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Preferred Instructional Design Strategies for Preparation of Pre-Service Teachers of Integrated STEM Education

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PREFERRED INSTRUCTIONAL DESIGN STRATEGIES FOR PREPARATION OF PRE-SERVICE TEACHERS OF INTEGRATED STEM EDUCATION

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ABSTRACT

PREFERRED INSTRUCTIONAL DESIGN STRATEGIES FOR PREPARATION OF PRE-SERVICE TEACHERS OF INTEGRATED STEM EDUCATION

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The purpose of this study was to identify the preferred instