (p. 92), and
4. Supporting the development of interest in identity. (p. 94)

Explicitly connecting materials and expanding upon the student's content knowledge was necessary since many of the concepts were found within the activities themselves and were not designed to help students make connections without appropriate teacher support. This was problematic if the activity or lesson was designed to occur over several days or class periods. Student may not carry over information from previous days to the present and build upon the content.

NRC (2014) mentioned the importance of "social aspects" (p. 92) in the design of I-STEM lessons. Teachers must consider the relationships and interactions between the students and between the teacher and the students. How much discussion and collaboration will occur in the lesson/activity that identifies when they will be learners and when they will be the directors of learning. Coupled with this aspect was the need to understand the "social process" (p. 93) of how the learning occurs. Simply because students were working in groups did not automatically imply learning had occur. What techniques the teacher and even the students to ensured students employed was reaching the desired learning outcomes.

The "Development of interest and identify" (p. 94) was a topic that needed additional research to better understand not just the what, but the how these were developed within the learner. However, NRC (2014) outlined some research identifying particular elements related to this topic in relation to the design of an I-STEM lesson/activity. These elements consisted of lessons/activities that 1) gave students time to pursue specific interests within a project, 2) had processes in place that provided feedback to students, 3) had time built into lesson for visiting with other students, 4) were given opportunities to make connections in what is called "triggers of interest" (p. 95), and 5) implemented project- or problem-based learning experiences, meaning multiple solutions are possible. If some or all of these elements were included then there was an increase in students' interest in STEM disciplines and possibly even identifying with certain STEM careers.

Jolly (2014), who also agreed that STEM was more than a "grouping of subject areas" (http://www.edweek.org/tm/articles/2014/06/17/ctq_jolly_stem.html), identified six specific qualities found in a well-designed STEM lesson. These characteristics overlap greatly with Cunningham and Higgins (2014) six principles that helped "girls and minority students embrace the "E" in STEM" (p. 42). Table 2-2 outlines the each of the respective authors guidelines.

Table 2-2
Side-by-Side comparison of six identified principles for integrated STEM lesson

Focus on Real World Issues and Problems	Set in Real-World Context
Lessons are guided by Engineering Design Process	Highlight How Engineers Help Others
Immerse Students in Hands-On Inquiry and Open-ended Exploration	Construct Activities with Multiple Solutions
Involve Students in Productive Teamwork	Value Failure
Apply rigorous Math and Science Content your Students are Learning	Foster Collaboration
Allow for Multiple Right Answers and Reframe Failure as a Necessary Part of Learning	Use Readily Available Materials

Understanding by Design. Wiggins and McTighe (2005) have developed a methodology that could potentially be a blueprint for teachers to use to achieve the elements listed previously. *Understanding by Design* (UbD), has three different stages in the development of an effective lesson: identifying desired results, determining the assessments and the evidence that is acceptable from the assessments, and planning the instruction so students can have deliberate learning experiences. The UbD method is non-content specific, yet provides a design process applicable to the integration of STEM disciplines, particularly in identifying the appropriate “intersections” (Wells & Earnst, 2012/2015) found amongst the STEM disciplines.

Previous research (NRC, 2014; Wang, et al., 2011) has shared some concerns regarding planning and designing of I-STEM lessons/activities. This author believes much of that is attributed to a more traditional way of creating a lesson, the “twin sins” (p. 16) Wiggins and McTighe (2005) describe the “twin sins of traditional design” (p. 16), are lessons designed to be activity oriented or designed to simply cover the content, undermine the effectiveness of instruction. Therefore, a teacher has not taken the effort to flesh out the four elements listed previously by NRC (2014) or worked to understand the “intersections” found amongst the STEM disciplines. To successfully achieve this, one must decipher between “knowledge” and “understanding” (p. 35) as he or she begins to design a lesson. Knowledge for these authors represents a student knowing facts or concepts related to a concept, as compared to the description given to understanding where the learner knows the meaning of facts along with ability to discern when to use the information in an appropriate setting. This is a critical difference between the two concepts for it is when understanding is obtained that transferability is attainable.

Two essential components to the success in the design of the lesson is the selection of one of the six “facets of understanding” (p. 82) and pairing it with a mechanism that collects the acceptable evidence of successful learning. It is at this point where the “backward design process depart[s] more from conventional practice" (p. 146). Each facet of understanding (explanation, interpretation, application, perspective, empathy, and self-knowledge) contains qualities and characteristics unique to them; selecting an appropriate assessment device creates the conditions in which the learner can demonstrate his or her understanding as related to the selected facet.

This model may be effective in the designing of integrated STEM lessons, but does not necessarily identify or outline the marks of a quality integrated STEM lesson. Putting the lesson together encourages the teacher to consider research-based teaching and strategies and learning activities that allows the student to move through the learning progression.

The terms "deliberate" (Wiggins & McTighe, 2005) and "coordination" (Nathan, et al., 2013) has been used previously to describe the intent of an integrated STEM lesson design and seems to be emphasized in the findings of NRC committee and their report (2014). Four design principals are identified as necessary for integrated STEM experiences: "making integration explicit, attending to the students' disciplinary knowledge, attending to the social aspects of learning, and supporting the development of interest and identity" (p. 89).

Experiential and Situational Learning. As discussed previously, integrated STEM is best learned through an experiential process. Wells (2010) cites research that encourages the integration of science with other disciplines for it provides an "authentic context for problem solving" (p. 203) and the transferring of knowledge. Two problems that arise for teachers in designing an integrated STEM lesson/activity is the integration of two or more STEM disciplines and creating an authentic context for a student. One possible solution to accomplishing an integrated STEM lesson/activity was presented by Nathan, et. al, (2013). They write, "one possible means of achieving STEM integration…is through learning experiences that foster cohesion production" (p. 83). Cohesion, according to these researchers, is important in supporting teachers' ability to integrate STEM concepts for it helps the instructor deliberately link concepts by the instructor and is seen as a "key mechanism of integrated STEM education" (NRC, 2014, p. 58).

An authentic context can be accomplished through the application of the Situated Learning (Lave & Wenger, 1991) and Situational Context Learning (SCL) (Bell, et al., 2013) theories. These describe the importance of emergence into the learning environment a student must find him or herself in to maximize the learning experience. To create such conditions, Bell, et al, (2013) identify four components of the SLC theory creating a framework where this should occur: cognitive apprenticeship and coaching, opportunities for multiple practice, collaboration, and reflection. Each has a specific purpose within the theory to enhance student learning. For example, cognitive apprenticeship works to "generalize" (p. 351) information so it can transfer to other situations, while coaching facilitates learning by scaffolding resources and asking guiding questions to encourage learning. The theory is "most effective when it occurs in an authentic context" (Bell, et al., p. 352). SLC and Situated Learning compliments Vygotsky's Zone of Proximal Development (ZPD) as a "cognitive-development theory" (Gredler, 2009), since it identifies "events and conditions necessary to attain [the highest levels of human thinking]…" (p. 263). The ZPD is simply the gap between what a student can do without any help and what cannot do unless assistance is provided (Gredler, 2009). Each teacher's classroom will have students at various stages of understanding in each of the STEM disciplines and practices; design of a lesson should address pedagogical practices that permit the overlaps and interactions between the different ZPDs between both teacher and student and reflect appropriate learning strategies to engage students at multiple entry points.

While important to understand the theoretical concepts regarding the context in which authentic learning experiences can occur, Strobel, Wang, Weber, and Dyehouse (2013) outline four principles to consider in the design of such authentic experiences. For them, teachers must consider which type of authentic experience the students will experience in their activity. From their study, Strobel, et al., (2013) analyzed literature the included the concept of authentic in the learning experience, specifically for engineering education. They discovered four types of authentic categories: context authenticity, task authenticity, impact authenticity, and personal/value authenticity.

Strobel, et al., (2013) summarize most succinctly their explanations of each the four categories. They wrote

> After careful reading and discussion of the 59 descriptions and definitions, we categorized them as “Context Authenticity,” “Task Authenticity,” “Impact Authenticity,” and “Personal/Value Authenticity” ...The common theme of all the different authenticity definitions is their relation to real-world experiences. Context Authenticity answers the question, What makes a context authentic? This type of authenticity should take place in authentic contexts and resemble daily life experiences. For example, the activity should contain a suspension of disbelief process, such as when watching a movie. Task Authenticity answers the question, What makes a task authentic? This type of authenticity focuses on constructivist type learning environments in which students may be challenged to make decisions in practical contexts. Impact Authenticity focuses on what impacts an authentic experience can deliver and asks, What impacts can an authentic experience deliver outside of school? Finally, Personal/Value Authenticity asks, What makes an experience authentic on a personal level? Personal/value authenticity includes actions that make an experience authentic on a personal level such as self-exploration. (p. 146, 148)

As the interest in I-STEM grows, the concept of authenticity must also be understood and applied appropriate for students to have the intended outcomes expected by the teachers conducting such lessons. Being able to consider which factor of authenticity students may wish to explore or grow in could be great foundations in which to construct a lesson and also reduce confusion about expected outcomes. For example, Larmer (2012), of *Edutopia*, discussed three different types of authenticity: Not Authentic, Somewhat Authentic, Fully Authentic. To be Fully Authentic, the work must be real to the student or can have an impact on the world in some manner. This is in contrast to Not Authentic lessons where one is asking students to create a poster that only asks a student reproduce information from a book or Internet site or write an essay. (http://www.edutopia.org/blog/authentic-project-based-learning-john-larmer). When compared with Strobel, et. al., (2013) findings, there is agreement that the experience must be more than an activity, however, Larmer's (2012) description appears to be a blend of task and impact authenticity.

Content is a primary component in the design of the lesson with each lessons/activities working to apply various levels of and backgrounds in the use of content knowledge during lesson interactions (Alonzo, et al., 2012; NRC, 2014). But another factor that must be considered in the design of a lesson: the *doing* of science.

Science and Engineering Practices. The *K-12 Frameworks* (2011) and the Next Generation Science Standards (NGSS Lead States, 2013) emphasize the relationship of the *knowing* of content as well as the *doing* of science and engineering. Two terms may be referenced by participants and referred to in this this paper: practices and inquiry. These terms will have distinct meanings for this author. NGSS (NGSS Lead States, 2013) quotes the following statement from the *K-12 Framework*

> Dimension 1 describes (a) the major practices that scientists employ as they investigate and build models and theories about the world and (b) a key set of engineering practices that engineers use as they design and build systems. We use the term "practices"

> instead of a term such as "skills" to emphasize that engaging in scientific investigation requires not only skill but also knowledge that is specific to each practice (Executive Summary, p. 4).

Using the term practices is an important distinction for it encompasses both the skills and the knowledge unique to the specific science or engineering practices. So why not use the term "inquiry," since this term also has a hallowed place in the halls of science? Scientific inquiry "refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world" (NRC, 2000, p. 1). NGSS (NGSS Lead States, 2013, Executive Summary) and Bybee (2011) both address this. Again, quoting the *Framework*, NGSS states,

> the term "inquiry," extensively referred to in previous standards documents, has been interpreted over time in many different ways throughout the science education community, part of our intent in articulating the practices in Dimension 1 is to better specify what is meant by inquiry in science and the range of cognitive, social, and physical practices that it requires. As in all inquiry-based approaches to science teaching, our expectation is that students will themselves engage in the practices and not merely learn about them secondhand. Students cannot comprehend scientific practices, nor fully appreciate the nature of scientific knowledge itself, without directly experiencing those practices for themselves (p. 4).

Bybee (2011) argues scientific inquiry is "one form of scientific practice" (p. 10) and does not replace it, but rather expands and enriches the "teaching and learning of science" (p. 10).

Studies Analyzing Integrated STEM

Part of the concern rose by Wang, et al., (2011) in their study was the lack of STEM curricula. This problem may be less of an issue today as it was when they conducted their research, but Wang, et al., (2011) succinctly suggest that we "treat STEM integration as a type of curriculum integration" (p. 3), therefore it manifests itself in a curriculum that integrates the four STEM disciplines. Barakos, et al., (2012) earlier described a continuum in how STEM integration could visually be represented, but it appears much of the manifestation is centering around engineering design concepts or environments. Several of the studies looking at I-STEM teachers and lessons were involved with engineering design environments or programs.

Nathan, et al., (2013) were interested in better understanding how the "mechanisms of integration" (p. 77) occurred in classrooms. For their particular study, they observed two different high schools that contained Project Lead the Way (PLTW) courses. In essence, they conducted a qualitative study, but they described their methodology as a "learning sciences perspective"…[and assumed] that knowledge and action are socially constituted are situated in the embodied, material, social, and cultural ecologies under observation" (p. 86).

The findings of the their study are two fold. First, cohesion is an important concept that can offer "new insights into pedagogical processes for fostering STEM integration" (p. 90). As described on pages 58 and 60, NRC (2014), citing Nathan, et al., (2013) outlines the four pedagogical mechanisms impacting the effectiveness of cohesion:

. identification of invariant relations and disciplinary concepts regardless of the surface features (Nathan et al. 2013);

. coordination that "supports students' reasoning and meaning making by constructing clear links across representations and activities" (Nathan et al. 2013, p. 110);

. forward projection to orient students to connections between current events or representations and future ideas and activities, which "facilitates planning, highlights pending importance, and prepares students for future learning opportunities" (Nathan et al. 2013, p. 110); and

. backward projection to previously encountered ideas and events, which "prompts students to engage in reflection and emphasizes making connections between new and prior knowledge" (Nathan et al. 2013, p. 110).

Second, Nathan, et al., (2013) argued this cohesion experience promoted "STEM integration at content and curriculum levels…connect[ed] ideas to representations…change[d] how students perceive these objects...and what meaning they [held] for students" (p. 109). It was this one concept called *cohesion* that permitted essential content standards to be represented and retained across the "range of representations, objects, activities, and social structures" (Nathan, et. al, 2013, p. 77) within the classroom. This group demonstrated examples of students improving their understanding of STEM concepts "during the course of project-based learning in the classroom" (p. 90). Further, students were able to make connections to concepts within the lesson/activity and across various lessons and activities, also called a "metalevel discussion" (p. 108). This study implies there are techniques teachers can use in the process of learning that can have both content level (more narrow) and curricular level (more broad) level implications.

Roehrig, Wang, Moore, and Park (2012) examined how secondary science, math, and technology teachers use an integrated STEM model to implement their new state STEM standards, which now included an engineering component. They asked the question, Is adding the "E" enough? to ensure integration would/could occur. More specifically, is the addition of engineering content enough to construct an integrated STEM lesson or activity?

This research group recruited a total of 46 STEM secondary teachers, of which, 33 were science, 33 were math, and 8 teachers has a background in technology education. They represented a total of 10 schools, 4 middle schools and 6 high schools. In the course of the professional development sessions, the 46 teachers created 41 lessons. Their initial analysis of 41 lessons found four categories as designed around the engineering design process: "1) integrated engineering design- product focus; 2) integrated engineering design- process focused; 3) engineering design with no integration; and 4) absence of engineering" (p. 37). Based on these preliminary lesson analyses, teachers' understanding of integrated STEM varied both in design process and content integration.

STEM integration was found to be on a "continuum from lessons that attempted to integrate all of the STEM disciplines"(p. 41) to lessons containing only two of the four disciplines. These two-discipline lessons made up the majority created by the teachers. Combinations of the integrated STEM lessons consisted of science and math, science and engineering, or math and engineering, which had the greatest number of lessons represented. Roehrig, et al., (2012) did clarify that science teachers prepared all integrated STEM lessons, even though other content teachers could participate in the instruction and execution of the lesson. In fact, the authors make a note that the "highest quality of STEM integration was found in the lesson co-planned and implemented by a science and mathematics teacher" (p. 41).

This study highlighted the variations of implementation and the impact state standards can have on the integration of engineering concepts into science standards. Of the 41 lessons created in both the middle school and high school settings, 18 of them were designed to go into some version of a science course. Variations in lessons were minimal with only three reflecting any life science standards; the majority consisted of physical science concepts. Even more revealing is the fact only two of the life science lessons combined engineering processes, even though several science concepts, like "genetic engineering, prosthetics, artificial heart valves, and neuroengineering," could have been incorporated.

The findings did illustrate a diverse approach to the curricular design of the lessons, in addition to the structural approach of the instruction. The level of STEM discipline integration in the lessons established a continuum that ranged from 12 lessons attempting to integrate all the STEM disciplines, five lessons using only engineering and technology standards, four lessons integrating science and mathematics standards, six lessons having combined science and engineering standards and 14 lessons consisting of engineering and mathematics standards.

Hershback (2011) would argue that teachers who use only two disciplines, specifically science and math, while meaningful, are giving schools the "illusion of STEM programming" (p. 111). However, researchers, like Stohlmann, et al., (2012) believe an, "integrated STEM education can involve multiple classes and teachers and does not have to always involve all four disciplines of STEM" (p. 30). It leaves one to wonder how frequently are lessons created to include multiple classes and multiple teachers in the design and implementation of an integrated STEM lesson. Additional curiosities are frequency of the intentional absence of two of the four disciplines in the design of an "integrated STEM" lesson in a classroom and if a teacher ever integrates the missing disciplines at any point during the school year.

It is important to recognize that integrated STEM lessons may not be organically generated at the school level. Teachers may use commercially produced resources intended to meet the integrated STEM expectations of the school or lesson. Both Nathan, et al., (2013) and Roehrig, et al., (2012) conducted their studies at a school that implemented the Project Lead the Way curriculum. This may help explain why there was an emphasis on engineering design processes in their studies.

Carter (2013) investigated six of the more common STEM curricula to better understand what characteristics make up an integrated STEM curriculum. This study "emerged from the inconsistencies between goals and outcomes that exist in the current STEM literature and commercially available STEM curricula" (p. 36). To determine if a consensus existed as to what and if any characteristics were needed or evident in the construction of a framework in developing integrated STEM curricula, he devised a modified Delphi study.

Carter (2013), put together a panel of 12 participants who had some experience or background working with STEM integration and its literature. The panel had representatives claiming to have a math, science, and engineering and technology background with diverse academic backgrounds from Masters degrees to Ph.Ds. According to the paper, the majority of participants on the study were male who had an engineering and technology background. After three rounds of the Delphi study, the panel concluded that much of the current STEM curricula was not integrated, but rather aligned to a specific STEM discipline: engineering. Based on this, Carter (2013) concluded that most did not provide a truly integrated experience. The panel also revealed an agreement that any curricula designated as integrated STEM "should include project-based work on open-ended problems, appropriate grade-level educational standards/content of each STEM discipline (without isolating it to one discipline), and that instruction in reading, writing, and numeracy used to enable effective communication in problem-solving" (p. 104). As with the previously listed characteristics of integrated STEM curriculum, this study also found that lessons needed a real-world problem.

Teachers' Perceptions about I-STEM

The success of an I-STEM lesson may lie in how comfortable a teacher is in teaching such a lesson or activity, because a "lack of confidence in mathematics and science knowledge…and fear of engineering…" (NRC, 2014, p. 119) are factors impacting a teacher's ability to teach an I-STEM lesson (NRC, 2014; Wang, et al., 2011; Rittmayer & Beier, 2008). In a 2011 study, Wang, et al., found that teachers' "perceptions of STEM integration strongly influenced how they designed their STEM integration unit" (p. 10). Purposefully selecting three secondary teachers (2 teachers from 6th grade and 1 teacher who taught grades 6-8), the research team examined the teacher's beliefs and practices after providing professional development and implementing "STEM integration activities" (p. 3). Of the three teachers (1 male, 2 females), Nate taught math with no history of teaching I-STEM, Kathy taught physical science, who was considered a novice by the authors in I-STEM, and Amy taught engineering, who was identified as intermediate in I-STEM experience. After a year's worth of training, planning and implementing, the researchers observed their lessons and interviewed the teachers afterwards.

They found that Nate "considered mathematics to be an important skill…and STEM integration provided an opportunity for students to apply mathematics skills and concepts in a real-world situation" (p. 8, italics removed by author). In other words, Nate understood to believe the concepts of science, math, and engineering were related, however STEM integration did not necessarily "help him teach his subject in a more effective way" (Wang, et al., 2011, p. 8). He also believed that collaboration with other teachers was necessary when an I-STEM lesson/activity was needed. For the lesson he conducted, Nate did collaborate with Kathy. According to the article, Nate appeared bound to his curriculum and the I-STEM approach did not help him cover the curriculum, therefore his lesson was only designed for one day.

Kathy collaborated with Nate in the design and implementation of her lesson, which lasted a total of seven days. She approached the idea of I-STEM with the belief that problem solving was the "key concept to integrated STEM subject and [was] the main focus of STEM integration" (p. 8). The content within an I-STEM lesson (math, engineering, and science) was used to help the students become more analytical in their solution development and therefore her lesson was designed around solving a problem. Kathy did admit that technology was the "most difficult part of STEM integration" (p. 9), but that may have been due to accessibility and lack of student training on how to use the computers more academically, as in on-line research. She believe the training "reinforced her beliefs about STEM integration, particularly the problem solving piece" (p. 9).

Amy, the most experienced of the three in both years of teaching (10 years) and I-STEM skills (she was considered intermediate), created a unit that lasted two months. Amy's beliefs about STEM integration needed to combine engineering, problem solving and the content knowledge of math and science. Application of such knowledge and skills would really help students' "think independently and become more confident in learning" (p. 10), along with help develop other skill sets like communication and teamwork. She is also the only teacher to consider the impact of I-STEM on other "non-STEM disciplines as a means to help students understand the world" (p. 10).

Wang, et al., (2011) concluded this case study highlighted how different perceptions influence the design of an I-STEM lesson/activity, along with how the participants believed an I-STEM experience was beneficial to the students in learning and in the building of confidence in math and science courses. Each teacher did encounter obstacles with technology integration and the lack of an I-STEM curricula, but overall gave a positive experience with the lesson due to the professional development offered.

Teacher Efficacy in STEM. One's decision to conduct I-STEM lessons/activities may rely upon how comfortable he or she is with integrating the various STEM disciplines. Because each discipline has its own content expectations and literacy outcomes, "content knowledge and quality pedagogy play a large part in feelings of efficacy" (Stohlmann, et al., 2012). NRC (2014) highlights that only 7 percent of high school science teachers feel "very well prepared to teach about engineering" (p. 119). While this study does not intend to measure teachers' self-efficacy, it may provide insight in how teachers' increase their self-efficacy (Gredler, 2009; Rittmayer & Beier, 2009; Fogleman, et al., 2011) in designing and conducting an I-STEM lesson/activity, and identify factors that may impact teachers growing and expanding their teaching to change their practices and perceptions (NRC, 2014; Herschback, 2011; Asunda, 2014, and Cochran-Smith & Fries, 2005).

Pedagogical Content Knowledge. Teachers' pedagogical content knowledge (PCK) is an appropriate understanding of the relationship between the subject matter and what needs to be taught (Shulman, 1986), but more importantly, it "allows excellent teachers to make disciplinary ideas comprehensible to non-experts" (Alonzo, et al., 2012, p. 1213). Some aspects of PCK include "typical student preconceptions, misconceptions, and ways of thinking; students typical developmental path in understating particular ideas, strategies for teaching specific content ideas, examples metaphors, analogies, and representations of specific content ideas; and how to organize and sequence content" (Roth, et al, 2011, p. 120). NRC (2014) writes, "a teacher's self-efficacy depends on adequate background in the STEM subjects being taught, the ability to transfer that knowledge and understanding to the students…[or] pedagogical content knowledge…and confidence in both areas (p. 119). Therefore, one can conclude that self-efficacy and PCK are intertwined and influence the ability and confidence of a teacher conducting an I-STEM lesson/activity.

Barriers to Integrated STEM Experiences

As stated previously, there is an agreement that students benefit from an integrated experience, but there is a wide variation in what it actually means to implement such a program (Barakos, et al., 2012). The effort to integrate four distinct disciplines may create a variety of responses or interpretations about which disciplines should be included and to what degree (Barakos, et al., 2012; Wang, et al., 2011). These issues alone complicate an I-STEM experience in a school or classroom. However, there are some additional identified obstacles that may also impact a teacher's ability to conduct an integrated STEM lesson or activity. Schools and teachers having appropriate materials and resources were considered necessary, along with a school's structure and use of time may prohibit the teaching of integrated STEM lessons (Carter, 2013). Other researchers also identified similar concerns.

Implementing an integrated STEM lesson/activity in secondary school setting presents unique challenges, which consists of both internal and external barriers (Asghar, et al., 2013, Barakos, et al., 2012). Significant obstacles to overcome are the teacher's own perspectives and beliefs regarding their ability to 1) design appropriate lessons utilizing skills and practices related to each of the four disciplines, 2) draw appropriate connections between content areas, and 3) explain or understand appropriately each of the four content disciplines (Rittmayer & Beier, 2008; Daugherty, et al., 2014; Asghar, et al., 2012).

External obstacles evident in secondary settings include such things as state mandated curriculum and standardized assessments. Asghar, et al., (2012) elaborated further time was the greatest variable in question when one was trying to balance covering the curriculum content and an in-depth experience.

For many schools or districts, the lack of administrative understanding on STEM education is also a barrier. Barakos, et al. (2012) argued administrators must view STEM content as equally important as literacy and math. Asghar, et al., (2012) support this concern. They write,

> The literature also points to the lack of administrative support and encouragement as a barrier to the adoption of an interdisciplinary approach to STEM…Teachers need a supportive environment to learn and adopt new approaches to instruction and assessment. Administrative support is vital to developing an environment that encourages teachers and facilitates their learning (p. 93).

Acknowledging and recognizing barriers that prohibit a teacher's ability to conduct an integrated STEM lesson/activity is necessary in creating dialogue about how to remove or minimize such obstacles.

Summary

The notion of STEM and later integrated STEM has become more prevalent in the past decade due to a sense of urgency created by analysis of student and economic data comparing the United States to international countries. This refocus and attention on the education system to address the needs of an ever demanding workforce in the field of STEM caused the production of various types of STEM schools and to the creation of commercially created STEM curricula. As monies poured into states, states and districts interested in creating a specific STEM school and or using STEM curricula, the outcome has continued uncertainty in both definition of STEM integration and concept of integrated STEM in a school or classroom.

As the research is beginning to catch up with the "STEMmania" (Sanders, 2009), identifiable qualities are being identified with the types of schools and with the principals being associated with integrated STEM lessons/activities. Research has shown that integrated STEM experiences can impact students in a positive way, but Nathan, et al. (2013) found these experiences were uneven and inconsistent. These findings make one consider the importance of lesson designing. It appears that most are in agreement that integrated STEM consists of two or more of the disciplines, involves an authentic or real-world learning, experience, and involves both the learning content and implementation of practices. Using a "backwards design" model (Wiggins & McTighe, 2005), teachers can organically create an integrated STEM lesson; it is recommended by some that six identified principles are incorporated in the design of such a lesson. If teachers are unwilling or unable to create these lessons/activities, commercially created resources do exist. It is concerning, however, from Carter's research (2013) that many are not considered integrated STEM lessons even though many teachers may be lead to believe they are by the companies. As for the individual's learning, the experience may vary and much of that could depend on the type of school a child attends.

As previous studies have shown (Nathan, et al, 2013; Wang, et al., 2011), the context in which a teacher operates within can influence the I-STEM lesson/activity. Teacher content expertise in one of the four disciplines can influence their perception and the product outcome (Wang, et al., 2011; Roehrig, et al., 2012). Another factor to consider is the school context within which the teacher resides.

NRC (2011b; 2011a) outlined four distinct schools that have emerged as STEM schools where the focus and expectations vary depending on the purpose of the school. Students with an aptitude for any of the four STEM disciplines may be heavily recruited to attend a selective school where unique experiences exist for student learning. These selective schools, however are exactly that, selective and may only contain a certain type of student, where as inclusive schools, have no selection criteria and typically serve more of the underrepresented student populations. In some schools, integrative STEM learning experiences are set up through various academies or pathways through career and technical programs. These programs can be found in a traditional high school setting or even as a regional school with a focus on career and technical courses. A fourth pathway can also be found in traditional schools where students can take courses specific in the STEM disciplines, such as Advance Placement (AP) courses, but may not conduct integrated STEM activities on a regular basis.

It is important to recognize the process of implementing an integrated STEM lesson/activity may have obstacles to overcome. Teachers' perceptions and beliefs can greatly hamper the attempt, let alone the design of such a lesson. External barriers, such as standardized curriculum and standardized assessments may impede teachers from being able to conduct such lessons, even if capacity exists. Finally, support from administrators is very important in such an endeavor for they can enhance or deny resources or opportunities dedicated to integrated STEM.

Chapter 3 describes the research procedures to be used in this study to better understand how secondary teachers understand integrated STEM, what a lesson consists of, and why they may not conduct an integrated STEM lesson/activity.

Chapter 3

Methodology

Statement of the Problem

There has been a tremendous effort to bring integrated STEM education into various school settings. Different models of STEM schools (NRC, 2011b; NRC 2014; Researchers without Boarders, 2013) are present even though there are no agreed upon definitions for STEM (Bybee, 2010), Integrated STEM (NRC, 2014), or for the characteristics of an integrated STEM curricula (Jolly, 2014; Cunningham & Higgins, 2014; Carter, 2013, Wang, et al., 2011). Nathan, et al., (2013) and the NRC (2014) reported integrated STEM lessons having positive impact on student learning in a variety of areas, but they also specifically reported that there were inconsistencies in how effective the I-STEM experiences are for students.

While previous reports addressed characteristics of STEM schools and the need for quality STEM teachers (NRC, 2014; Researchers without Boarders, 2013), none listed characteristics pertaining to integrated STEM lessons/activities. Some factors related to integrated STEM lessons suggested use of problem based learning experiences and use of real-world contexts (Jolly, 2014; Cunninham & Higgins, 2014, Wang, et al., 2011), along with the use of deliberateness (Wiggins & McTighe, 2005) in the design of a lesson to ensure cohesion (Nathan, et al., 2013) across the various disciplines and science and engineering practices in order to achieve the desired student outcomes of such lessons. While practical suggestions, three things still remained unclear at the beginning of the study: 1) how secondary teachers defined I-STEM, 2) how a teacher's understanding of I-STEM influenced the design of and assessment of an I-STEM lesson/activity, and 3) what factors influenced a teacher implementing an I-STEM lesson. An interesting outcome from the study would have been to see if teachers were generally purchasing commercially generated lessons/activities (Carter, 2013) or if they were creating their own lessons/activities in order to conduct I-STEM lessons. This, however, was not of primary concern or a component of the study.

Purpose of the Study

I designed this study to better understand how secondary teachers' from each of the four STEM disciplines defined I-STEM, used their definition of I-STEM to influence their design of or selection of I-STEM lessons/activities, if they do conduct such lessons, and assess I-STEM lessons/activities.

Research Questions

The questions that guided this study were

1. How do secondary teachers (grades 9-12) of various STEM disciplines define the concept of I-STEM?
2. How does a select group of teachers defining I-STEM manifest their definition in elements or components related to a lesson or activity as gauged from a review of artifacts submitted?
3. How do select teachers who have designed and/or contributed I-STEM lessons assess student achievement?
4. What factors and/or rationales influence select teachers to conduct or not conduct an I-STEM activity or lesson?

Nature of the Study

A qualitative research approach was used to conduct this study. Qualitative researchers search to find meaning behind the answers (Hatch, 2002, Merriam, 2009) and "how they construct their worlds, and what meaning they attribute to their experiences" (Merriam, 2009, p.

5). Secondary teachers were recruited primarily through a purposeful sampling technique called "snowball or chain sampling" (Merriam, 2009, p. 78). There was no maximum number of persons solicited or pieces of evidence collected since the initial start was an email on a Listserv requesting participating and then encouraging the recipient to share with colleagues on a system of referrals, however, a goal of six (6) completed surveys from teachers, along with artifacts from activities/lessons, will be set as a minimum. Data was collected through a survey, artifact submission, email responses, and interviews, until 1) the deadline set for data collection expired or 2) it appeared the data being collected began to be repeated, whichever came first. It was analyzed through a hybrid approach of typological analysis and inductive analysis in order to develop common categories or patterns found in the evidence provided.

Participants: Secondary Teachers Grade 9-12. Subjects were volunteer teachers from grades 9 through 12 choosing to contribute in the research. Requests were sent through the following professional organizations: National Science Teachers Association (NSTA), the International STEM Education Association (ISEA), National Council of Teachers of Mathematics (NCTM), and International Technology and Engineering Educators Association (ITEEA). Each organization was asked to distribute the survey on their member Listserv, or distribution list equivalent. Respondents who volunteered and completed a survey (Appendix 1), were asked to provide their best example of a secondary integrated STEM activity, which could include a lesson plan, a textbook activity from a specified page number and book, PowerPoint slides, teacher notes/handouts, worksheets, laboratory activities, assessments (tests and quizzes), and gave brief summaries of expected outcomes and beliefs about how the lesson is an integrated STEM lesson. As part of the survey, each person was asked to provide contact information, if they wish to be contacted, for follow up questions (Appendix 2) giving a teacher a chance to elaborate on and for the researcher to clarify their answers provided in the survey regarding their lesson/activities artifacts and their understanding of integrated STEM. The number of participants was a small but diverse group of individuals (n = 10). Table 3-1 provides a synopsis of the participant diversity.

Table 3-1

Demographic Data of Participants (n =10)

Subjects	Grade Level				Professional Organization				Pathway Designation*			
	9	10	11	12	ITEEA	ISEA	NCTM	NSTA	I	S	Yes	No
					Engineering	Technology	Mathematics	Science				
Mike			X		X					X		
Preston		X			X							X
Archer	X				X							X
Michelle		X						X				X
Gavin				X				X				X
Joel	X							X				X
Shannon			X					X				X
Marsha	X							X			X	
River		X						X				X
Maverick	X					X			X			
Totals	4	3	2	1	3	1	0	6	1	1	1	7

* I- Inclusive-No criteria to attend, draws from surrounding area/schools; S- Selective- Criteria exists to attend, draws from surrounding area/schools; Yes-Designated Pathway or Academy for Students; No- Does not have a Designated Pathway or Academy for Students

Based on the number of responses, six participants were male and three were female. Only one was unknown, Preston. Each grade level and pathway options had a representative, while only three of the four professional organizations were represented. The survey asked each participant to select either the grade they taught or, if they taught more than one grade level, to select the grade level most associated with their I-STEM lesson or experience. Four participants taught or most associated with the Grade 9, three taught or most associated with Grade 10, two taught or most associated with Grade 11, and one taught or most associated with Grade 12.

Three participants identified with the ITEEA organization, one selected ISEA, and six, the majority of participants, designated NSTA as their professional organization. None identified as NCTM, so no subjects identified with the mathematics discipline. From the various pathway options, the majority (7) identified their current school as NOT having a designated I-STEM academy or a pathway for students. However, each remaining pathway had one teacher who worked either in a school that did have a designated I-STEM pathway, was an Inclusive school that drew from the surrounding area and did not have an admissions criteria, or was a Selective School, which drew from the surrounding area and did have an admissions criteria.

Each person who completed a survey was given a pseudonym that reflects his or her gender. Only one individual was unknown about gender identity and was given the name Preston. This chapter describes the information shared by the participants from the surveys, artifacts, email responses, and interviews and highlights their results.

Data Collection Methods

Survey. A survey (Appendix A) was sent to the each participant prior to any follow up interviews. Results from the survey helped to identify teachers having a definition of I-STEM and conducted a lesson/activity, and those who had a definition, but did not conduct an I-STEM lesson/activity. These survey results helped identify teachers who were willing to participate in a follow up interview, but also created targeted, specific questions based on responses (Appendix C). Survey questions were intended to address Research Questions 1 and 4.

Interviews. Semi-Structured Interviews (Merriam, 2009; Hatch, 2002) were designed to gather additional data specific to all Research Questions based on the information submitted and artifacts provided. Each participant was asked a set of initial questions (Appendix B).

Additional questions or follow-up questions (Appendix C) depended on the survey and oral responses given or from artifacts submitted. Follow up data was completed from interviews or email responses. Participants were asked to provide in their survey response which of the one they preferred as a way to provide follow up information. These interviews and email responses were intended to address Research Questions 1 and 4.

Phone Calls. For a respondent indicating a follow up conversation via phone call, one of two steps occurred. For those who indicated an email, a message (Appendix E) was sent to the person proposing a date and time for the phone call. If there is only a phone number, then a call was made to set up an agreed upon date and time for the interview. Those who conducted a phone call interview was informed the conversation was going to be recorded for accuracy in information and later transcribed for research purposes. Three participants conducted Phone call interviews, which lasted approximately 30 minutes each.

Email Responses. A participant who wished for an email experienced the following protocol. An initial email was sent to the provided email and confirmed it was still active and thanked them for their participation. Appendix E contains the email statements. The
As soon as a participant responded with their follow-up information, it was printed and analyzed.

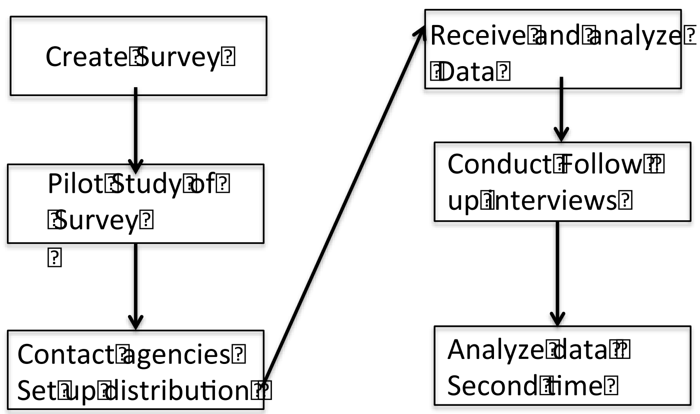
Unobtrusive data. Artifacts, such as lesson plans, lessons, and rubrics, were considered unobtrusive data (Hatch, 2002). These resources were a useful form of gathering data. According to Hatch (2002), these types of data told "their own story independent of the interpretations of participants" (p. 119) allowed for a "comparisons with data from other sources such as…interviewing" (Hatch, 2002, p. 119). Artifacts were requested in in the survey and submitted through a digital platform, such as *Gmail.*

There was a wide possibility of a teacher's interpretation of artifacts, so it was unknown exactly what types of artifacts were going to be sent. Each one was accounted for through the creation of an artifact spreadsheet listing every artifact submitted by each participant and was then analyzed through the inductive process. Artifacts collected were designed to address Research Questions 2 and 3.

Specific Research Procedures

The research process followed the flow chart as illustrated in Figure 2.

Figure 2- Flow Chart of Procedures



The process began by contacting various professional associations from different STEM disciplines and requesting they send out the survey to their members (Appendix A). As provided in the directions of the survey, each participant who received an email were asked to participate in the survey and then share the email with a colleague who was willing to complete the survey, who was then asked to pass along the survey, and so on and so forth. The colleagues could be in the same building or district or from a neighboring school or district.

Organization of Data and Analysis Procedures. Once the data was stopped being collected, I organized the ten subjects response data into a spreadsheet with 10 columns that contained their pseudonym name, grade level, and organization affiliation and four rows so their survey responses could be see in parallel. Each row represented an Item question from the survey questions. Row One was Definitions, Row Two was Objectives Meeting Definition, Row Three was the Objectives/Goals of Submitted Lesson, and Row Four was How Students were Assessed. Only six of the ten subjects provided follow-up responses. Following previous steps, I placed the email and interview responses in parallel related to the follow up questions (Appendix B).

Categorization of Survey Data. I organized the data from the survey into a spreadsheet that put Items 4, 9, 10, and 11 in parallel with one another from each of the subjects' responses. This allowed me to see each response and begin to identify patterns and common statements. For each of the item response, I color coordinated similar terms and phrases, which helped distinguish concepts from one another.

Each participant was grouped together according to professional organization affiliation within each category. Therefore, all participants who identified themselves either as ITEEA, NSTA, or ISEA, were grouped together. Their data was analyzed within each professional association and then all of the participant's data was analyzed to determine if any new data or conclusions could be drawn. In other words, each organization's participant had their statements analyzed amongst themselves and then assessed as a whole group within the broad survey category.

Typological Analysis. Two broad typologies were considered for an initial sorting of data categories based on survey responses: Teachers who conduct I-STEM lessons, and Teachers who do not conduct I-STEM lessons. Results from the surveys, however, did not produce enough of a data set to conduct such a comparison. Therefore, the typological analysis did not occur in this study.

Inductive Analysis. Open coding (Merriam, 2009) was conducted and created additional categories. As Merriam (2009) describes, "assigning codes to pieces of data is the way you begin to construct categories" (p. 179) and is more commonly called an "open coding" (p. 178). Once the data has been evaluated, analysis coding (Merriam, 2009) occurred, which created some additional categories. Surveys, interviews, responses from both phone and email, and artifacts were re-analyzed within their organizations and in their entirety through an open coding analysis that developed additional theme generations and through constant comparison better defined the categories which emerged from the three different collection methods. This process determined what patterns were found across the spectrum of participants and within the various professional organizations.

Survey Items 3 and 5 collected data from participants about the influence and type of school with which a participant may be associated and identified any patterns that existed based on the school model. Based on research from NRC (2011), three types of STEM schools currently exist: selective, inclusive, and STEM-focused Career and Technical Education. Participants were asked to identify from various choices, which school type best describes them.

Survey Items 8, 9, and 10 were designed to understand how a lesson or activity was designed and if there were any factors influencing the products submitted, while Survey Item 11 was examining the ways students were being assessed during the initial review of the data. The first analysis of the data from each participant determined if there were any formative assessments, summative assessments, or both. Based on the evidence provided by the participants, a second category was used to analyze the data to determine types of questions being used in the assessments. Table 3-2 outlines the categories considered during the Analysis.

Table 3-2

Categorical Type Assessment Questions

Type 1: Questions that address the basic details and process and are easy
Type 2: Questions that consist of more complex ideas and processes and are more difficult for students
Type 3: Questions that go beyond the material taught in class

Items 6 and 7 were intended to better understand participants account of why one chooses to conduct an integrated STEM lesson or activity. Responses provided for this question were analyzed using an open coding format (Merriam, 2009) generating broad categories followed by analysis coding (Merriam, 2009) that further identified categories.

Formal interviews (Hatch, 2002) were conducted with some of the participants, with field notes collected as part of the interview process. Subjects who did not want an interview were given the same questions (Appendices B) in an email. They returned their answers via email. Any follow up questions (Appendix C), were submitted via email. All responses were analyzed through the hybrid analysis consisting of the open coding (Merriam, 2009) process. For any initial open coding identifying initial themes, categorical coding occurred to better define the categories from all the evidence collected.

Steps for collecting the was the following:

1. Set up a data collection device through Google Forms.
2. Constructed a survey to include rationale and data collection capabilities for information, like demographics and lesson descriptions.
3. Contacted various science agencies representatives, like NSTA, ISEA and ITEEA, to ask

for assistance in distributing my request for artifacts and responses.

4. Sent email to representatives for distribution.
5. Set appropriate length of time for data collection based on frequency of artifacts being submitted.

Selections Procedures

There was a probability the requests for teacher participants could produce dozens and dozens of responses. However, the study generated a number fewer than 20, therefore, all subjects' data and artifacts were used.

Research Timeline

Data collection started in late January 2016 by sending surveys to each respective group. Data collection window lasted approximately eight weeks, since the data continued providing original data. During the eighth week, a decision was made to not extend the data collection window, since the minimal number of participants had been meet.

Ensuring Reliability and Rigor

The topic of I-STEM impacts the areas of planning, instructing, and assessing in teachers' classrooms. Attempting to better understand this paradigm (Hatch, 2002; Kuhn, 1993) of integrated STEM as manifested in teacher planning and activities was the focus of this research through a qualitative study. Campbell and Machado (2013), in their article, reiterated there was "no single method of guaranteeing the quality for [a] qualitative study" (p. 574), but they strove to achieve that ideal for their study. This research study was no different.

It was not uncommon for some skepticism to be raised as to the validity and reliability of qualitative studies, but measures were being taken to ensure "trustworthiness" (Golafshani, 2003, citing Lincoln & Guba, 1985) by "establishing confidence in the findings" (Golafshani, 2003, p.

602) through various techniques of validation. Thoughtful and careful design (Hatch, 2002; Merriam, 2009), of this research approach paralleled the methodology of the “naturalistic inquiry” (Hatch, 2002, p. 26.). Hatch (2002), drew much from Lincoln and Guba (1995) and identified “Naturalistic Inquiry” (p. 26) as the “goal of capturing naturally occurring activity in natural settings” (p. 26). Even though previous authors claimed there was no one method for qualitative research, this particular qualitative study was designed to parallel data collection procedures associated with naturalistic inquiry. Table 3-1 outlines of the naturalistic inquiry procedures, as presented by Hatch (2002). Results were intended to be credible, transferable, dependable, and confirmable (Merriam, 2009) and to increase one’s level of “understanding” (Merriam, 2009, p. 212) related to the topic addressed in this paper.

Table 3-3

Procedures associated with Naturalistic Inquiry

1.Determine a focus for the inquiry.
2. Determine the fit of the paradigm to the focus.
3. Determine the fit of the inquiry paradigm to the substantive theory selected to guide the inquiry.
4. Determine from where and from whom data will be collected.
5. Determine successive phases of inquiry.
6. Determine instrumentation.
7. Plan data collection and recording modes.
8. Plan data analysis procedures.
9. Plan logistics.
10. Plan for trustworthiness.

Credibility

Qualitative research continuously needs to justify its processes and outcomes, because it works on the "assumptions…that reality is holistic, multidimensional, and ever-changing…" (Merriam, 2009, p. 213). This could create a credibility problem in that no one methodology exists (Campbell & Machado, 2013) and the paradigm in which it operated could have multiple understandings of realities. For my study, I used steps found in the naturalistic inquiry method and operated in the theoretical framework of a constructivist paradigm (Hatch, 2002), where participating individuals constructed the realities. In other words, the participants created a "subjective reality" (Hatch, 2002, p. 15) by working in collaboration with the researcher.
In another effort to show this research process and its results were credible, triangulation was employed using three different methods of data collection: survey, unobtrusive data (artifacts) and interviews.

Triangulation. This method of authentication increased validity to the findings based on the data provided. To triangulate data, I compared and crosschecked data (Merriam, 2009) with different sources to confirm or negate statements or concepts shared by participants. Validity for the study occurred in the efforts of triangulation (Merriam, 2009, Golafshani, 2003) of the data by comparing the results from the survey, from the submitted artifacts, from email responses, and from the interviews corroborated information found in the three different resources. Each component was analyzed to ensure what the teacher stated in the interview was reflected in their survey responses and artifacts submitted. In other words, this process was used to ensure the "results [were] consistent with the data collected" (Merriam, 2009, p. 221).

Triangulation enhanced the credibility of unobtrusive data and "improve[d] confidence in reporting findings based on such information" (Hatch, 2002, p. 121). Participants were made aware of what types of artifacts will be acceptable at the beginning of the process (Hatch, 2002) for they were asked to share artifacts they believed represented an integrated STEM lesson/activity, which could be anything from a lesson plan to an identified page out of a textbook.

Transferability

This concept can be problematic for qualitative studies (Merriam, 2009), but, like quantitative studies, it can have "generalizations…made within specified levels of confidence" (Merriam, 2009, p. 224). It all really depended on whether or not the reader of the study found the information fitting into "his or her particular situation" (Merriam, 2009, p. 224). The responsibility of the researcher was to provide "enough detailed description of the study's context" (Merriam, 2009, p. 224) for the reader to decide if the research was applicable to their situation. To address this, I used "thick descriptions" and "maximum variation" in the study (Merriam, 2009, p. 227).

Thick Description. This strategy referred to the "description of the findings with adequate evidence presented in the form of quotes from participant interviews…and documents" (Merriam, 2009, p. 227). By the time a user finished reading the information, he or she would have a good sense of who the participants were and what their perceptions were about integrated STEM. This was accomplished by providing a "highly descriptive, detailed presentations of the setting, and in particular, the findings of the study" (Merriam, 2009, p. 227). For this study, details were provided regarding demographics in three primary areas: 1) grade level, 2) an organization they most associated with, 3) and whether or not they conduct I-STEM lessons/activities. The findings were discussed in the context of the generated categories and themes and included short quotes or statements (Merriam, 2009) from individuals to help the reader better understand the factors that made the different categories.

Maximum Variation. The concept of I-STEM deals with science, technology, engineering, and mathematics. Therefore it was plausible that representatives in each of the four disciplines were conducting some version of integrated STEM lessons, as understood from their perspective. Participants were solicited from each of the four disciplines through the specific organizations of National Science Teachers Association (NSTA), the International STEM Education Association (ISEA), National Council of Teachers of Mathematics (NCTM), and International Technology and Engineering Educators Association (ITEEA). The study only had three of the agencies with whom subjects self-reported an association.

Dependability

Reliability for this research project assessed the consistency of the data that was collected over the time of the research (Merriam, 2009; Golafshani, 2003). This can be problematic for a qualitative study, since human subjects can change their understandings and answers over time (Merriam, 2009). To address these concerns, this study controlled the distribution of the instruments used to collect data, provided an audit trail, applied triangulation when applicable, and verified information from participants through a “member check” (Merriam, 2009, p. 217). For each participant, the same survey will be administered (Appendix 1) and the same initial research questions (Appendix 2) will be asked. The reliability of each set of data over time will rest on the participants who answer and contribute to the study.

Audit Trails. The relevance of an audit trail provided a reader a description of how the study was conducted and how the “data were collected, how categories were derived, and how decisions were made…” (Merriam, 2009, p. 223 throughout the process. This can be best thought of as a researcher's journal log (Merriam, 2009). Located in the appendices, I placed the survey, an explanation of the survey's purpose for participants, the initial list of survey questions, the interview questions, the follow up interview questions, and the emails sent to subjects who wanted to send email responses rather than an interview.

Member Checks. Once data was collected from participants, analysis occurred and categories were created based on comments and artifacts. Six of the ten subjects provided contact information. To ensure correct interpretation of the information provided, participants, who provided contact information, received a follow-up email asking them to confirm my interpretation of their comments and artifacts. This helped minimize any misunderstandings and any bias on my part (Merriam, 2009, citing Maxwell, 2005).

Confirmability

Merriam (2009) states, "Investigators need to explain their biases, dispositions, and assumptions regarding the research to be undertaken" (p. 219). As stated previously in the *member checks* section, it is important to remove any bias from the report and analysis of the data. This is accomplished by understanding one's position of 'self' in the study (Campbell & Machado, 2013). In other words, it is necessary to account for one's "own voice [and one's] own place in the telling of other's stories" (Hatch, 2002, p. 203)

Reflexivity. Campbell and Machado (2013) highlight an argument regarding qualitative studies that researchers "cannot maintain objectivity" (p. 574) since they interact with their subjects. This argument is countered by reflexivity, where the researcher outlines biases and perceptions about the study and takes into account how the presence of the researcher can impact the study (Campbell & Machado, 2013). I understood my various experiences and conversations could impact my perception about this topic, but did believe there was value to share in the information collected in this study.

The idea of an integrated STEM lesson was not unique to any one of the four STEM disciplines, but many of the resources and articles pertaining to I-STEM lessons/activities were based in engineering design methods. This author anticipated another delivery method, scientific investigation, existed for integrated STEM lessons/activities. It may not had the same publicity as the engineering design model or may not be viewed as integrated STEM, if it used as the model of delivery. Research existed describing a continuum of STEM integration, along with some definitions of descriptions. However, it was unclear if and when any teachers move along the continuum to vary the levels of integration between the disciplines. There was concern by the author that external factors encouraged only engineering design types of I-STEM lessons/activities or prohibited the implementation of any I-STEM activities/lessons. This concern was based on a school or teacher's use of a commercially produced lesson or activity; since many were an engineering design format (Carter, 2013). My other concern was the lack of understanding schools, districts, and states had regarding I-STEM, as evident by the lack of an agreed upon definition. Various interpretations of I-STEM have implications for implementations within the classroom or in a district, as discussed above.

Author's Perception and Definition of I-STEM. This researcher acknowledges and understands his participation in various STEM/Science Education related classes, professional development sessions, professional conferences all contribute to his current understanding of I-STEM. Based on these previous experiences I developed an understanding of what I believed I-STEM is and what I-STEM is not, both on a micro-level (individual) and a macro-level (Building/District/State).

I previously and formally defined STEM as an "acronym commonly referred to one or more of the four disciplines (science, technology, engineering, and/or mathematics) that are seen as related to each other" (Hayward & McComas, 2014, p. 102). Since I wrote that definition, my understanding of integrated STEM had developed into the following:

> I-STEM is the deliberate integration of three or all four of the STEM disciplines within a single learning experience. This learning experience can occur within one or more classrooms and can occur over various lengths of time, such as one class on one day or over multiple days in various classes, but must occur in a shared learning unit. Each discipline must be applicable to scenario, contribute to the outcome, and must retain the integrity of the individual STEM discipline in which the user applies appropriate content knowledge and skills associated with the disciplines.

From my studies and experiences, I have come to understand the need to distinguish my previous definition from my current definition of I-STEM, specifically in the delineation of the number disciplines needed to be considered integrated. The distinction is twofold. First, there is an inherent level of increased complexity when adding three or four disciplines to a solution. This entails more deliberate application of the applicable skills and content knowledge relevant to the solution of the problem; therefore, the user must have more intimate knowledge of the disciplines or an appropriately selected group of individuals contributing to the solution. Second, it distinguishes from a STEM activity that already occurs in a traditional physics or chemistry classroom, where two disciplines, in the very nature of the course, already exist for the user to experience.

Author's Definition of I-STEM Education. Too many persons used I-STEM lessons and I-STEM education interchangeably, when this author believed they were distinct entities. They were intertwined, but had different implications. I-STEM lessons were a micro concept addressing the unit or classroom experience, while I-STEM Education was a macro concept and dealt more with the vertical and horizontal design of the learning students would encounter in a K-12 setting. Some believed I-STEM education prepared students to be "college and career ready" (CCSS, 2012; NGA, 2007) and ready for the workforce; this was most definitely a potential outcome of such a program.

The author's definition for I-STEM Education during this paper was

> A systemic integration of the four content areas of Science, Technology, Engineering and Math in inter-disciplinary or trans-disciplinary units and its deliberate employment of such learning experiences for all K-12 students to develop appropriate content knowledge and process skills to solve problems (Scientific) or create solutions (Engineering) preparing them for tomorrow's society and opportunities.

This author understood inter-disciplinary STEM integration as a lesson centered primarily in one of the four disciplines and drew from the other disciplines unequally. Trans-disciplinary, from the author's perspective, can be thought of as a "meta" unit where three or all four disciplines are integrated and are applicable to the problem design.

I understood the nature of I-STEM Education more as a philosophy or belief that individual STEM literacies should be integrated throughout the entire learning process for each student K-12. Bybee (2012) agreed with that sentiment when he wrote, "STEM literacy involves the integration of STEM disciplines and four interrelated and complimentary components" (p. 31). It is this individual and collective understanding of STEM literacies as the outcome that drives the nature of I-STEM Education.

STEM Literacies. Interestingly, the NGA committee (2007), in its effort to assist states in promoting an agenda, did not provide a definition for I-STEM Education. Instead they cited Lederman (2007) and used his definition of *STEM literacy*. Lederman (2007) defined *STEM literacy* as "the ability to adapt to and accept changes driven by new technology work with others (often across boarders), to anticipate multileveled impacts of their actions, communicate complex ideas effectively to a variety of audiences, and perhaps most importantly, find 'measured yet created solutions to problems which are today unimaginable'" (NGA, p. 3).

I-STEM education was distinguished from STEM literacy in the following fashion: STEM Literacy is an outcome of student learning, is a product of I-STEM Education, and should be a primary goal of any I-STEM Education program. This was important to understand and clarify, because there was a distinction between the *nature* of I-STEM Education and the *products* of I-STEM Education, such as science, technology, engineering, and mathematics literacies development. In each of these, there are certain skill sets students will acquire or enhance as they experience I-STEM lessons. The goals of *STEM literacy* were for students to understand and connect science, technology, engineering, and mathematics literacies within school, community, work, and global issues, while developing skills necessary to compete in the new economy and recommends an interdisciplinary instructional approach coupled with the study of rigorous academic concepts in real-world contexts (Tsupros et al., 2009).

Each STEM letter has literacies defined by their respective organizations. In the NGA (2007) publication they were presented collectively citing the appropriate organization or organizations defining each respective category. They are as follows:

1. *Science* is the study of the natural world, including the laws of nature associated with physics, chemistry, and biology and the treatment or application of facts, principles, concepts, or conventions associated with these disciplines.
2. *Technology* comprises the entire system of people and organizations, knowledge, processes, and devices that go into creating and operating technological artifacts, as well as the artifacts themselves.
3. *Engineering* is a body of knowledge about the design and creation of products and a process for solving problems. Engineering utilizes concepts in science and mathematics and technological tools.
4. *Mathematics* is the study of patterns and relationships among quantities, numbers, and shapes. Mathematics includes theoretical mathematics and

applied mathematics (p. 7).

Bybee (2010) also argued the need to clarify and incorporate STEM literacy into the I-STEM conversation. His approach to STEM literacy identified more holistic outcomes for students and being able to apply them to "…personal, social and global issues" (Bybee, 2010, p. 31). STEM literacy, for Bybee (2012) was

> - Acquiring scientific, technological, engineering, and mathematical knowledge and using that knowledge to identify issues, acquire new knowledge, and apply the knowledge to STEM-related issues.
> - Understanding the characteristic features of STEM disciplines as forms of human endeavors that include the processes of inquiry, design, and analysis.
> - Recognizing how STEM disciplines shape our material, intellectual, and cultural world.
> - Engaging in STEM-related issues and with the ideas of science, technology, engineering, and mathematics as concerned, affective, and constructive citizens (p. 35).

Defining the respective literacies and knowing each the applications of the literacies was important. Students should understand each STEM component individually and independently from one another, but more importantly, realize how all the literacies together are greater as a whole and are collectively used to solve real-world problems.

Author's Perception of What I-STEM is Not. Based on my experience and definitions, I understand two representations for STEM education: I-STEM Education and S.T.E.M. Education. Each depiction could be embodied on both a macro (school/district) and micro (classroom) level. I-STEM Education integrated all disciplines deliberately throughout the student's learning experiences, both in a classroom/unit experience and over the K-12 grades. S.T.E.M. Education focused primarily on the skills and content within a single discipline. In other words, it provided various courses based on STEM disciplines, such as mathematics, technology, engineering, or science. We see these most often represented by singular courses in a high schools setting, such as Advance Placement (AP) Biology, physics, AP Physics, chemistry, AP Chemistry, and environmental science courses, just to name a few. However, there were no deliberate attempts to integrate three or more of the discipline concepts or even associate natural connections to a larger I-STEM idea. This was best seen in the *US News and World Report* using Advance Placement criteria from College Board in selecting high schools as their *Best STEM Schools for STEM.* They explained their methodology as the following excerpt taken directly from their website (http://www.usnews.com/education/best-high-schools/articles/stem-rankings-methodology):

> To be included in the U.S. News Best High Schools for STEM rankings, a public high school first had to be listed as a gold medal winner in the 2015 U.S. News Best High Schools rankings. That meant that the top 500 nationally ranked high schools were eligible for the STEM rankings. Those eligible schools were next judged nationally on their level of math and science participation and success, using Advanced Placement STEM test data for 2013 graduates as the benchmark to conduct the analysis. The U.S. News Best High Schools for STEM rankings methodology does not rely on any data from the U.S. Department of Education. AP is a College Board program that offers college-level courses at high schools across the country. College Board defines STEM Math as AP courses in Calculus AB, Calculus BC, Computer Science A and Statistics; and STEM Science as AP courses in Biology, Chemistry, Environmental Science, Physics B, Physics C: Electricity and Magnetism and Physics C: Mechanics. Math and science success at the high school level was assessed by computing a STEM Achievement Index for each school that ranked in the top 500 of the 2015 Best High Schools. The index was based on the percentage of all the AP test-takers in a school's 2013 graduating class who took and passed college-level AP STEM Math and AP STEM Science tests. The higher a high school scored on the STEM Achievement Index, the better it placed in the Best High Schools for STEM rankings.

This ranking system by College Board perpetuated the S.T.E.M. model of understanding and increased the confusion of what really are I-STEM learning experiences. The author did not argue or disagree with teaching such subjects in a school setting; these courses were rigorous and rich in content. My greatest concern by this description was numbers of courses offered and score outcomes were being interpreted by the *US News and World Report* as the "best" of a STEM experience in a high school setting, which possibly influenced schools' and districts' understanding of and decisions about how to implement an I-STEM learning experience.

As seen with this explanation, this extensive background may influence the analysis of the data in the development of categories and the assessment to which data may or may not be included. To minimize bias within the data collection or analysis, audit trails were implemented.

Ethical Practices

The quality of this project relied upon the ethics applied by the researcher (Merriam, 2009). Prior to the distribution of the survey, all standards of conduct as set forth by the university was adhered to, specifically detailed in the institutional review board (IRB) policies (Appendix D). Participants received an overview of the purpose for the study and explained that consent was given if they choose to complete the survey. Flexibility was given to participants by allowing them to contribute at a level they feel comfortable with. If they choose to only submit responses in the survey, then that was acceptable. If they wished to participate in an interview process or email response, they contributed information in that manner as well. Great effort was taken to ensure participants' information and comments were be shared or used against them in any manner.

Summary

This qualitative study was under a constructivist paradigm influenced by the naturalistic inquiry method and was designed to capture teacher's perspectives and artifacts related to integrated STEM lessons/activities. Teachers from each of the STEM disciplines were encouraged to participate and provide information for this research. As teachers responded to the survey and submit artifacts, their data was placed initially into a spreadsheet that organized and provided a platform to analyze information through a hybrid of typology and open coding processes. Steps were taken to ensure rigor and reliability through various means, such as triangulate the data from surveys, unobtrusive data, and interviews in order to validate the information. Chapter Four will go into specific details about the findings of the data.

Chapter 4

Results

Introduction

My previous chapters discussed reasons for the study and literature about what some research was finding in regards to integrated STEM. This information revealed missing data and questions that needed answering. I was interested in better understanding how secondary teachers' (grades 9-12) defined I-STEM, what they perceived as an I-STEM lesson or activity, and how they evaluated students from the provided information. My study looked for any discernable patterns or shared characteristics in the stated I-STEM definitions, in ways the subjects' definitions may have manifested into a submitted lesson or activity, in how teachers assessed students in such lessons or artifacts, and in reasons why teachers conducted such lessons.

Data from survey responses, email responses, and interviews, were analyzed using a hybrid of typological and inductive analyses to determine if there were any common characteristics or patterns in their understanding of I-STEM definition (Research Question 1), how their perceptions of I-STEM were manifested in submitted artifacts (Research Question 2), how teachers assessed students in based on submitted artifacts (Research Question 3), and understand teachers' factors or rationales influencing their teaching of an I-STEM lesson (Research Question 4).

Research Question 1- How do secondary teachers (grades 9-12) of various STEM disciplines define the concept of I-STEM?

Findings on Research Question 1

Each of the ten (N=10) respondents self reported his or her definition of integrated STEM. From these statements, an analysis of the subjects' definitions/descriptions produced four broad themes: STEM disciplines identified by subjects, Subjects' description of integration, Lesson delivery methods, and Student outcomes as stated by subjects. The following paragraphs address the findings from each of these themes as it was related to Research Question 1.

STEM Disciplines Identified in Subjects' Definition/Description. Analysis of the data from the subjects' surveys (Appendix A) and interview question 1 (Appendix B) provided some interesting insight into how these teachers defined I-STEM. Only Michelle, Gavin (both NSTA) and Archer (ITEEA) included all four of the disciplines in their definition/description. When looked at collectively (Table 4-1), the group of subjects identified all four STEM disciplines. However, technology and math were most identified STEM disciplines in the definitions/descriptions. This result was an unexpected and unanticipated outcome. Science and Engineering were found explicitly mentioned in only five of the ten definitions submitted in the survey.

Six of ten definitions contained either the term "technology" or concept related to technology. Mike, Archer, Preston (all ITEEA) incorporated technology into their definition/description for I-STEM. This was seen by the courses mentioned, such as "Technology of Robotic Design" and "Technology Foundations Course." Michelle (NSTA) stated technology in her definition/description with AutoCAD (Computer-aided Design), along with Marsha (NSTA) who included the term "technology" as part of her definition/description. It was encouraging to consistently find the three respondents who self-reported as members of ITEEA included technology concepts into their definition, since it was the organization that explicitly identified technology and engineering components in their organization's definition (see Chapter 2). Even though technology was mentioned in the definition of participants from NSTA, ISEA and ITEEA, some described the application of technology in a specific manner. Three of the six subjects who included the discipline of technology described it as a support discipline that was "brought in" after the lesson was underway. Four participants did not mention technology in either their definition/description or interview/email response.

Of the ten participants, only four (Michelle, Gavin, River, and Maverick) included mathematics in their definition. Similar to technology, mathematics was perceived in the respondents definitions/descriptions as a support discipline, as a "tool" used to support science and engineering disciplines.

River (NSTA) and Maverick (ISEA) did not identify any specific STEM disciplines in their definitions from their survey responses. Joel's (NSTA) definition/description was presented more as his philosophy of how students should experience I-STEM rather than the nature of what he thought it was. Maverick (ISEA) stated in general terms "all content areas" as he referenced I-STEM in his definition/description. River (NSTA) and Maverick (ISEA) did identify specific STEM disciplines in their interview responses, while Joel (NSTA) did not. Maverick (ISEA) explained lessons were based on a physical science concept, chemistry or Newton's Laws, respectively. Table 4-1 illustrates how subjects presented their incorporation of the STEM disciplines as submitted in their I-STEM definition.

Table 4-1

STEM disciplines mentioned in Subjects' Definition of I-STEM.

STEM Disciplines/ Participants*	Science (Physics/Chemistry Environmental*)	Technology	Engineering	Math
Mike(11) ITEEA		X	X	
Preston (10) ITEEA	X	X		X
Archer (9) ITEEA	X	X	X	X
Michelle (10) NSTA	X	X	X	X
Gavin (12) NSTA	X	X	X	X
Shannon (11) NSTA			X	X
Marsha(9) NSTA		X		
River (10) NSTA	X			X
Maverick (9) ISEA	X			X

* Joel (NSTA) is not included in this table since he did not mention any specific STEM disciplines.

In follow up interview or email responses, six subjects expanded on their definition and identified specific STEM disciplines. Table 4-2 below illustrates the definitions submitted in survey and/or with those who provided follow-up responses. Mike (ITEEA) expanded on his definition by giving additional information related to technology and engineering. He explained he taught several career and technical education (CTE) courses and Project Lead the Way classes, along with specific coding sections. Archer (ITEEA) elaborated his definition by describing specific science and engineering concepts taught in his classes. He described his primary course was the Technology Foundations course in which he incorporated alternative fuels and power sources in an engineering design activity. Archer (ITEEA) also discussed his teaching of an Auto-CAD (Computer-Aided Design) class. Michelle (NSTA) expanded on her definition as she explained she saw math, science, and technology as equal components, or, in her words "integrative STM". Gavin (NSTA) offered additional details on his definition by elaborating on his previous statement math and technology were "tools". For him, science and engineering are primary concepts for student to learn and students use math and technology as needed. This was seen in his submitted artifact where physical science was, according to him, his primary STEM discipline. Maverick (ISEA) did not state any specific STEM disciplines in his definition. When asked about this, he explained he was interested in developing both science and math skills. For this particular lesson, physical science (Newton's Laws) and the associated math were the primary parts of the lesson.

Table 4-2

Summary of I-STEM Disciplines from Subjects' Definitions/Description and Interview

Participants (Grade/ Organization)	Identified STEM Disciplines from Respondents Definition and/or Interview Question 1
Mike (11/ITEEA)	• Digital Electronics, Civil Engineering and Architecture, Technology of Robotic Design and Engineering Design and Development. • CTE Courses • Engineering Courses • PLTW Courses • Python/Arduino Sketch • Technology of Robotic Design
Preston (10/ITEEA)	• Math and science related curriculum • Technology Education class.
Archer (9/ITEEA)	• High school science, math, technology, and/or engineering class framework. • Technology Foundations Course • Alternative fuel and power sources-wind, solar, nuclear • AutoCAD
Michelle (10/NSTA)	• Science, math, engineering and technology • Integrative STM • Technology, Math, and Science • AutoCAD
Gavin (12/NSTA)	• Science and Engineering Practices • Technology and Math • Foundations of Physical Science • Fundamental [science] laws
Shannon (11/NSTA)	• Engineering and Math
Marsha (9/NSTA)	• Technology
River (10/NSTA)	• Scientific Literacy • Mathematics
Maverick (9/ISEA)	• Generally stated "All content areas" • Newtonian Problem • Science skills and Math skills

*Joel (NSTA) was not included in this chart since he did not provide any specific STEM disciplines in his definitions from Survey Item 4 or respond to any interview requests. Other survey items did reveal specific content areas that were considered as part of other research questions.

Subjects' Description of Integration in their Definition. How subjects described and understood the relationships between the STEM disciplines in their definitions varied by individual and not necessarily by organization affiliation. As illustrated in the tables above, technology and math were the most often cited STEM disciplines in subjects' definitions. However, when it came to the subjects' understanding of the integration of disciplines within the definition/description, science and engineering were the most common disciplines discussed by the subjects. In some of the statements, respondents appeared to describe two of the disciplines as equal contributors in the concept of Integrated STEM with the remaining disciplines applied as needed, while others had one central discipline as their focus with the remaining disciplines applied as needed, if at all.

Mike and Archer (both ITEEA) appeared to understand engineering and technology disciplines as equivalent, both being contributed equally in the experience for students, while Preston, from his definition, appeared to describe technology that "reinforced" science and math. For the ITEEA participants, Preston appeared to differ from Mike and Archer, who applied both engineering and technology disciplines equally. Mike's (ITEEA) statements regarding engineering and technology were present both in his definition and in the context of the courses he taught. Archer (ITEEA) also described the students' application of engineering and technology in equal importance as part of his definition/description. Students in his "Technology Foundations Course" would apply both in the development of a solution, which in this case, was a model using an alternative fuel and power source. Preston appeared to align with Maverick's (ISEA) perception that science and math were equally applied disciplines. While Maverick (ISEA) did not identify any particular STEM disciplines in his definition from Survey Item 4, he described in his interview math and science disciplines as equal contributors in his lesson.

Students were to work on a “Newtonian problem” having “science and math skills all work together to give [the] broadest and…complete understanding of the task.” Maverick (ISEA) further clarified his understanding of integration could be “trans-disciplinary” or “interdisciplinary” concepts. For him, trans-disciplinary was a “thematic project” allowing students to apply and array of STEM content knowledge and multiple skills associated with STEM, while the interdisciplinary concept is more “focused” and “addresses a specific problem.” The Newtonian problem was one that represented his description of interdisciplinary.

Gavin (NSTA) stated mathematics and technology were “tools” used to accomplish the lesson, which supported primary disciplines of science or engineering. River (NSTA) and Marsha (NSTA), started their lesson focusing on science curriculum and then brought in math and/or technology curriculum at a later point. Their description of integration implied one or more of the disciplines were used as a tool to enhance understanding of another primary STEM discipline, such as science. River (NSTA) did confirm, in his member check, technology was seen more as a support component. He said, “[Technology is] seen as a resource that students use as a process in their solving their problem. Most often students will use their computer to plot the data and do the graphs.” Marsha (NSTA) stated she would “introduce the phenomena,” most often a science concept, and then “bring in technology” afterwards to enhance the learning experience.

Two participants did not make clear their understanding of integration in their definition/description. For Joel (NSTA), integration occurred in a “wet-lab setting”. It appeared for him that integration needed to occur in some context or setting. Shannon (NSTA) stated integration occurred in a “seamless lesson” and in a “sequential process”. However, in the next section for lesson delivery, they revealed more about how they understood the relationships between the STEM disciplines.

One unexpected finding from Michelle (NSTA) and Archer (ITEEA) were their statements about integration on a macro level. Each described as part of their definition their I-STEM lessons were designed for and incorporated across more than one classroom. This was different from the others that described integration within the context of their specific classes. Michelle (NSTA) had her students “complete the calculations” in her class and the “technology teacher [had] the students complete the AutoCAD [computer-aided design] drawings.” Archer (ITEEA) identified working with a lesson in one class and then incorporated it “a second high school course within the STEM acronym. Table 4-3 outlined the statements from the participants in how it appeared they understood integration between the disciplines.

Table 4-3

Subjects' Description of Integration from Subjects' Definitions, Survey Items and Interview Questions.

Participants (Grade/ Organization)	Subjects' Description of Integration from Definition and Responses
Mike (11/ITEEA)	• Discrete STEM subjects • Engineering and Technology based
Preston (10/ITEEA)	• A correlation of math and science curriculum.is reinforced by Technology
Archer (9/ITEEA)	• Multidisciplinary content, scope, and sequence • Incorporating with a second high school course within the STEM acronym. • A new initiative in his southern state called STEAM • Lots of ways to include the arts into engineering
Michelle (10/NSTA)	• Partnership between the teachers • Combine lessons to support STEM curriculum • Joint projects with technology and math teachers • Work with students in both classes • Complete calculations in [one] class and complete AutoCAD drawings in [another class]
Gavin (12/NSTA)	• Aspects of Practices • Technology and Math are tools • Arises from foundations of physical science/science law
Joel (9/NSTA)	• Bench Research • Wet Lab type setting
Shannon (11/NSTA)	• Seamless Lesson • Sequential Process
Marsha (9/NSTA)	• Bring in Technology after phenomena is introduced
River (10/NSTA)	• Combine Scientific Literacy with Math • Defined to Address all four letters of STEM • Make it as concise as possible
Maverick (9/ISEA)	• Integration of STEM techniques • Trans-disciplinary • Trans-disciplinary concept • Thematic project allowing students to use multiple skills and content • Science and Math skills all working together to give broadest and most complete understanding of the task • Interdisciplinary concept: more narrowly focused-to address a specific problem-such as a Newtonian problem using a specific math process

Lesson Delivery Methods. Nearly all of the subjects (9 of 10) provided a delivery of instruction as part of their definition. Therefore, based on the information provided, subjects were either placed in the scientific investigation category, the engineering design category or the hands-on category. The engineering design method was the most common instructional strategy. Preston (ITEEA) was the only one who did not identify an instructional strategy or delivery method. Half (5 of 10) of the participants described using an engineering design strategy; three NSTA participants (Michelle, Joel, and Marsha) and two ITEEA participants (Mike, Archer) included it in either their definition or response regarding their definition. Maverick (ISEA) and River (NSTA) identified scientific investigations as their instructional strategy, while Gavin and Marsha (both NSTA) identified their method as "Hands-On/Interactive". Table 4-4 illustrates these classifications.

Table 4-4

Lesson Delivery Methods

Delivery Method Identified	Engineering Design	Scientific Investigation	Hands-On/Interactive	Not Provided
Participants	Michelle Joel Shannon Mike Archer	Maverick River	Gavin Marsha	Preston

The author was surprised to see the term "hands-on" used as a delivery method from the subjects, particularly since the a recent NRC (2012) publication makes an effort to identify and define pedagogical practices unique to the STEM disciplines. National Research Council (2012) discussed succinctly the similarities and differences between the two methodologies of engineering design and scientific investigation. Scientific investigation was "to develop a set of coherent and mutually consistent theoretical descriptions of the world that can provide explanations over a wide range of phenomena" (p. 48), whereas, engineering design developed prototypes to an identified or stated problem and was "measured" (p. 48) on its success of addressing the specified need.

As seen in Table 4-5, several subjects used the term "hands-on" to describe their lesson delivery method, which took on particular meanings relevant to the subject who used the term. For them to engage the students, they were making their lessons "hands-on." This term is a bit ambiguous. This last category has traditionally been associated with Project or Problem Based Learning strategy (McComas & Hayward, 2014; Kolodner, Camp, Crismond, Fasse, Gray, Holbrook, Puntambekar, & Ryan, 2003). Hands-on, as understood by this author, is defined as "instructional activities that give students opportunities to directly explore, investigate, and/or observe, probe or manipulate objects or scientific phenomena" (McComas, 2014. p. 45). In other words, students are actually doing something interactive.

Mike and Archer, both ITEEA, were very consistent in their use of engineering design as their lesson delivery method. In Survey Item 4, Mike (ITEEA) first described his delivery method as "hands-on, minds-on." Later, he clarified his statement by explaining engineering design was the methodology of his courses. Archer (ITEEA) was not explicit in his definition from the survey response, but was clear about his use of the engineering design model for his students to engage them in the learning in his interview. For him, students were creating a new product based on the criteria and conditions set forth in his scenario.

NSTA respondents were not as consistent with their description of lesson delivery methods. Table 4-5 illustrates the statements given by subjects' depicting their use of integration within their definition and, if provided, from a response, such as an interview or an email. Of the six NSTA participants, Michelle and Shannon explicitly described in their definition engineering design as their lesson delivery method, while River explained he used scientific investigation as his delivery process. Gavin, Joel, and Marsha (all NSTA) used in their definitions the term "hands-on" to describe their delivery method. Joel (NSTA) later clarified in one of his other survey responses he used engineering design, while Gavin (NSTA) and Marsha (NSTA) did not. In his interview, Gavin (NSTA) stated the activity was a "hands-on" activity, even though he did state he did a lot of "mini-engineering design lessons" in his courses. Marsha (NSTA) defined I-STEM as "inquiry based with hands-on experience." Attempts for clarification were unsuccessful; therefore, her lesson delivery method remained in the "Hands-on" category.

Having teachers identify the scientific investigation method as their lesson delivery method was a surprise. I did not anticipate any such lessons or descriptions from respondents, since I consistently observed engineering design in many of my professional development sessions, as I discussed in Chapter 3. Further, much of the available resources, such as Project Lead the Way, Engineering is Elementary, and the Infinity Project are engineering design based (Carter, 2013). River (NSTA) and Maverick (ISEA) both described their lesson delivery method as a scientific investigation in their interview responses, but not in their definition.

Table 4-5

Lesson Delivery Methods as described in Subjects' Definitions and Responses

Participants* (Grade/ Organization)	Lesson Delivery Methods From Respondents' Definitions and/or Respondents' Comments
Mike (11/ITEEA)	• Hands-on, Minds-on Activities • Engineering design
Archer (9/ITEEA)	• • Engineering Design Method
Michelle (10/NSTA)	• Engineering Design
Gavin (12/NSTA)	• Hands-on
Joel (9/NSTA)	• Experimentation • Hands-on • Engineering design
Shannon (11/NSTA)	• Discover and investigate physical world • Investigate and think how to apply in Engineering Challenge
Marsha (9/NSTA)	• Inquiry based with hands-on experience
River (10/NSTA)	• Means of Education • Means of delivering content in teacher guided instruction clarified as Scientific Investigation
Maverick (9/ISEA)	• Trans-disciplinary approach • Scientific Investigation

*Preston (ITEEA) did not provide a specific lesson delivery method.

Stated Products/Outcome Expectations. The majority (8/10) of the participants identified an outcome or product of the lesson as part of their definition/description of I-STEM. Based on the information provided, respondents expected students to create a product, demonstrate some competency in I-STEM Skills, exhibit some proficiency in I-STEM knowledge, or some combination of the three. Preston (ITEEA) and Marsha (NSTA) did not provide any evidence or details of an expected product or outcome in their definition/description or from an interview or email response. The remaining subjects provided either a product/outcome in their definition, from an interview or email response, or both. Table 4-6 illustrates these statements in parallel, where appropriate.

ITEEA participants Mike and Archer described two different products. For Mike (ITEEA), students were to demonstrate their proficiency in knowledge and skills in "designing, building, testing, and presenting prototypes to outside audiences." He also elaborated on his I-STEM skills outcomes for students by explaining they were to demonstrate skills related to programing and building robots and troubleshooting non-working components. Students were also expected to demonstrate knowledge about two software-coding programs, Python and Arduino Sketch.

For Archer (ITEEA), no expected outcome was identified in the definition he provided, however, he did state in his interview students were to produce a "real-world model" that either floated, flew, or drove on an alternative fuel/power source, along with writing a paper and a creating a video discussing the boat, plane, or car in more detail. Students were also to create a video and paper that captured their I-STEM knowledge about various fuel and power characteristics related to alternative power sources use in their prototype. Archer (ITEEA) did make mention of partnering with a "second high school course within the STEM acronym" as part of the learning experience. For both Archer and Mike, (ITEEA) their expected outcomes were very aligned to the ITEEA organization's definition as described in Chapter 2.

Participants from NSTA also had a variety of expected outcomes based on their definitions. Michelle (NSTA) identified an "engineered project" that had students working in one classroom completing math calculations, while completing the AutoCAD drawings in the technology teacher's classroom. Michelle's (NSTA) explanation about expected outcomes was the only other one that identified a multicourse experience for students. For this subject, her definition appeared to be more in line with the ITEEA definition expectations and experiences. Gavin (NSTA) was expected to create a product; he asked students to design a model that helped solve their problem. Ultimately, this experience was expected to increase I-STEM knowledge and to “better understand the universe.”

River (NSTA) and Maverick (ISEA) both described outcomes that were not tangible in nature, such as products described by the ITEEA subjects. River (NSTA) described expected outcomes of students developing I-STEM skills in students to ask better “What-If questions,” and predicting human impact on the environment. Maverick (ISEA) expected students to demonstrate I-STEM skills, such as designing a hypothesis, an experimental design, steps associated with a scientific investigation, and to describe an accurate understanding of I-STEM knowledge related to Newton’s Laws.

Joel and Shannon (both NSTA) wanted students to grow in I-STEM content either to be “learned and used,” or to “find applications that could improve quality of life,” respectfully. Neither responded to any follow up attempts to further clarify their statements as related to their definition. However, Joel gave some insight to his meaning some explanations found in other survey responses. These will be identified later in this chapter.

Table 4-6

Subjects' Stated Products/Outcomes from Subjects' Definitions, Survey Items and Interview Questions.

Participants* (Grade/ Organization)	Stated Products/Outcomes From Definitions and/or Responses
Mike (11/ITEEA)	• Students do simulations and build real-world systems • To employ what they have learned outside their "source courses by designing, building, testing • Program and build basic robots • Learn and Program [robots] • Learn and troubleshoot [robots]
Archer (9/ITEEA)	• To expose students in more than one discipline • A real-world current model that can either float, fly, or drive • Modify fuel and power sources of this current model to run on alternative fuel source • Paper • Video
Michelle (10/NSTA)	• Students complete the calculations [in one class] • Students complete AutoCAD drawings • Engineered project
Gavin (12/NSTA)	• Use [information] to model and solve problems • Solve problems • Increase scientific knowledge about our universe
Joel (9/NSTA)	• Content to be Learned and Used
Shannon (11/NSTA)	• Goal to find applications that can improve quality of life or be authentic in nature
River (10/NSTA)	• Increase scientific literacy • Use knowledge and Skills to address 21st century problems • Propose and/or develop realistic viable solutions • Get students to ask "What-if" questions • Student can predict human impact on environment
Maverick (9/ISEA)	• Integration of STEM techniques in all content areas • Integration of STEM understandings in all content areas • Use science and math skills

Research Question 2: How does a teacher defining I-STEM manifest their definition in elements or components related to a lesson or activity as gauged from a review of artifacts submitted?

Findings on Research Question 2

The findings related to this question come from a review of the six artifacts submitted from six of the ten participants (n=6). Therefore, an analysis for this question will only deal with those survey responses and interview questions that correspond with the participants who submitted the artifacts. The same themes used to analyze Research Question 1 were also used on the artifacts and responses (survey, interview or email) related to this topic. Mike (ITEEA), Preston (ITEEA), Joel (NSTA) and Marsha (NSTA) did not submit any artifacts. These four participants will not be included in this section of the data analysis. Research Question 3 addresses assessments; therefore, any rubrics submitted as artifacts were analyzed later in this chapter. Information related to instructions or directions found on a submitted rubric were included in the analysis for this section.

The types of artifacts varied from participant to participant, with some participants giving multiple artifacts. Archer (ITEEA), Michelle (NSTA) and Shannon (NSTA) all submitted a rubric for their artifacts. Gavin (NSTA) submitted an activity. River (NSTA) and Maverick (ISEA) both submitted what I considered lesson plans. For this research project, lesson plans contained the content components the teacher was introducing to the students over a period of time. River's lesson plan consisted of a PowerPoint detailing the specific science terms and concepts, along with an activity within the PowerPoint related to the concepts, while Maverick's lesson plan included an activity and a rubric.

The idea of how integration was understood was further revealed in the statements made in the surveys, email responses, and phone interviews. All but one, Shannon, (5/6) submitted an artifact and conducted either a phone interview or provided responses to questions in an email. The interview data helped expand upon the understanding of the integration as related to their artifact. Table 4-8 illustrates each of the four themes.

STEM Disciplines Identified in Subjects' Definition/Description. Participants' artifacts revealed the specific STEM disciplines they incorporated in the submitted lesson/activity. All participants who submitted an artifact used a science discipline as the basis for their activity. Four of the six participants included in this section used Physical Science (Physics and Chemistry) concepts in their lesson. For instance, Archer (ITEEA) and Michelle (NSTA) asked students to consider energy concepts as they used alternative fuel/power sources to construct a new prototype using that source of energy. Maverick (ISEA) incorporated physics by asking students to pick one of the three Laws of Newton, setting up an experiment to collect data, and to present the data demonstrating if their findings support the foundations outlined by the particular law they selected. Shannon (NSTA) was asking students to determine the conductivity in a solution (Chemistry). Earth and Life Science concepts were used to provide the background and the context for two lessons. Gavin (NSTA) used Earth/Space Science content as his lesson foundation and asked students to imagine themselves in a space scenario where they are coordinating the movement of a spacecraft in zero gravity. River (NSTA) asked students to implement ecology concepts (Life Science) to better understand how different variables can impact the environment, specifically human activities.

Integration as found in subjects' artifacts. This was a unique finding regarding the artifacts and the integration of disciplines. Of the submitted artifacts, two of the four disciplines were explicitly paired with one another. Three lessons contained the science and engineering disciplines, while in the remaining three artifacts; science and math were the primary disciplines. For the three artifacts based in science and engineering, Archer (ITEEA), Michelle (NSTA), and Shannon (NSTA) appeared to design a scenario that modified or enhanced the science content in order to make the engineered prototype work.

Gavin (NSTA), River (NSTA) and Maverick (ITEEA) seemed to integrate both math and science equally in the their activities. In order for students to have the intended experience of the lesson, it appeared the teacher constructed the lesson where the science seemed equally dependent upon the math. In other words, the concept students were to understand would be incomplete without the context of the other discipline. For example, Gavin asked students to calculate the necessary amount of force needed to readjust a spacecraft to correct heading. For this particular activity, the concept of Newton's 3rd Law provided both the foundation and the parameters in which the students operated. For students to understand the physics law of "for every action there is an equal and opposite reaction" as related to a spacecraft's thrusters operating in space, students needed to calculate the mathematical value of the thrusters used to counteract external forces that resulted in moving the spacecraft out of its original position. Students used provided data sets to calculate correct vector data that adjusted the trajectory of a spacecraft, all within the context of Newton's 3rd Law.

Maverick (ISEA) also designed a lesson and activity around Newton's three laws. He asked students to select one of the three Newton's Laws, develop an experimental design, collect data, and report on one's findings determining if the data demonstrated the selected law. For his lesson, the science created the scenario and students used mathematics from the collected data produced by their experiment. River (NSTA), stated in his interview, he constructed his lesson around the biological content of environmental science that created a scenario using various data points for students to apply in carrying capacity graphs. From these trends, students were then to make predictions about the impact on the planet based on certain variables, particularly the human impact on earth. Question such as, “How would removing the growing of coffee from an African country impact the region?” or “What impact does growth of human populations have on a region?” were asked. Students then investigated outcomes based on data provided by the teacher. While mathematics appeared to be integrated equally with the science for these three, mathematics appeared to be used as a support discipline in the activities for the first three subjects.

Mathematics, however, in the three lessons that paired science and engineering disciplines, appeared to only support these two primary disciplines. For example, in Archer’s (ITEEA) activity, math was used to calculate the efficiency of the alternative fuels in the car, boat, or plane prototype. Archer gave instruction for students to calculate efficiency of a new power source, defined by speed, cost, and distance traveled. Michelle (NSTA) had students design an “inexpensive” prototype based on the materials and resources found in a specified African country. To demonstrate “inexpensive,” she asked students to calculate the cost of their project. Shannon (NSTA) had her students build a conductivity meter. With this tool, students estimated amperes based on bulb brightness and then calculated percent error between predictions recorded with the homemade product and actual recordings of a commercial product designed to also measure amperes.

Technology was the one discipline that was not explicitly identified as a discipline in these artifacts. In Archer’s (ITEEA), Michelle’s (NSTA), and Shannon’s (NSTA) activities, students engineered some prototype needed to address a scenario based on science concepts, such as alternative/natural resources (Archer and Michelle) or solutions (Shannon). For Gavin, River, (both NSTA) and Maverick (ISEA), technology, as a discipline, was minimized for these lessons. It was seen as a tool in which to conduct calculations or make presentations of data, as demonstrated in River's and Maverick's lesson. For Gavin, it was absent in any part of the lesson or conversation. I distinguish these participants' use of technology from Mike's use, in that I believed he had the most explicit use of the technology discipline in his responses, even though he did not submit an artifact. Mike (ITEEA) used components found in the technology discipline, computers and robotics, to engineer solutions within those components, such as troubleshooting issues through rewriting software programs and programing robots with applicable coding software.

Lesson Delivery Methods. The most common instructional strategy was the engineering design method. As found in most commercially produced lessons (Carter, 2013) and typical of many STEM professional development workshops (Laboy-Rush, 2012; Davis, et al., 2010; Davis, et al., 2008), this was not unexpected. Lessons containing scientific investigations were probable, but were not anticipated. Therefore, it was surprising to have two lessons explicitly identified as scientific investigation for its delivery method. Only one lesson was identified as hands-on and not either engineering design or scientific investigation strategy.

Michelle (NSTA) and Archer (ITEEA) both had students construct a prototype powered by some form of alternative fuel or power source. Shannon (NSTA) asked students to construct a homemade version of a conductivity meter, so they could learn about conductivity in solutions. The quality of the instrument was determined by brightness of bulb.

For Maverick (ISEA) and River (NSTA), each implemented a scientific investigation strategy. Both asked students to design an experiment, collect data, and then draw conclusions about the data. Maverick (ISEA) wanted to deepen students' understanding on one of Newton's

Laws, while River (NSTA) conducted a guided instruction lesson, providing some of the data to the students, who then applied the data to various ecological models of Carrying Capacity and Succession and drew conclusions and likely outcomes based on the data.

Gavin (NSTA) characterized his activity as a “hands-on” project. When interviewed, he said that his class consisted of “lots of hands-on, mini-engineering projects,” but he never specifically called this lesson an engineering design project. The activity appeared to have the characteristics of a scientific investigation, since it described a series of data collection points in their effort to correct a spacecraft. Based on the activity and the outcome expectations, I would classify this as an engineering design lesson delivery method because students created a model. In fact, I would argue Gavin’s (NSTA) activity was centered around the math discipline set in the context of science information.

Stated Products/Outcome Expectations. The Products/Outcomes stated in this section were taken from responses identified in Survey Items (Appendix A) and Interview Question 2 (Appendix C). Lesson delivery methods were aligned with a specific product or outcome they were anticipating. Archer (ITEEA), Michelle (NSTA) and Shannon (NSTA) identified engineering design as the instructional strategy, in which their students were expected to construct some type of prototype related to the scenario. Maverick (ISEA) and River (NSTA) asked students to conduct a scientific investigation. Their students implemented science practices and produced various explanations to the questions being asked in their specific scenarios. Students explained their findings within the context of the science content, which in this case for Maverick (ISEA) was Newton’s Laws and for River (NSTA) ecological concepts of succession and carrying capacity. The only participant who left some ambiguity was Gavin (NSTA) and his use of “hands-on” in the description of his lesson. Students constructed a mathematical model based on the data collected. However, this was a virtual model and not a physical model. Again, Table 4-8 illustrates each of the four themes described above.

Table 4-7

Four Themes that Emerged from the Participants' Submitted Artifacts

Participants (n= 6) (Grade/ Organization)	Identified STEM Disciplines in Artifacts	Integration as Portrayed in Artifact	Lesson Delivery Methods found in Artifacts	Stated Products/Outcomes From Artifact
Archer (9/ITEEA)	• Newton's Law of motion explained in science and math • Class	• Students are given scenario to construct a prototype (Engineering) using alternative fuel and power sources (Science). Students are asked to calculate efficiency of new power source, along with speed and distance capabilities (mathematics) as part of the write up and video	• Engineering Design	• Newton's laws of motion explained • Create a working prototype
Michelle (10/NSTA)	• Renewable Energy Resources • Generators and Motors	• Understand how energy source (Science) provides energy (Science) to clinic • Design and build energy source components (Engineering)	• Engineering Design	• Working prototype designed on a renewable energy resource
Gavin (12/NSTA)	• Telescope and aperture concepts • Newton's 3rd Law- equal and opposite actions • Force and angles • Vectors and the corresponding mathematics	• Students play role of spacecraft members understanding how spacecraft operates in space (science) but are given scenario to correct a flight error (incorrect vector) and to calculate (math) how to reorient craft	• Hands-on	• Provide a mathematic model to describe motion (vectors)

Four Themes that Emerged from the Participants' Submitted Artifacts (Cont.)

Participants (n= 6) (Grade/ Organization)	Identified STEM Disciplines in Artifacts	Integration as portrayed in Artifact	Lesson Delivery Methods found in Artifacts	Products/Outcomes portrayed In Artifact
Shannon (11/NSTA)	• Physical Science class: looking at the difference between electrolytes & nonelectrolytes.	• Building a device (engineering) to measure conductivity in a solution (Chemistry) • Compare built meter reading to a professional meter and calculate percent error (Math)	• Build a Conductivity Meter • Engineering Challenge	• Construct a conductivity meter
River (10/NSTA)	• Primary and secondary ecological successions • Populations and communities	• Describe succession, population, and communities definitions (Science). Understand carrying capacity data (Math) impact on these concepts.	• Scientific Investigation • Guided Instruction by teacher	• Apply information to changing 21st Century world - See the ironic inverse that human activity increases human population at the cost of other populations • Make predictions about ecological succession
Maverick (9/ISEA)	• Newton's 3 Laws (Physics)	• Integrate math (data collected by students on law), science (specific Newton Law) and literacy skills.	• Scientific Investigati on	• Demonstrate their understanding of Newton's 3 laws of motion • Designing, conducting, demonstrating, and evaluating an experiment. Students will write a lab report.

Findings on Research Question 3

Question 3- How do Teachers who have designed and contributed I-STEM lessons/artifacts assess student achievement?

Responses from subjects phone interviews, email questions and/or survey items (Appendices A, B, and C) were analyzed to answer Research Question 3. Two subjects (Preston (ITEEA) and Marsha (NSTA) did not provide data for this particular survey question, therefore only eight were included in this section (n= 8).

In the previous sections, most subjects (7 of 8) stated some type of expected product or outcome. In this section, subjects provided specific topics they were assessing as part of the outcome expectations. After looking at submitted lessons/units or rubrics, four themes were generated from analysis: Creation of a Product, Soft Skills, Assessed I-STEM Skills, and Assessed I-STEM Knowledge. For most of the participants, student was going to be assessed based on their ability to create a product, exhibit various "soft skills" (Grugulis and Vincent, 2012), or demonstrate an I-STEM Skill or I-STEM Knowledge. It was anticipated teachers would assess students on a product creation, an I-STEM skill, and/or I-STEM knowledge incorporated into the learning experience. Products that were expected to be created by the students included a working prototype, a model, a presentation, a paper about their prototype, or some combination. I-STEM skills and I-STEM knowledge have been separated from the collective understanding of practices (NRC, 2012, NGSS Lead States, 2013) as discussed in Chapter 2. I-STEM skills were understood to be those competences applied by the student related to the engineering design or scientific investigation, while I-STEM knowledge was understood as the content specific to the discipline being incorporated in the lesson. The idea of integration was not considered for this section, since it was addressed from the participants' perspective in Research Question 2 and it would have required collecting data from students to determine how they would have understood integration in the context of the lesson. This study did not focus on that aspect of integration.

An interesting find from this data was an underlying expectation students developed "Soft Skills" (Grugulis and Vincent, 2012), even though most subjects did not make this an explicit outcome in their responses. Grugulis and Vincent (2012) describe such skills as "communication, problem-solving, team-working, ability to improve personal learning and performance, motivation, judgment, leadership and initiative" (p. 598). They also describe how soft skills are impacting more and more the workforce in a variety of ways, particularly in hiring situations and considerations for leadership roles. They were also distinguished from technical skills by employers. Soft Skills were most often seen from the responses and artifacts as attributes demonstrated by the student in the process of organizing a paper or presentation, but were not necessarily I-STEM skills specific.

Outcomes stated explicitly by subjects from their statements or artifacts included expectations of students to develop their I-STEM Skills, I-STEM knowledge, and/or the construction of product. Seven of eight participants discussed the development and expectation of enhanced I-STEM Skills and I-STEM knowledge as an outcome as a result of the activity/lesson. Maverick (ISEA), Gavin, and Michelle (both NSTA) and Mike (ITEEA), explicitly stated their desired outcomes related to I-STEM skills and I-STEM knowledge. For example, Gavin (NSTA) expected students to transfer their knowledge of mathematical modeling from previous lessons to the current one, while Maverick (ISEA) emphasized components of scientific investigation (designing an experiment, collecting and analyzing data) as desired outcomes. Mike (ITEEA) expected students to "troubleshoot" computer systems to determine which was working and not working. Again, seven of the eight respondents asked students to construct a product, either a in the form of a prototype, as seen in Archer's (ITEEA), Michelle's (NSTA) and Shannon's (NSTA) artifacts, a communications expectation, such as a paper or presentation, as seen in Maverick's (ISEA) and Shannon's (NSTA) lessons, or a model as seen in Gavin's (NSTA) activity. River (NSTA), for example, did not identify a tangible product, but rather an application of the select I-STEM Knowledge and I-STEM skills based on the content and material provided in the classroom. Students in River's (NSTA) class were being asked to develop better "What If?" questions based on their understanding of population, carrying capacity, and succession. In order to do that, they analyzed data provided by the teacher under various scenarios that produced differing outcomes. Table 4-9 outlines each of the themes and the subjects' data relevant to the category.

Comments provided by the participants alluded to two separate, but intertwined ideas of soft skills and I-STEM skills. To clarify the difference between "Soft Skills" theme from "Assessed I-STEM Skills" theme, I-STEM Skills was understood to be "technical skills, " (Grugulis and Vincent, 2012, p. 598). In an activity/lesson, students were expected to demonstrate the I-STEM skills set relevant to the product they were asked to construct, but apply necessary soft skills in their demonstration of the concept. Six participants identified these particular skills as related to the engineering design process. Four of the six used the term "Engineering Design" in either their survey or interview data, while two stated their students would either build or construct a product (a rocket or conductivity meter), an engineering design characteristic. Two participants, Maverick (ISEA) and River (NSTA), incorporated scientific investigations as their process to develop these skills.

Six of the eight participants described “Soft Skills” in their data. From their comments, four aspects of “Soft Skills” emerged: Time management, Teamwork, Communication-Written, and Communication-Oral. The oral communication was represented as student presentations. These data sets demonstrated some insight and understanding of *how* participants assessed particular student outcomes for the I-STEM lesson/activity that was described or provided.

In Table 4-8, Mike’s (ITEEA) statement “Ability to troubleshoot a system” was placed in both the I-STEM Skills and I-STEM knowledge categories and not in the Soft Skills category. Mike explained in his responses that “[Students were] to…take apart, diagnose and repair computers… to program and build basic robots and to lean to program and troubleshoot them.” It became clear his intent was for students to apply I-STEM knowledge and skills to resolve the issue. Since, this was not stated in the survey, but rather clarified through an email correspondence, the original statement was used with this explanation provided to the reader.

Table 4-8

Four Themes based on Subjects' Perceptions of their Assessments responses

Categories/ Participants (n= 8) (Grade/ Organization)	Creation of a Product	Soft Skills (Time Management, Teamwork, Communication.)	Assessed I-STEM Skills	Assessed I-STEM Knowledge
Mike (11/ITEEA)	• A working robot/computer	• Time on Task • Overcome obstacles as a group	• Ability to troubleshoot a system • Separate working parts from parts that do not work • Either products work or they do not [work]	• Know working system from problematic sub-system
Archer (9/ITEEA)	• Design a model that floats, flies, or drives • A paper • A video	• Peer evaluation (Got 29 eyes evaluating another's work) • Writing/Rewriting paper • Producing a video	• Constructing a real-world model of a car, boat, or plane	• -Study Guide • -Quiz • -Test on fuel and power sources • -Teacher question and answer
Michelle (10/NSTA)	• Two papers • Build a prototype	• Detailed paper with references	• Use understanding of engineering design process to build prototype • Modify prototype to improve design	• Resource available in African Country for prototype • Understanding of physics of motors • Understanding of materials
Gavin (12/NSTA)	• A mathematical model	• Successful team completion of the activity	• Transferability of modeling skills learned during lesson	• -Exam to determine any weaknesses in students' understanding • A formal exam aligned to mathematical nomenclature
Joel (9/NSTA)	• A [working] rocket	• None Provided	• Constructing a rocket • Launching a rocket	• None Provided

Four Themes based on Subjects' Perceptions of their Assessments responses (Cont.)

Categories/ Participants (n= 8) (Grade/ Organization)	Creation of a Product	Soft Skills (Time Management, Teamwork, Communication.)	Assessed I-STEM Skills	Assessed I-STEM Knowledge
Shannon (11/NSTA)	• 1 page write up of instructions	• Presentation of instructions	• Engineering was evaluated by examining conductivity meter [and] whether it worked	• Studying about ionic and covalent bonding
River (10/NSTA)	• None Provided	• Group Conversation	• Makes connections with cause and effect and stability and change • Analysis of maps, graphs	• -Explain difference between Primary and secondary succession, population, growth curves, carrying capacity
Maverick (9/ISEA)	• Presentation • Formal lab write up	• Quality of Presentation • Accuracy of research • 2-3 students working in groups	• Fidelity of experimental design • Data collection	• Newton's 3 Laws

Characteristics of Submitted Rubrics.

Criteria Identified in Submitted Rubrics. Four participants, Michelle and Shannon (both NSTA), Archer (ITEEA), and Maverick (ISEA), submitted some form of a rubric based on their lesson/activity. As displayed in Table 4-9, the four rubrics provided each had different criteria and categories in how their products were assessed. Rubrics from Michelle (NSTA), Shannon (NSTA), and Maverick (ISEA) were designed to produce a grade based on the criteria being met, while Archer's (ITEEA) rubric did not award a grade but was designed to give specific feedback. Table 4-9 illustrates in parallel each of the rubric's criteria from each submitted rubric.

Table 4-9

Criteria from Submitted Rubrics from Four Subjects

Michelle (12/NSTA)	Shannon (11/NSTA)	Maverick (9/ISEA)	Archer (9/ITEEA)
• Research of Topic	• Effective Reading Compared to actual reading	• Focus	• Purpose and Usefulness
• Product	• Size- Convenient; Hand held •	• Controlling Ideas	• Design and Appearance
• Collaboration/Teamwork	• Creativity of parts, likely to find these items easily	• Reading/Research	• Carrying Capacity- Cargo or passenger
• Evaluation of Reliable Resources	• Instructions of how to build conductivity meter	• Development	• Speed and distance
• Documentation		• Organization	• Power Plant Adequate
		• Conventions	• Propulsion System matches design
		• Content Understanding	• Time to recharge and how does it recharge
			• Distance Travel per charge
			• Materials used to build it
			• Overall costs are realistic

No two rubrics were alike, even though some shared similar characteristics. At first glance, it appeared some of the criteria were evaluating different things, however, a closer inspection revealed they were evaluating the same outcome but using different criteria categories. For example, Michelle's (NSTA) rubric contained a category labeled "Product" that focused on the communications outcome and contained criteria assessing points on correct grammar, usage, spelling and mechanics, along with visuals that were appealing to the audience. Shannon's (NSTA) rubric "Conductivity Meter Assignment Rubric" did not define specific product criteria as related to the conductivity meter, but rather contained criteria assessing reading and writing instructions skills. Maverick's rubric was also designed to assess a communications product and contained "scoring elements" specific to features found in a written product, such as "Focus," "Controlling Idea," "Organization," and "Development."

The concept of weighting the score was included in two of the four of the rubrics. Michelle and Shannon (both NSTA) weighted each criterion by percentage distribution. Shannon (NSTA) weighted each criterion equally at 25% of the point value, while Michelle (NSTA) assigned higher point values to some criteria than others. Her rubric had the *Product* weighted at 30%, while *Collaboration/Teamwork* was weighted at 15%. Maverick's (ISEA) rubric did not weight categories.

The most unique of the rubrics, however, came from Archer (ITEEA). As he described his classes, it appeared students worked on an assumption they were already awarded the points. In his interview, Archer explained each project (paper, video, and prototype) was worth 100 points. Students had multiple opportunities to correct any mistakes they made with a prototype, video, or paper. To help correct the mistakes or improve the projects, peers and the teacher used a rubric with a coding system to highlight areas that needed to be addressed. These abbreviations gave students feedback/guidance on what to correct, however they did not assign point values. Archer mentioned some of his students had papers go through "8 to 10 revisions" and each revision gave the student a "bump up in grade." The point totals related to the different products (vehicle, paper, and video) were deducted from the total based their original presentation.

What made his rubric unique was way it provided specific feedback rather than assign points, as found in a more traditional rubric. Codes were tailored to the engineered product. Students received rubrics with markings next to abbreviations, such as “RBPS” that told them they needed to “research a better propulsion system” on their vehicle. Or they received “INA” and knew their “information [was] not accurate.” Another example was the abbreviation “INP,” which stood for “Information not Provided- Please Provide the Information- Look it up.” Another was “RAMC,” which told a student to “Research Additional Material Choices for your Vehicle and add them in your paper.”

Each rubric assessed various “Soft Skills” and had a particular focus on communication skills, specifically in the written format. Michelle (NSTA) graded on the correctness of language skills, such as grammar, spelling and mechanics and literacy skills of comprehension and organization of material. For her rubric, these criteria were found in the categories of *Product* and *Evaluation of Reliable Sources*. Shannon (NSTA) had two separate rubric categories assessing communication, both in writing and in oral products. The rubric category called *Effective Reading Compared to Actual Reading* assessed in two different ways. First, it evaluated students’ presentation of the instructions or “Actual Reading.” Second, it assessed how the class interpreted the instructions based on the *Effective Reading* from the student. It was unclear if the students, as part of the presentation, were to elaborate on the various parts or steps of the instructions in order to clarify the intended instruction. When asked if the product was ever scored, Shannon (NSTA) stated the conductivity meter was evaluated on whether or not it worked in *How Students are Assessed*.

For these artifacts, two discrepancies were found between the subject’s I-STEM definition and how it was to be assessed. First, the rubrics appeared to not provide feedback on the I-STEM processes, for either engineering design process or scientific investigation, or indicate if the practices associated with the respective I-STEM skills (Engineering Design or Scientific Investigation) were improving, transferring, or being internalized.

The second discrepancy found in three of the four rubrics focused feedback primarily on the outcome of a writing project, the presentation of information, or some combination of the two. Archer's (ITEEA) rubric was designed to give students feedback on both the prototype and paper, but no rubrics were submitted assessing or evaluating I-STEM skills being applied in the activity. Maverick (ISEA) was the only one who explicitly expected to assess this information, based on his responses and his submitted artifacts. In addition to learning about concepts and practicing skills, students were demonstrating their understanding of the content primarily through a literacy demonstration. As stated previously, his students were to pick one of the three Newtonian Laws, conduct an experimental design on one of the three laws, collect data from the experiment related to that law, create a write-up describing the data, and present the information to the class at a set time. The submitted rubric was an assessment of this written product and presentation.

The matter of concern was with the quality of the rubrics and not with the learning objectives for the lesson/activity. This point is mentioned by others such as Allen and Tanner (2006) who wrote, "A more challenging aspect of using a rubric can be finding a rubric to use that provides a close enough match to a particular assignment with a specific set of content and process objectives" (p 198). All too often products created by students leave teachers disappointed, because they did not get the anticipated outcomes, and leaves students frustrated and confused by the results of the grade for they did not have an appropriate understanding of the instructor's intent (Wilson and Onweigbuzie, 1999). A well-designed rubric can give students' effective feedback and constructive guidance (Boston, 2002).

Another interesting find was the lack of comments about creativity or ingenuity in either of the survey or interview data. These concepts were considered in three of the rubrics and were evaluated, but were not mentioned in the survey and interview data. For two of the four rubrics, points were awarded. Michelle's rubric had in her "Product" criteria "Original, inventive, and creative." Shannon had constructed a "Creativity of Parts…" criteria based on the use of household items (as explained in her directions) and ease of finding such items. Maverick (ISEA) and Archer (ITEEA) did not have criteria or points awarded towards creativity or ingenuity in their rubric.

Findings on Research Question 4

Research Question 4- What Factors and/or Rationalities influence teachers to conduct or Not-Conduct an I-STEM activity.

Results from previous sections provided some insight into *what* some teachers considered as I-STEM and *how* they constructed lessons and assessments based on their responses. Understanding *why* he or she conducted or not conducted an I-STEM lesson/activity was considered equally important. From all ten subjects' responses (n=10), it appeared the information could be divided into Factors and Rationales impacting a teacher's decision to implement an I-STEM lesson. Data collected in the responses from surveys (Appendix A), interviews (Appendices B and C), and email responses (Appendix E), constructed the following themes: School Influence, Collegial Support, Teachers' Perceptions of Authentic Experiences, and Time Allocated by Teachers to Conduct I-STEM lessons. Themes generated from the artifacts that appeared to give Rationales in conducting such lessons were: Subjects' Perception about the Ethos of I-STEM, Prior I-STEM Experiences, and Subjects' Perceptions on Motivation.

Subjects' Statement Regarding School Influence. The lack of a school definition/description did not appear to inhibit the majority (9/10) of these teachers from conducting what they believed to be I-STEM lessons. Preston was the only person who stated I-STEM lessons were not conducted. Nine of the ten participants indicated their school/district did not influence their definition. Only Marsha (NSTA) indicated that her school or district influenced her definition. She designated her school as a "STEM Academy or Having a Designated Pathway", but it was unclear if the "student-led projects," as she described her lessons, were directed by the school to accomplish as part of an overall curricular goal, if they were integrated into specific lessons designed by the school or district for certain courses, or if it was some kind of semester final project. For her definition of I-STEM, she said it was an, "Inquiry based with hands-on experience. Phenomena would be introduced at the beginning of a lesson. Bring in technology, class discussion, formative and summative evaluation." How exactly her district influenced her definition was not determined. Also it was not possible to investigate the school's definition, since subjects were not asked to provide their school information. In Chapter 3, Table 3-1 contains the results of the survey data indicating if the school influenced a teacher's definition.

Most subjects stated their definition was a product of their own making and developed through various learning experiences, professional development, or other STEM definitions. Mike (ITEEA) said his definition "[came] from experience and my opinions," while Maverick (ISEA) identified professional development opportunities, such as STEM team committees. Archer (ITEEA) said his definition "came right out my heart and not from a textbook." River

(NSTA) admitted to conducting Internet searches on STEM definitions after having read the Next Generation Science Standards (Achieve, 2013). He found most were "too wordy" wanted his definition to "cover the four disciplines and be concise."

Collegial Support in Implementing I-STEM. An important component for implementation for some of the subjects was the roll of colleagues as part of the I-STEM lesson. Archer (ITEEA), Preston (ITEEA), Michelle (NSTA), River (NSTA), and Maverick (ISEA) (5 of 10) all mentioned working with and/or receiving support from another educator. Archer (ITEEA) discussed that his support came from various community partners like NASA to support his lesson. Preston (ITEEA) stated the "Technology Education class" reinforced his science and math curriculum, while Michelle (NSTA) explained in some of her responses that she "worked with a great group of teachers" who were always willing to work with her on "different projects." River (NSTA) indicated he shared lessons with fellow teachers and then would make any necessary "adjustments" to the lesson, related specifically to scaffolding techniques. Finally, Maverick (ISEA) experienced in his setting both "STEM and non-STEM [teachers] who [wanted] to conduct STEM activities." Based off these comments and statements, for half of the participants, the support of fellow teachers encouraged the implementation of I-STEM lessons.

Subjects' Perceptions of Authentic Experiences. The idea of "authenticity" kept remerging in subjects' responses and explanations. Most participants (7/10) described the lesson as being authentic in some way as a necessary part of the leaning experience. Of the seven who alluded to an authentic experience, five mentioned lessons containing a real-world scenario, while the remaining two participants described their lesson/activity as containing unknown variables. This was to give students some "practical experiences".

For those who appeared to place students in a real-world scenario, the setting varied as the lesson did. Michelle's (NSTA) scenario placed students in an African country to create their generator prototype. Gavin's (NSTA) students had to imagine themselves as a person working on a spacecraft that had gotten off course and must recalculate to return to correct trajectory. River (NSTA) wanted students to recognize the current reality of this planet's populations and communities and apply concepts to current settings to predict outcomes. Mike (ITEEA) stated students were "working on real systems that…[either] function or not function," and included resources, such as computers and robots. Archer (ITEEA) asked his students to imagine themselves 25 years into the future. In this setting they were to take a current mode of transportation (car, boat, or plane) and imagine a new power source for that vehicle using an alternative fuel.

Shannon (NSTA) and Joel (NSTA) were slightly different. They designed scenarios where students had a situation with "numerous problems" or had "no way to determine" the status of a chemical solution. For Joel (NSTA), his students had to work through these unknowns in their effort to construct a rocket, while Shannon's (NSTA) students constructed a conductivity meter from household items in order to determine the properties of the solution. Table 4-10 illustrates the information.

Table 4-10

Subjects Perception of Authenticity in I-STEM Lessons/Activities

Participants (Grade/Organization)	Evidence for Authenticity	
	Real-World Scenario and Activity Designed by Teacher	Working with Unknown Variables in a Teacher Designed Activity
Mike (11/ITEEA)	-Take apart and repair computers -Build basic robots -Configure peripherals and loading OS system.	
Archer (9/ITEEA)	-City of the Future, Earth 25 years into the future	
Michelle (10/NSTA)	-Scenario of Friend who does mission work in an African country and the need to power clinics	
Gavin (12/NSTA)	-Person working in a Spacecraft that has gone off course	
Joel (9/NSTA)		-Students confronted numerous "problem" and thus had to redirect their work in a manner they "thought" would be successful
Shannon (11/NSTA)		-Students were given a practical problem -No way to determine if a solution was an ionic or covalent solution
River (10/NSTA)	- Presents students with current ecological reality and asks students “What-If?” questions to understand impact of decisions on community/population/succession	

Time Allocated by Teachers to Conduct I-STEM Lessons. Time was a variable inconsistently applied across the various lessons discussed. Five of the ten subjects shared information about the amount of time dedicated to the I-STEM lesson they conducted. The amount of instructional time ranged from a few class periods to several weeks. Most classes were 80-90 minutes in length, but none reported having less than 50 minutes per class session.

The participants with shortest amount of time dedicated to their activity were Gavin (NSTA) and River (NSTA) with three class periods. For Gavin (NSTA), two class periods were pre-planning and mathematic practices with one hour conducting the activity. River (NSTA) had three periods (80 minutes apiece) devoted to the activity. Mike (ITEEA) and Michelle (ITEEA) had similar timelines for their activity. Mike (ITEEA) anticipated five class periods (90 minutes in length), but had the lesson go to ten class periods in prior situations. This was dependent upon "students' abilities and how many things broke and needed to be replaced along the way." For Michelle (NSTA), five class periods are dedicated to the activity/lesson. One to two periods (90 minutes in length) focused on different energy sources, "such as water wheels and exploring solar power." Another class period investigated motors and generators, while the remaining two class periods were used to test prototypes and make modifications. Maverick (ISEA) and Archer (ITEEA) dedicated a significant amount of time to their lessons/activities. For both they allotted 20 to 25 class periods, which was equivalent to four to five weeks of their class time. For Maverick (ISEA), the majority of the time (50 minutes in length) was dedicated to the presentations, while Archer's time was used in researching, building and modifying of projects based on feedback.

Most of the participants did not describe any particular reasons why their lesson may take three periods or several weeks. Maverick (ISEA) explained in his interview his lesson went much longer than anticipated. He scheduled two weeks for this activity. In reality, it took closer to five weeks to finish. Mike (ITEEA) described some factors impacted his timeline by extending his activity, such as how often he needed to replace materials or resources or the ability of students.

Rationales Influencing I-STEM Implementation

Prior I-STEM Experiences. Half of the subjects (5 of 10) mentioned or discussed prior experiences in their statements regarding their I-STEM definition/description. Email and interview responses (Appendices B and C) expanded on their comments or provided additional information about their years of teaching experiences or professional experiences. Subjects from each of the organizational affiliations each had formative experiences in both educational and non-educational fields. Prior experience for participants gave them a unique perspective about how the content/learning experience could be organized in their class. Mike (ITEEA) taught various levels and types of career and technical education (CTE or CATE) courses, Project Lead the Way (PLTW) courses, and even wrote curriculum for non-PLTW courses. Michelle (NSTA) worked with an "engineering development lab" as an electrical technician specializing in laser systems. Joel (NSTA) worked in a bench setting, while Archer (ITEEA) had "40 years of architectural design and architectural experience."

Subjects' Perception about the Experiences of I-STEM. The subjects provided comments and statements that appeared to describe characteristics associated with an I-STEM lesson and with I-STEM experiences. Seven of the ten subjects described their lessons and the ways they engaged their students. From these descriptions, the participants described as part of their rationale an ethos to such I-STEM lessons. There appeared to be a consistent philosophy in why they taught I-STEM lessons. Within their accounts, two categories emerged from the ethos theme: Curriculum associated with the I-STEM lesson and a Belief in the I-STEM Experience. Table 4-12 outlines the different statements for each of the characteristics.

Curriculum in the I-STEM lesson was implemented, as Mike (ITEEA) stated it best, to ensure students had "appropriate experiences." In order to accomplish this, several subjects explained various steps they would take to ensure this occurred. For Mike (ITEEA) he wrote curriculum to ensure there was one for students. Archer (ITEEA) allowed his curriculum to be expanded by the students as they encountered new material. He described in his interview that students taught him about nanotechnology as a power source, so he redesigned his lesson to incorporate this information. Michelle (NSTA) “got endorsed to teach technology, physics, and earth science,” because her own personal non-educational experiences influenced her ability to design lessons incorporating these content areas. Gavin (NSTA) designed a lesson that allowed him to engage and reach students with a difficult concept. River (NSTA) and Maverick (ISEA) also re-wrote curriculum for it to not be a “regurgitation of facts” and allowed for ‘relevant ways to…connect concepts,” respectfully.

The concept of the teacher’s belief in the I-STEM experience provided some more valuable insight into why teachers implement I-STEM lessons. It became evident from several of the statements, these teachers believed in the idea of integrated content and the I-STEM lesson provided the avenue for such an experience. It appeared from the comments the I-STEM lesson gave some freedoms to the teachers, along with some possible permissions, to conduct learning in a different fashion. Gavin (NSTA) explained the “teaching environment must be very flexible,” while Joel stated, “STEM is only successful when one gets their hands dirty.” Archer (ITEEA) and River (NSTA) had similar explanations for their belief in the I-STEM experience. Archer (NSTA) explained his classes provided a place to fail, which was his “modus operandi.” River understood such lessons “[allowed him] to help redirect students onto right path” for “there [was] no one right way or always a correct answer.” In both these classes, students were learning through constructive feedback from teacher and/or peers.

It seemed for several of the respondents, the characteristics of these lessons were unique to I-STEM lessons and were needed for particular student outcomes to occur. Maverick (ISEA) described his intentions of implementing I-STEM lessons as very deliberate for he wanted both students and “people to understand [the] many ways STEM can [fit] into different disciplines.” Archer (ITEEA) had a similar philosophy about his I-STEM lesson for he wanted students to be exposed to “more than one discipline” that taught the same or similar material. Mike (ITEEA) described lessons being “set in some form of context…CTE courses [brought] real-world experiences to the table.” Michelle (NSTA) wanted to ensure students were prepared for the “real world” and/or the 21st century. For her, the idea of integrated appeared to be a natural phenomenon for STEM subjects and should not be taught in “silos” as Maverick (ISEA) indicated. It became evident from these other comments the rationale for students to experience such lessons was to ensure students could make appropriate connections with the disciplines, as seen in Michelle’s (NSTA) and Maverick’s (ISEA) statements and potentially develop certain characteristics in the students, as alluded to in Joel’s (NSTA) and River’s (NSTA) statements. Table 4-11 illustrates these categories in this theme.

Table 4-11

Ethos of the I-STEM Experience based on Subjects' Perceptions

Categories/ Participants (Grade/Organization)	Subjects' Perceptions about the Ethos of I-STEM	
	Curricular	Belief in I-STEM Experience
Mike (11/ITEEA)	• Wrote curriculum for Non-PLTW ® course to ensure there was a curriculum that gave students appropriate experiences	• Personal Belief that I-STEM is the best thing for students. • Lessons must be set in some form of context • Believes CTE courses brings real-world experiences to the table
Archer (9/ITEEA)	• They have taught me about nanotechnology and cars that can drive by themselves based on this technology.	• I provide a place to fail. I provide a second chance. • Want to expose student to more than one discipline of the same or similar material.
Michelle (10/NSTA)	• Got endorsement to teach technology, physics, and earth science • Cannot keep teaching science separate from math separate from engineering separate from technology	• Want to prepare kids for college/real world/21st Century • Help students learn about STEM careers and how integrated they are
Gavin (12/NSTA)	• Wanted to design a lesson so students could access the content information • Rubrics must accommodate creative solutions to problem.	• Teaching environment must be very flexible
Joel (9/NSTA)		• I believe STEM is only successful when one gets their [sic] hands dirty • I strive as much as possible to apply the knowledge my students learn with experimentation in a wet-lab type setting.

Ethos of the I-STEM Experience based on Subjects' Perceptions (Cont.)

Categories/ Participants (Grade/Organization)	Subjects' Perceptions about the Ethos of I-STEM	
	Curricular	Belief in I-STEM Experience
River (10/NSTA)	• Rewrote lesson to not have it be a regurgitation of content knowledge	• Belief lesson allows [him] to help direct students onto right path • No one right way or always a correct answer
Maverick (9/ISEA)	• Do not teach in isolation • Moving away from silos	• Looking for relevant ways to make [Curricular] connections • Helping people understand many ways STEM can [fit] into different disciplines.

The participants provided many different comments and statements that helped one better understand how they understand I-STEM and why these participants were motivated to teach I-STEM lessons. Chapter 5 examines the implications of such findings.

Chapter 5

Conclusion

Overview of Chapter

I designed a study to better understand how teachers defined I-STEM, manifested those definitions into lessons and/or artifacts, how they assessed students in such lesson settings, and what factors or rationales supported their ability to conduct I-STEM lessons. In this chapter, I will discuss how the data collection from surveys, interviews, email responses, and artifacts began to reveal the answers to questions related to these topics.

My discussion will be in three broad categories. First, it appeared teachers constructed a definition of I-STEM based on different personal experiences, and did so in the absence of a formalized definition. These definitions revealed that participants had various perceptions about integration and which disciplines were to be implemented in an I-STEM lesson.

Second, I discuss the findings from the artifacts, what they were asking students to do, and what the assessments valued. Third, the participants appeared to share three things in their perceptions about their understanding of I-STEM. Lastly, I will discuss different factors that appeared to assist in their implementation of I-STEM in their classroom. I will discuss those findings and some considerations related to research in literature in regards to implementation of I-STEM in select teachers' classroom.

In the final sections of this chapter, I will provide some recommendations and possible reflections for school leaders and teachers who may be planning on conducting I-STEM lessons or implementing I-STEM programs in a secondary setting (grades 9-12). Included in this section are limitations regarding the study and future research opportunities.

Discussion

Three distinct factors emerged from an analysis of the participants' data: Lack of Consistency among I-STEM Disciplines, Assessments of Students that was Predominately Soft-Skills Focused, and Three Shared Characteristics Highlighting Participants' Experiences for I-STEM. Additionally, I have included a section entitled Factors Effecting Implementation of I-STEM that emphasizes some rationales participants described enhancing their ability to implement I-STEM lessons. In the following paragraphs, I will talk about the results from these three areas. In a subsequent section I will exam the factors influencing teachers' decisions to implement I-STEM lessons.

Lack of Consistency among I-STEM Definitions After analyzing the participants' definitions and statements about their definitions, the greatest take away was that each participant had their own unique understanding of the integration of STEM. This finding was surprising to me. I thought there would be more consistency in the definition, but not necessarily in the lessons that teachers would submit as exemplars of those definitions. It appeared each participant's own perspective and experiences shaped their understanding of and development of an individual I-STEM definition. Table 5.1 highlights the mentioned STEM disciplines from participants' definitions and how they represented integration from their responses. Two things shared by the participants were the commitment each had regarding the I-STEM lesson and the belief in an authentic product and experience. These will be discussed in subsequence sections.

The diversity among the participants' definitions surprised me. I anticipated more consistency in the definitions from those who identified as implementing I-STEM lessons. Should I have been as surprised to find a lack of uniformity in these definitions? The answer should probably be “No” since, a review of the literature showed that scientific community had no agreed upon definition for STEM (Bybee, 2010b) or even I-STEM (NRC, 2014). As discussed in Chapter 2, the various organizations either defined integrated STEM from their perspective or provided no definition regarding I-STEM (NRC, 2011; NRC, 2012; NRC 2014; Bybee, 2010b, Hershback, 2011; Barakos, et al., 2012). Therefore, there was a broad range of interpretation even in the literature. This study, even with its limited number of subjects, demonstrated an inconsistency in a shared understanding and reinforced the notion there was a lack of consistency within and among teachers regarding I-STEM.

The study revealed in more depth how little consistency there was between the participants. Interpretations of I-STEM highlighted the differences between teachers belonging to different organizations, as well as among educators within the same organizations. There were a total of 10 participants with six from National Science Teachers Association, three from the International Technology and Engineering Education Association (ITEEA) and one from the International STEM Education Association (ISEA). NSTA, an advocate for science education and STEM experiences, did not provide a definition of STEM for its members (www.nsta.org). While a possible coincidence, this lack of a definition appeared to be reflected in the participants’ varied interpretation of I-STEM. The NSTA participants were the most diverse in their understanding of I-STEM, how the STEM disciplines were integrated, and how pedagogical practices were applied. Of the six NSTA participants, three of the six NSTA participants mentioned science in their definition, while the other three did not, and two of the six mentioned all four disciplines in their definition. No other self-reported organizational representatives had a higher number of persons mention all the disciplines as part of their definition.

No representatives from the National Council of Teachers of Mathematics (NCTM) participated in this study. This raised an interesting point and possible future research question about whether or not teachers who associate with NCTM believe they could conduct integrated lessons with any or all of the STEM disciplines. Wang, et al., (2011) did have Nate, an identified math teacher, participate in their study, however, it was made clear that Nate had no previous I-STEM teaching experiences until he participated in the research program.

This study did not do a comparative analysis between participants' definitions and the various professional organizations, so any assumptions about the amount of influence made by an organizational definitions were just that: an assumption. However, it is interesting to note that two teachers associated with ITEEA, Mike and Archer, held perceptions about engineering and technology that were closely aligned with ITEEA's definition that embodied "application of technological/engineering design based pedagogical approaches" (www.iteea.org). Preston, who also self-reported as ITEEA, identified math and science classes that were "reinforced by Technology classes;" this approach appeared to apply technology as a separate entity. Further, he stated he did not conduct lessons that were considered I-STEM.

The majority of the participants (six of ten) did identify at least two STEM disciplines in their definition. NRC (2014) stated the "most well-studied integrated STEM education pairing is that of mathematics and science" (p.53). However, the most frequently paired I-STEM disciplines found in this study were science and engineering. Most often engineering was incorporated as a lesson delivery method. For example, NSTA, with its six participants, had three identified engineering design, two were scientific investigations, and one was hands-on for their self-reported pedagogy strategies. The last one, hands-on, had several markings in his lesson for engineering design, but the participant did not alter his description regarding this approach.

Barakos, et al. (2012) described a continuum of perceptions about I-STEM lessons that displayed variations of integration in the STEM disciplines. The majority of the lesson artifacts fell onto the continuum in the categories labeled as "Combining two or more STEM content areas using enrichment activities" or "Curriculum combining content and practices of two or more disciplines in order to support understanding of both" (p. 8). Most often the lesson was designed around either the science or engineering content. Math and technology were the two most often minimized disciplines in the application of an I-STEM lesson. From the participants' submissions, there was no example that demonstrated all four STEM disciplines being equally incorporated into a lesson. Barakos, et al. (2012) classified this as "Fully Integrated STEM." Views about the mathematics discipline will be discussed below, while perceptions of the technology discipline will be discussed in a separate section.

Mathematics was either identified and/or incorporated into half of the definitions (5/10), but was not a primary discipline in which the lesson was built around or consistently included as an equally applied discipline. Mathematics was most often seen in the role of reinforcing the findings from the engineering or scientific experience and, if removed from the lesson or experience, it would not have prevented the students from completing their product. Michelle had her students construct a generator using resources found in the African country, but the mathematics applied was to calculate the cost of development. Students conducting the lesson in Archer's class were to use math to calculate the efficiency of the fuel and power sources as part of their explanation in selecting their particular natural resource, such as solar or wind. Shannon had students calculate the percent error between the constructed meter device and a commercially produced one.

Neglecting the "T" in I-STEM. Another finding emerged from the statements and artifacts dealing with technology. The concept was included in five of the ten definitions, but was not incorporated into most of the lessons/activities identified in the participants' definitions. Part of the issue may be how some organizations defined technology. In the ITEEA definition mentioned in Chapter 2, technology and engineering were described as a single entity or so intertwined they cannot be distinguished from one another, as seen in the phrases "technological/engineering design based pedagogical approaches" and the "the content and practices of technology/engineering education" (http://www.isea-stem.org/#!about/cipy). They were not distinguished as technology and engineering practices. This lack of clarity was continued with NRC (2014) description of technology. NRC (2014) defined the discipline of technology as the following:

> *Technology*, while not a discipline in the strictest sense, comprises the entire system of people and organizations, knowledge, processes, and devices that go into creating and operating technological artifacts, as well as the artifacts themselves. Throughout history, humans have created technology to satisfy their wants and needs. Much of modern technology is a product of science and engineering, and technological tools are used in both fields (p.14).

This definition acknowledged various interpretations of technology in the I-STEM field. It was previously understood as "industrial arts" (p. 17), but was understood as different from vocational education. However, it was referred to as "educational, or instructional technology…[that] included technologies such as filmstrips, movies, television, videos, and learning aids, such as calculators and electronic whiteboards" (p. 18). NRC (2014) described a third interpretation in which the discipline of technology could also contain the "tools used by practioners of science, mathematics, and engineering" (p. 18). These tools could range from supercomputers, to microscopes, to telescopes and other resources that help these scientists and engineers examine various phenomena. One's understanding of how technology in the context of I-STEM could impact how technology and other STEM disciplines are integrated.

From the participants, only one lesson (Mike's) clearly distinguished technology as a discipline the students were to incorporate in their designing of solutions and was included in his original definition. Students were to program, troubleshoot, and design solutions for computers or computer-based systems. Archer, Michelle, Gavin, and Preston included technology in their respective definitions or explanations, but applied it differently than Mike. If technology was used in the their lessons, it appeared to be as a "tool used by practitioners" (NRC, p. 18). Archer and Michelle asked students to integrate technology into their design, such as building fuel and power sources (Archer) or generators that run on alternate energy (Michelle). Gavin and Preston described in their definition how technology was to be used, in both cases as a support discipline, but neither had it in a lesson or shared an activity with technology integrated in it. Gavin explicitly stated it was a "tool" used in the creation of solutions, while Preston and Marsha described students learning math and science with technology classes to reinforce these disciplines.

Technology was stated in five of ten definitions, but was not seen in many of the artifacts or discussed much in the survey, email, or interview responses. Could this be due to a need for teachers to better understand the nature of the technology discipline? This was alluded to in some research literature. Wang, et al. (2011), stated there was a need to incorporate technology with the other STEM disciplines. However, some literature implied teachers might not have the aptitude to integrate technology that retained the integrity of the discipline. Neiss (2005); Koehler, Mishra, Yahya, (2007); and Archambault and Barnett (2010) all argued for a need develop a technology pedagogy that made it more comfortable for teachers to apply.

Neiss (2005) and Lewis (2012) both discussed the need to develop and train Technology

Pedagogical Content Knowledge (TPCK) as part of teacher preparation and development. But, as Neiss (2005), particularly identified from his research, was the application of TPCK in a lesson that incorporated "teaching and learning with…technologies" (p. 513). Both studies identified teachers' underdeveloped understanding of technology as pedagogy, as content, and how to integrate technology into a lesson. Each author described various barriers to the incorporation of technology, such as a teacher's "recognition of her own limitation with technologies" (Neiss, 2005, p. 520) or with appropriate training and support on various technology resources (Lewis, 2012).

While this study did not specifically investigate teachers' comfort level with technology, participants' responses and artifacts gave some insight into understanding how the discipline of technology was considered in the context of an I-STEM lesson. Additional follow up questions with these participants would have been needed to better understand more accurately their perceptions on technology. Mike, Archer, and Michelle appeared to be comfortable with technology. Based on the information, these three reflected the interpretation of ITEEA's definition as well as, the description of technology that incorporated technological tools in the design of the solution of a problem as described by NRC (2014).

Three Shared Characteristics Emphasizing Experiences of I-STEM. The previous section discussed how a teacher thought about I-STEM, but did not reveal much about *why* they may conduct an I-STEM lesson. Part of the intent of this study was to better understand *why* teachers might conduct I-STEM lessons. In their responses, teachers described factors that influenced their perception about teaching I-STEM lessons.

Nearly all participants shared three characteristics that can be best described as an ethos regarding their understanding of I-STEM. When the data was looked at as a whole, the participants consistently thought of I-STEM as a unique experience, I-STEM could assist in providing an authentic experience, and prior work experience influenced their perception about I-STEM.

I-STEM as a Unique Experience. A certain conviction in the I-STEM experience underlined the purpose for conducting such a lesson. Mike stated, "I-STEM is the best thing for students." For others, an I-STEM lesson gave students multiple opportunities to demonstrate proficiency. Archer understood these lessons as a place for students to have a "second chance" on assignments. Further, students had a place to fail, but it also provided a chance for him to teach and for students to improve their grade. River aligned with Archer in his belief that many scenarios did not have "one right way" or a "[single] correct answer." Failures experienced in class by students allowed him to "help direct students onto the right path." This author shares a similar perspective with Archer and River in the idea that students need to have "successful failures" (my term) in order to understand what they missed or not correctly designed as a solution or product; these lesson designs provide students opportunities for such experiences. Maverick and Michelle shared a similar belief in their efforts to show students how the disciplines were very much integrated. Gavin and Archer stated the environment established by an I-STEM class was accommodating enough and flexible enough allowing students to have two or more chances in solving the problem or designing a solution. One participant, River, expressed his delight in the coming of the new science standards for they were aligned to his own teaching philosophy, particularly the defined science and engineering practices and the cross cutting concepts (NGSS, 2013). For them, I-STEM is the most appropriate way for students to make connections across the disciplines and construct lessons for such purpose.

Six of the ten participants revealed things they did to continue to improve learning experiences and well as the lessons for students. Mike wrote curriculum for students in courses that did not use Project Lead the Way, a commercially produced STEM curriculum for grades K-12, so they could have an appropriate experience. Archer stated these lessons continue to teach him about current events and topics. He was being a learner along with the students. His shared example is on how one student taught him about nanotechnology and its impact on driverless vehicles. Michelle got additional teaching endorsements in technology, physics, and earth science to ensure her students had an I-STEM experience. Joel actively searched for ways to conduct I-STEM lessons in his classroom with his curriculum, which was very similar to River's effort to rewrite lessons to ensure students conduct I-STEM lessons and not participate in a "regurgitation of content knowledge." Maverick continuously looked for relevant ways to make content and application connections for his students as he designed his I-STEM lessons. There was a real passion and persistence to construct a learning experience that students could begin to conceptualize what it meant to participate in an I-STEM experience.

The Desire of an Authentic Experience in I-STEM Lessons. As stated previously, one of the shared traits among the participants was this idea of authenticity. It became an undeniable factor for most (8/10) participants' decision to conduct an I-STEM lesson was the need to provide an authentic experience for their students with the STEM content. Most participants stated the experience had to be "real-world" or authentic in some way. Michelle designed a lesson/activity around a scenario where students imagined they were in an African country and needed to construct a generator from resources available in that country. Mike had lessons/activities troubleshooting systems found in the common devices, such as computers. Archer asked students to take a current form of transportation and project themselves 25 years into the future to build a transportation vehicle that operated on a new fuel and power system. Gavin asked students to imagine a scenario where they had to manipulate a spacecraft.

The two teachers who conducted scientific investigations, however, did not ask students to imagine a scenario. Rather, they placed students into their current reality and asked them to predict certain outcomes based on parameters set by the lesson. For example, Maverick asked students to design their own experiment, collect the data, and present on one of the three Newton's laws. River introduced several environmental science concepts, such as succession, population, and carrying capacity, and asked students to predict outcomes when certain variables are changed. Both applied science practices to an ordinary situation, by which the student could influence an outcome.

This idea of authenticity in an I-STEM lesson was also found in literature (Davis, et al, 2008; Davis, et al., 2010; Laboy-Rush, 2012). Lombardi (2007) defined the idea of authentic as the "learning typically focused on real-world, complex problems and their solutions, using role-playing exercises, problem-based activities, case studies, and participation in virtual communities of practice. The learning environments are inherently multidisciplinary" (p. 2). It was this definition of authenticity that guided me in my study. Lombardi (2007) goes on to explain, by referencing Lave and Wenger (1991), that authentic learning emerges the learner engaged in a context where they become responsible for their own learning. As seen from their responses, several described what Strobel, et al., (2013) would have categorized as a "context authenticity" (p. 149) and "task authenticity" (p. 149). What participants did not describe in their responses or indicate in their artifacts were authentic experiences that reflected Strobel, et al., (2013) concepts of impact or personal/value authenticities.

None of the participants ever actually defined authenticity, but some of the comments alluded to their philosophy about the importance of an I-STEM experience. In the next section, I will discuss prior work experiences, but the relevance of such experience cannot be underestimated or overlooked. Participants openly described such experiences as ones they wanted to transfer into the classroom for students, as was evident from Joel's prior experience in bench research, Michelle's time working as an engineer, and Archer's experiences working with NASA engineers.

Prior I-STEM Experiences for Participants. Part of what appeared to fuel this passion and provide this foundation for the ethos in conducting I-STEM lessons was the fact most discussed or provided information about previous experiences in a STEM field at some point in their careers. Not only did it appear to provide the motivation for conducting such lessons, these findings appeared to reinforce the notion of how a teacher understood I-STEM was reflected in a lesson or activity. Previous studies (Lin, 2013; Wang, et al., 2011; Roehrig, et al., 2012; Mong, 2013) each found a teacher's perspective about a STEM discipline influenced how it was designed and conducted. The findings in this study were also consistent with findings mentioned in literature that I-STEM experiences influenced a teacher's aptitude in conducting such lessons. Mong (2013) found "specific experiences gained as a STEM professional [could] affect teaching practice, with teachers who were STEM researchers more likely to find value in and use an inquiry approach than those who held non-research STEM positions" (p. 105). Similarly, Lin (2013) found teachers who had work experience in a STEM career were more likely to implement these practices. She wrote, "teachers' [with] prior work experience in the STEM industry…[who] had such experiences appeared to achieve more organized data collection, more use of extra material such as design logs, and more activities that were designed to help the students learn better." In the Wang, et al., (2011) study, they selected three participants, one from math, one from science, and one from engineering. Their study found teachers with a particular content background influenced their lesson design and purpose of lesson. They wrote,

> In these three teachers' cases, their perceptions of STEM integration strongly influenced how they designed their STEM integration unit. These included perceptions about he foci of STEM integration, perceptions regarding the processes of how to teach a STEM integration unit, and beliefs about how STEM integration can improve their students' learning. It is interesting to note that the three teachers, who teach different subjects, have differing perceptions about STEM integration, and this led to different emphases in their STEM lesson units (p. 10-11).

For some teachers, prior professional development or work-related experiences in I-STEM appeared to be a reason for conducting I-STEM lessons. This lowered affect may have been caused by the experience gained or by the number of years they worked in the various professional experiences in and out of the educational field. Mike and Archer stated specific number of years they had in various I-STEM experiences. For Mike, he had 26 years teaching Career and Technical Education (CTE) courses, 22 years teaching engineering courses, and 7 years teaching Project Lead the Way (PLTW) classes. Archer stated his years of experience included "40 years of architectural design and architectural experiences." Other participants did not specify the total number of years, but comments made by participants, such as Michelle's, Maverick, and Joel, implied they were all veteran teachers who had experiences with various STEM disciplines.

Data from this study regarding integration of STEM disciplines appeared to support literature's claim that teacher integrate disciplines in accordance to their own perceptions (Lin, 2013; Wang, et al., 2011). Pedagogical practices described by participants included both engineering design and scientific investigations. Two of the three ITEEA participants, Archer and Mike, both had experience in engineering fields and used an engineering design methodology. NSTA participants had a mix of educational and professional experiences, which gave a variety of pedagogical practices. Michelle, Shannon, Marsha each mentioned in their responses professional and education experiences with engineering backgrounds and, therefore, had the engineering design method in their activity or description, while River, a biology teacher, used scientific investigation. Maverick used scientific investigation as his means of integrating the other disciplines as part of the problem solving process. Joel, who had "bench research experience" surprised me as he identified engineering design delivery method; I would have assumed a lesson using a scientific investigation method based on his wet lab type of experience.

Participating on committees that studied the changes in standards and frameworks appeared to influence River and Maverick in their teaching of I-STEM lesson. River's comments described the change in his state's science standards to the new Next Generation Science Standards (Achieve, 2013) appeared to be a catalyst for the implementation of the types of lessons he always believed in conducting. Maverick incorporated the Common Core State Standards and their literacy components into the design of his I-STEM lesson. His Literacy Design Collaborative (LDC) unit focused much on literacy outcomes using science as the context. The product from the lesson addressed written communication standards. It was unclear from Maverick, if the development of STEM literacy was specific to this one lesson/activity or if the concept was part of a greater goal within the classroom. These attributes based on participants' statements are illustrated in Table 5.1.

Table 5.1

Table Summarizing Participants' Definitions, Perceptions of Integration, and Attributes Influencing I-STEM Implementation

Participants Grade/Organization	I-STEM Disciplines identified by Participants' Definition	Integration Portrayed by Participants	Attributes Identified by Participants
Mike (11/ITEEA)	• Technology, Engineering	• Engineering Design-Technology, Engineering equal contributors	• Authenticity • Prior Experience • Ethos • School Did Not Influence Definition
Archer (9/ITEEA)	• Science, Technology, Engineering and Math	• Engineering Design-Science and Engineering equal contributors, Math support role	• Authenticity • Prior Experience • Collegial Support • Ethos • School Did Not Influence Definition
Preston (10/ITEEA)	• Science, Technology, Math	• Technology support role	• School Did Not Influence Definition
Michelle (10/NSTA)	• Science, Technology, Engineering and Math	• Engineering Design • Science, Engineering equal contributors, Math support role	• Authenticity • Prior Experience • Collegial Support • Ethos • School Did Not Influence Definition
Gavin (12/NSTA)	• Science, Technology, Engineering and Math	• Hands-on • Science and Math equal contributors	• Authenticity • School Did Not Influence Definition
Joel (9/NSTA)	• None Mentioned	• Engineering Design	• Authenticity • School Did Not Influence Definition
Marsha (9/NSTA)	• Technology	• Hands-on • Technology brought in	• None Provided • School Influenced Definition
Shannon (11/NSTA)	• Engineering, Math	• Engineering Design	• Authenticity
River (10/NSTA)	• Science, Math	• Scientific investigation	• Authenticity • Ethos • School Did Not Influence Definition
Maverick (9/ISEA)	• Science, Math	• Scientific Investigation	• Authenticity • School Did Not Influence Definition

Comparing My Definition with Participants' Definitions

As I investigated this project, I was pleased to find I shared the same conviction and passion about I-STEM and the need for students to participate in an I-STEM experience that most participants expressed in their statements. However, we differed on how it should be defined. My definition required an I-STEM lesson incorporating at least three disciplines equally contributing to the scenario. By equal I mean, a situation requiring three disciplines in the development of the solution. In other words, if one is removed, the student could not solve the problem.

As I stated for my definition in Chapter 3

> I-STEM is the deliberate integration of three or all four of the STEM disciplines within a single learning experience. This learning experience can occur within one or more classrooms and can occur over various lengths of time, such as one class on one day or over multiple days in various classes, but must occur in a shared learning unit. Each discipline must be applicable to scenario, contribute to the outcome, and must retain the integrity of the individual STEM discipline, in which the user applies appropriate content knowledge and skills associated with the disciplines.

None of the participants would have been classified as having conducted an Integrated STEM lesson if their lessons were compared to my definition. Participants had only two primary disciplines relevant to the outcome of their product. Their definition would have been more in line with Sanders (2009) definition, which reflects Virginia Tech's Integrative STEM Education Graduate Program. He stated, "integrative STEM…includes approaches that explore teaching and learning between/among any two or more of the STEM subject areas…" (p. 21). And therein lies the rub: various experiences and influences have shaped one's understanding of I-

STEM as perceived by the participant. Therefore, it is very necessary for the members of the Science/STEM communities to have an agreed upon definition from which to start from. If we agree with Sanders (2009) definition, then have we not already been integrating STEM disciplines long before we labeled it Integrated STEM? A traditional high school physics course could be considered integrated if we work with that definition. In many ways, Sanders (2009) concern with "STEMania" (p. 20) was prophetic and became reality.

If we want to continue using the term Integrated STEM or I-STEM, then we must begin to demarcate this concept from more traditional science, engineering, or technology lessons. I agree with Sanders (2009) position that we do not need a "new stand alone subject" (p. 20), but I differ in that we need some form of endorsement or certification indicating that a teacher who implements integrative STEM lessons has qualifications to do so. If there is no desire to have such certification, then we need to stop making such a push for I-STEM and provide better training and professional development for teachers to implement inquiry, project based learning, and/or purposeful design and inquiry (Sanders, 2009; McComas, 2014).

Assessment of Students was Predominately about Soft Skills

Another development that emerged regarding assessments, particularly from the participants who submitted both survey and interview responses was a mismatch between the described lesson/activity and the submitted artifacts used in assessing students. Soft Skills (Grugulis & Vincent, 2012) was the skill set assessed based on submitted artifacts. Grugulis and Vincent (2012), from Chapter 4, explained this concept as demonstrating one's ability in "communication, problem-solving, team-working, ability to improve personal learning and performance, motivation, judgment, leadership and initiative" (p. 598). Most participants (7 of 10) expressed in their definitions outcome expectations as a physical object developed by an engineering design method or data/information collected by scientific investigation. However, from submitted artifacts, much of the lessons' structure and point values lay in the ability of one to write about or present upon the topic and not necessarily the I-STEM content or skills used to create such a product.

The majority of participants (seven of ten) described the creation of a product, which could be a physical object (conductivity meter, generator, vector model, or a prototype of a car, boat, plane) and/or a communications product, either written (paper, instructions) or oral (presentation). From their data, six of ten participants mentioned various soft skills as part of the evaluation process. For them, it was important to see students work as a group/team, exhibit perseverance through troubleshooting, and implement the appropriate literary mechanics. Nearly all (seven of ten) discussed assessing I-STEM skills and knowledge through various means, such as exams, quizzes, or feedback provided by either students or teacher.

While most statements from surveys and/or interviews discussed I-STEM skills and/or content knowledge, points were typically awarded to Soft Skills, specifically to one's ability to communicate, either orally or in writing, their findings and procedures. Rubrics contained few or any point values related to a student's ability to perform the I-STEM skill or internalize the I-STEM concept. Maverick's rubric was intentionally designed to assess the communication aspect, both written and oral, of the lesson, for his lesson was a literacy-designed exercise. Only a few of the overall points were awarded to I-STEM Skills and/or I-STEM knowledge.

The most unique way of assessing students was found in Archer's artifacts. For this particular lesson, students were to construct three different projects: a vehicle, a paper, and a video. As students were designing and constructing each of these projects, students and the teacher were providing feedback to an individual student about their projects. The rubric for this assignment was not assigning point values to the projects, rather it was giving student specific information about his/her project. If a student received a “RAMC,” they needed to “Research Additional Material Choices.” Another abbreviated feedback was “RDPS,” which told the student to “Research a Different Power Source.” With this information the student then returned to the respective project (vehicle, paper, video) and made appropriate adjustments.

The submitted rubrics provided structure and feedback for students only on the writing project. Technical writing could be considered an assessment of I-STEM skills (Girill, 2012); this was not the problem. The concern was the lack of feedback/assessing for the I-STEM process and product development. It felt a bit unbalanced, since the majority of the scoring was the writing product.

The discrepancy found between the lesson’s expected outcomes and what was to be assessed raised some questions about why this was the case. Literature from Wiggins and McTighe (2005) describes how for many teachers thinking like an assessor “does not come naturally or easily to many teachers” (p. 150) in designing an activity without first identifying the performances and/or products from the lesson. This leads to a mismatch between the assessments with the activity. Another possible factor could be the difficult task of constructing rubrics, particularly “analytical rubrics” (Allen & Tanner, 2006, p. 188). Such rubrics are designed to measure specific criteria, but many teachers “make the mistake of relying on criteria that are merely easy to see as opposed to central to the performance and its purpose” (Wiggins & McTighe, 2005, p. 172). Allen and Tanner (2006) described two common rubric types, analytical rubrics and holistic rubrics. They state, “Analytical rubrics use discrete criteria to set forth more than one measure of the levels of an accomplishment for a particular task…[and] often…have the best match between an assignment and its objectives for a particular course” (p.

198). These are distinguished from "holistic rubrics" (p. 198) that are more generalized and have undefined categories and/or qualities. Of the submitted rubrics, two of the four would have been classified as a holistic rubric, since they contained categories that were not well defined or tightly focused on the lesson attributes specific to I-STEM skills and content.

As discussed previously, there was little agreement in the how they understood I-STEM; the design of assessment mechanisms was not much different. These findings suggested teachers were assessing outcomes different from what they were stating in their own definitions and descriptions. With no rubrics designed to assess or evaluate the constructed prototype or the skills applied in the development of the object, students may not be making the appropriate connections between the various STEM disciplines or developing the skills or content knowledge. Mike stated it most succinctly, when he wrote "We have to understand how systems interact to make things work properly…[by] getting the relationships between systems to be at the core [*sic*] of what students are experiencing makes the activity truly a STEM experience." These outcomes have raised a concern about when and where in the process will the content and skills of STEM disciplines be assessed during the lesson experience.

Soft skills are certainly abilities, in which we want our students proficient. However, these skills are not unique to science or STEM communities. They are universal attributes that students apply across all content areas. What is unique to the STEM community is the ability to transfer, apply, and create knowledge and skills based on the four STEM disciplines. It should be these skills we are deliberately assessing with a rubric or assessment system that allows students to understand their own strengths and weaknesses.

Two Notable Factors Related to Teachers' Implementation of I-STEM

Some literature (Ashgar, et al., 2012; Park & Ertmer, 2008; NRC, 2014) described factors limiting or even preventing teachers from conducting their own I-STEM lessons. Ashgar, et al. (2012) identified some specific external barriers in their article related to administrative support and curricular expectations. While some findings from this study did overlap with conclusions from previous research, there was an additional outcome, collegial support that appeared to add depth to the conversation about why teachers conducted I-STEM lessons.

School Influences on I-STEM Models of Instruction. It appeared the school had little influence on a teacher's reason for conducting a lesson. The majority of teachers (9/10) stated their school/district did not have an influence on their definition or understanding of I-STEM. Only Marsha stated her definition was influenced by her school/district. Schools or districts not having a common definition for teachers did not stop the majority (9/10) from conducting what they believed were I-STEM lessons. No evidence was submitted or provided by the participants indicating they taught these lessons because they had to or was a part of the teacher's curriculum constructed by the school or district to use in the classroom.

Ashgar, et al., (2012) raised a point from their study that lack of "administrative support and encouragement" (p. 94) was a barrier. As described by Ashgar, et al., (2012), this support was necessary for it created an environment that encouraged teachers to "adopt new approaches to instruction and assessment" (p. 94). I did not receive from any of the participants' comments or statements that they did not have the support of their administrators in implementing I-STEM lessons. As described in Chapter 3, three of the ten participants indicated they had a designated STEM pathway for their students in their setting. For them, administrative support would be expected. However, the majority (9/10) did self-report they conducted I-STEM lessons regardless of the school setting.

Collegial Support for I-STEM Instruction. Much of the research examined individual teacher's perception about conducting I-STEM lessons (Wang, et al., 2011; Roehrig, et al., 2012; Mong, 2013; Lin, 2013). However, Rockland, Bloom, Carpinelli, Burr-Alexander, Hirsch, and Kimmel (2010) described a factor they identified as "collective participation" (p. 55). This concept was described as teachers meeting in "discipline and grade level groups to discuss strategies and content, and to develop approaches that they present to their peers" (p. 55-56). What my study appeared to also reveal was the importance of collegial support in the design of and implementation of participants' perceived I-STEM lessons.

Literature hinted about opportunities for teachers to work together, but was inhibited by the lack of common planning time. Asghar, et al., (2012) wrote, "Several teachers pointed out…different students would be in different classes, they would not be able to work out an arrangement with a colleague to cover all discipline-specific curriculum material in an interdisciplinary fashion…without such an agreement they could not commit the time to interdisciplinary problems because they had too much material to cover" (p.106). However, some of the participants' responses ran counter to this argument.

Four of the participants mentioned experiences where they had support from colleagues or community partners. Three (Maverick, Michelle, River) described scenarios where they had collegial support in the design of and implementation of I-STEM lessons in the one classroom or across multiple classrooms. Archer revealed he has community partners, NASA engineers, to aid in his lesson implementation, which were developed in a previous professional experience.

As he explained in our conversation, these engineers were resources he could call upon to either 1) verify or clarify data or information or 2) set up conferences for his students to ask questions.

Future Opportunities for Research

From the comments and responses, the teachers who participated in this study were dedicated to this idea of integrated STEM. However, the lack of a common definition greatly inhibits one in assessing the effectiveness or impact of such lesson. Consider the impact upon students if we had such a definition and expected outcomes.

This study anticipated a variety of participants from the four organizations and did receive data from persons identifying with three of the four organizations. Of the ten participants, only one stated no I-STEM lessons were conducted. This study would have benefited more from having additional participants like Preston. Analyzing artifacts and lessons from teachers who self-reported as not conducting I-STEM lessons with those who did claim they were conducting I-STEM lessons would have been an interesting comparison. How similar and different are the two groups? Do the lessons have patterns across organizations? How similar are teachers like Preston, who state they do not conduct I-STEM lessons, to those who do state they conduct I-STEM lessons? How similar are lessons, rationalities, assessments and/or experiences between these two groups?

Another research project to consider is measuring the impact of student learning from such lessons. It is necessary to determine what needs to be measured in the study. I recommend, at a minimum, measuring the amount of content knowledge gained, along with the level of integration conducted within the disciplines. How well did the user blend the skills and practices of the different disciplines as part of the solution development? Another thing I would measure is the level of creativity demonstrated by the learner. There seems to be an ever-growing demand for creative thinkers in STEM (Larkin, 2015). Ramirez (2013) described it as the "secret in the sauce" (www.edutopia.org). If we want to see an increase in creativity in our students' thinking, then we need to measure for it.

The study would need to start with a shared I-STEM definition followed with some professional development to ensure all have a common working definition in the classroom, and, finally, an instrument would need to be created to analyze the lessons, such as one described by Nathan, et al., (2013). It would then have to measure pre- and post-assessment data on concepts identified prior in the study, such as confidence in the application of STEM skills, ability to identify connections across STEM disciplines, and/or an increase in STEM knowledge. This could be expanded to the four different school settings, as discussed in Chapter 2 (NRC, 2014), to measure effectiveness on student learning within each of the four school types. Keep in mind, this study did not evaluate or determine effectiveness of submitted I-STEM lessons.

An additional study could be to seek volunteers who believe they teach STEM or I-STEM lessons and collect various lessons over the course of a year to determine the type of lessons are implemented in multiple lessons. What was not pursued further in this study, for example, was if the engineering design pedagogical practice happens every time for the ITEEA participants. This study asked only for each participant to submit artifacts from a lesson best representing I-STEM, so multiple lessons was not collected from participants. Mike and Archer, both ITEEA, identified the classes they teach. Mike and Archer teach an engineering course, technology course, a Project Lead the Way (PLTW) course, or some combination, so one could assume their lessons are designed primarily around the engineering design method. However, this study did not directly ask which class or classes they taught on to submit lessons/activities they thought were I-STEM in nature. It was also not pursued for NSTA or ISEA participants.

Implications Regarding I-STEM Instruction

So what does this mean when there is clearly a lack of research of integrated STEM, a lack understanding about the impact of I-STEM on student learning, and lack of consensus on a definition? If each person or even each organization understands or defines I-STEM differently is it even possible to conduct an effective study between teachers who claim to teach integrated STEM lessons? More importantly how can one determine if I-STEM is any more effective than a traditional project-based lesson (McComas & Hayward, 2014) that used engineering or science as the central concept?

If I-STEM is to be considered a serious instructional practice, then some factors must be discussed. First, schools and/or districts need to develop an agreed upon definition for the term and the allowable interpretations of I-STEM. While there may not be a nationally agreed upon definition for I-STEM, schools and even districts can construct a working definition and methods for evaluating effectiveness. This would provide guidance to teachers in their efforts constructing and/or implementing I-STEM lessons.

In many ways, we are right back where we started in 1996 when the then new standards emphasized both content and inquiry, which was in support of a then new emphasis of "national education goals" (NRC, 1996, p. 12). The new standards provide new and unique opportunities, but also reveal teacher weaknesses and areas of need, since new material has been included. The need to establish an agreed upon, working definition for I-STEM can give focused professional development support and the development of appropriate resources for teachers to implement into the classroom.

Second, the teacher needs to understand his or her own perception about I-STEM. As seen from the participants, nine of the ten stated their school had no bearing on their definition or description of I-STEM. For most, it was constructed from personal experience, both educational and non-educational. Teachers own biases about I-STEM influences their definition of and application of I-STEM; they should identify their own strengths and weaknesses in conducting I-STEM lessons and collaborate with others to construct lessons for students that give a truly integrated experience. Literature suggests teachers having a background in engineering and technology are more likely to conduct lessons in those contexts, as well as, teachers who have a background in other science fields may design lessons with attributes containing science content and scientific investigation methods.

Another suggestion is the need for teachers to understand why I-STEM is necessary. Roberts (2012) wrote the primary purpose of I-STEM is for economic purposes. She stated, "it serves to benefit the economy by enticing more students into the study of STEM fields following secondary education" (p.2). This economic concept for I-STEM was also pushed in previous literature (NGA, 2007). However, we must be more focused on the development of student competencies and skills sets in the various STEM disciplines, as well interest in STEM fields. Sanders (2009) pointed out students who "lose interest in science and mathematics…make an early exit from the 'STEM pipeline'" (p. 22). This loss of students could potentially influence economic outcomes. While an admirable cause to cause a positive economic impact, another outcome should be to develop citizens who can think critically.

Recommendations

Develop a shared understanding of Integrated STEM. The importance of having a shared definition in which all persons can have a similar starting point cannot be overemphasized. In fact, we have an example in the history of science education of such an agreement occurring for an entire community: the concept of inquiry.

The scientific community agreed a more comprehensive curriculum was needed and a more stringent understanding of what it meant *to do* science was needed. To meet this need, the National Research Council (NRC) (1996) published the National Science Education Standards in order to build upon "the best of current practice…" (p. 12). In addition to defining the content, a shared definition of inquiry was produced. NRC (1996) wrote,

> Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world (p. 23).

While the content strands solidified what concepts should be taught in the various grade levels, the *doing of* science was still an enigma. To address this, NRC (2000) produced another book *Inquiry and the National Science Education Standards: A Guide for Teaching and Learning* that in essence defined how to do science through inquiry. This publication discussed what inquiry looked like in the classroom, how it should be assessed, and how teachers should be prepared to conduct inquiry in the classroom. A similar approach is needed if we want to implement I-STEM.

Conduct Studies based on Established Definitions. If we have taken a step back and established a working definition, then we need to reconsider how we understand the concept. It would be necessary to understand NGSS (Achieve, 2013) incorporation of the idea of practices, which is a comprehensive term that includes both content and skills, and is therefore understood to be applied simultaneously. Second, the standards were expanded to include Technology and Engineering. These two disciplines have their own entities and definitions, as discussed in Chapter 2. Because of this all four disciplines are equally accessible to students in ways they have never been so before. In many ways, we are right back where we started in 1996 when the then new standards emphasized both content and inquiry, which was in support of a then new emphasis of "national education goals" (NRC, 1996, p. 12).   The new standards provide new and unique opportunities, but also reveal teacher weaknesses and areas of need, since new material has been included.

If we begin using a shared definition, like the one described above, then we should see two things. First, we should see an increased level of transference of content knowledge and skills across the various disciplines. Second, we should see an increase in the level of creativity in how one uses the disciplines to solve a problem. One example of creativity was presented in a recent episode of *CBS Sunday Morning* where a team of scientists, in their efforts to cure late infantile metachromatic leukodystrophy (MLD) used the HIV virus to fix the single gene causing the condition.

Limitations

This study had some diversity in its participants with three of the four national organizations were represented. One aspect of this study was to compare characteristics and patterns of definitions, artifacts, and assessments with those who self-reported they did conduct I-STEM lessons/activities with those who self-reported that they did not conduct I-STEM lessons/activities. However, only ten subjects (N=10) responded to the survey. Of those ten, only one self-reported no I-STEM lessons/activities were conducted. There was not an adequate data sample to conduct an analysis between these two categories.

Within this small number (n = 10) of participants, it would have been most ideal if two to three teachers from each of the four organizations (NSTA, ISEA, NCTM, ITEEA) would have responded and if, at least, one fell into each of the typological categories. However, that was not the case with this specific research project, therefore, generalizability is greatly reduced to other populations.

Another generalizability limitation was limited number of artifact submissions from the participants. The findings can only construct conclusions based on artifacts/lessons representing a snapshot into a teacher's classroom. Therefore, it is unknown if these identified characteristics are found consistently in other lessons conducted in the course. A more confident interpretation of the teacher's definition of and manifestation of his or her I-STEM definition into his or her lessons would have come from analyses of multiple artifacts from the same person over the year they conducted the course and through multiple classroom observations.

Another limitation was the majority of the information was self-reported either in a survey or email response. Three participants did conduct a phone interview so follow up questions could be asked for clarification and were recorded for accuracy. However, three responses were conducted via email, with some follow up emails returned, and all artifacts and survey responses were self-reported. One must assume they were correct, accurate, and truthful.

Summary

As NRC (2014) identified in their work, additional studies were needed in the area of Integrated STEM. This study was done to add to the conversation regarding I-STEM, albeit it was a small piece in a much larger conversation. What I hope this study does is allow conversations to happen among colleagues and organizations about how I-STEM should be identified and implemented in both classrooms and across the grade levels. It is important to move beyond the catchphrase of I-STEM (Bybee, 2010b) and to develop a better understanding of the “nature of integrated STEM education…[so we can] contribute constructively to this…movement” (Heil, et al., p. 1).

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APPENDICES

APPENDIX A

PURPOSE OF THE SURVEY

I am asking for secondary (grades 9-12) teachers to send me their best example(s) of the components of an integrated STEM (Science, Technology, Engineering, and Math) activity or lesson, which can include a lesson plan, powerpoints, assessments, rubrics, notes, student handouts, textbook activities, or any other resource applicable to that lesson. Please share this survey with any other colleague in or out of your school, who may or may not implement integrated STEM lessons and would be interested in participating in this survey. As responses are submitted and artifacts uploaded, an analysis of the survey questions and artifact data will be analyzed. Each participant will be asked to provide, voluntarily, contact information for any potential clarifying questions.

PARTICIPANT DISCLAIMER and INFORMED CONSENT

Thank you for participating in our survey. Your participation in this survey is voluntary and, if completed, will indicate an informed consent and an agreement to share your resources with Jacob Hayward, doctoral student at the University of Arkansas, Fayetteville, for the purpose of research towards the completion of a dissertation. You are free to refuse participation in this research or may discontinue your participation at any time. Your choice to participate or not will have no negative consequences or penalty.

Confidentiality: All information collected will be kept confidential to the extent allowed by law and University policy. To ensure confidentiality each participant will be known only to the researcher and no form of identification will be used during data analysis. The data will be stored on a computer or external hard drive in which only the researcher has access. Data or information provided by a participant and used in the study will be given a numerical code identifier, such as Participant 23.

Risks and Benefits: There are no anticipated risks to participating in this study. Potential benefits include expanding the research literature regarding integrative STEM lessons for teachers to use/refer to in designing/implementing integrative STEM schools.

Informed Consent:

Thank you for participating in this survey. Your participation is voluntary and, if completed, will indicate an informed consent and an agreement to share your resources with Jacob Hayward, doctoral student at the University of Arkansas, Fayetteville, for the purpose of research towards the completion of a dissertation. No names, schools, or any other forms of identification will be given in the production of the dissertation or will be shared with any third parties. Only the researcher has access to the data and web sites collecting the information. If you have questions or concerns about your rights as a research participant, please, please email or call Jacob Hayward at jhaywar@uark.edu or 479-750-8777 or Dr. Stephen Burgin, faculty advisor, at srburgin@uark.edu or 479-575-4283 or email or call Ro Windwalker, the University's Compliance Coordinator, at irb@uark.edu or 479-575-2208.

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Survey for Teachers

ITEM 1a- Please provide a name. This is what you will need to use as your identifier for any artifacts you provide.

ITEM 1b- Please provide contact information, such as email or phone number (if you wish to participate as a follow up interview).

ITEM 1c- Select one of the following organizations that you identify most with as a professional association:

- National Science Teachers Association (NSTA)
- International STEM Education Association (ISEA)
- National Council of Teachers of Mathematics (NCTM)
- International Technology and Engineering Education Association (ITEEA)

ITEM 2- Please indicate which grade level (Grades 9, 10, 11, or 12) you teach or most often teach. If you teach multiple grade levels, please select the grade level that most aligns with the artifacts submitted.

- Grade 9 -Grade 11
- Grade 10 - Grade 12

ITEM 3- Please select the description the best matches your secondary school (any combination of Grades 9-12)

- A secondary school with NO STEM academy or designated STEM pathway
- A secondary school with a STEM academy or designated STEM pathway
- A secondary STEM school that draws from a selected area, but has no entrance criteria (inclusive)
- A secondary STEM school that draws students from a selected area and does have entrance criteria (selective)

ITEM 4- Please provide your definition or description of Integrated STEM and describe how it would look like in a secondary classroom?

ITEM 5 - Is your definition influenced by a school, district or state definition? If yes, please provide that definition (if different than the one provided above).

ITEM 6- Based on your definition, have you conducted an integrated STEM lesson or activity? Yes or No

If YES, please continue to ITEM 8.

If NO, please go to ITEM 7 and give a brief explanation as to why these types of lessons are not conducted at your school.

ITEM 7- If you said "NO" in ITEM 6, please provide any information about why such lessons are not conducted. Please, if you said "NO" in ITEM 6, do not proceed further; ITEM 7 concludes your participation in the survey.

ITEM 8- Please upload artifact(s) used in your class that represents an integrated STEM lesson. This may consist of lesson plan, PowerPoint, assessments, rubrics, notes, student handouts, textbook activities, or any other resource applicable to that lesson.

ITEM 9- Please provide the objectives/goals related to the submitted lesson/activity.

ITEM 10- Briefly describe how the objectives provided in your activity or lesson meets your definition of Integrated STEM.

ITEM 11- Briefly describe how students are assessed or expected to demonstrate their understanding of the lesson or activity objectives.

APPENDIX B

Semi-Structured Interview Questions

Participants will have a choice when they submit their contact information, if they chose to participate in the follow-up opportunity, to respond with an Interview over the phone or through an email. The same five questions will be asked in either scenario. However, additional questions may be added based on the survey responses.

1. In your survey response, you stated your definition for integrated STEM is__________(Read the Statement)____________________________. Can you elaborate on how you developed that definition or description?

2. In your survey response you stated your reason(s) for conducting/reasons for NOT conducting an integrated STEM lesson/activity is/are ________(Read the Statement)________________. Can you elaborate on this statement?

3. Based on the artifacts or lesson submitted, discuss why/how these activities were selected as part of the learning experience

4. Discuss how the assessments were selected or created to allow students to demonstrate their understanding of the integrated STEM concepts?

5. Can you provide an example of a student assessment/product that went beyond your expected outcomes?

APPENDIX C

FOLLOW UP INTERVIEW QUESTIONS

1. In your survey response, you stated your definition for integrated STEM is…
Can you elaborate on how you developed that definition or description?

2. Based on the artifacts or lesson submitted (IF APPLICABLE), discuss why/how these activities were selected as part of the learning experience. You may include additional artifacts if necessary.

3. Discuss how assessments were selected or created to allow students to demonstrate their understanding of the integrated STEM concepts?

4. Can you provide an example of a student assessment/product that went beyond your expected outcomes?

5. How long does this lesson/activity typically take? How many days, weeks, or months do you allow in your planning for this activity?

6. In your lesson (IF APPLICABLE), how do failed attempts by students reinforce your understanding of integrated STEM?

APPENDIX D

UNIVERSITY OF ARKANSAS

Office of Research Compliance
Institutional Review Board

January 6, 2016

MEMORANDUM

TO:	Jacob Hayward Stephen Burgin
FROM:	Ro Windwalker IRB Coordinator
RE:	New Protocol Approval
IRB Protocol #:	15-12-433
Protocol Title:	*Analysis of Secondary Lessons Prepared as Integrated STEM Lessons: Common Characteristics, Learning Expectation and the Impact of Definition*
Review Type:	☒ EXEMPT ☐ EXPEDITED ☐ FULL IRB
Approved Project Period:	Start Date: 01/06/2016 Expiration Date: 01/05/2017

Your protocol has been approved by the IRB. Protocols are approved for a maximum period of one year. If you wish to continue the project past the approved project period (see above), you must submit a request, using the form *Continuing Review for IRB Approved Projects*, prior to the expiration date. This form is available from the IRB Coordinator or on the Research Compliance website (https://vpred.uark.edu/units/rscp/index.php). As a courtesy, you will be sent a reminder two months in advance of that date. However, failure to receive a reminder does not negate your obligation to make the request in sufficient time for review and approval. Federal regulations prohibit retroactive approval of continuation. Failure to receive approval to continue the project prior to the expiration date will result in Termination of the protocol approval. The IRB Coordinator can give you guidance on submission times.

This protocol has been approved for 250 participants. If you wish to make *any* modifications in the approved protocol, including enrolling more than this number, you must seek approval *prior to* implementing those changes. All modifications should be requested in writing (email is acceptable) and must provide sufficient detail to assess the impact of the change.

If you have questions or need any assistance from the IRB, please contact me at 109 MLKG Building, 5-2208, or irb@uark.edu.

109 MLKG • 1 University of Arkansas • Fayetteville, AR 72701-1201 • (479) 575-2208 • Fax (479) 575-6527 • Email irb@uark.edu

Appendix E

Email Correspondence

First email statement.

Dear __(Insert Participant Name)____,

Thank you for your responses in the survey and your willingness to participate in a follow up interview. Your input will help provide much needed data for this doctoral research study. As you have indicated in your survey response, you wish to provide additional information through an email. At this time, I am reviewing your survey statements and artifact submissions. Within five (5) business days, you will receive a second email containing the interview questions.
Sincerely,
Jacob Hayward, Ed.S.
Doctoral Student
University of Arkansas, Fayetteville

Follow-up email message.

Dear ____(Insert Participant Name)___,

I again want to thank you for participating in this study. The following questions are asked to help clarify your comments made in the survey and to accurately reflect your understanding of integrated STEM. You will find the questions are listed below and as attachment. Your responses may appear directly in an email or may be submitted as an attachment. In either format, please be sure to identify your answers with the appropriate question number. As with the original survey, you may chose to not answer any question or stop participation at any time. Please return your responses as soon as possible. Thank you.
Sincerely,
Jacob Hayward, Ed.S.
Doctoral Student
University of Arkansas, Fayetteville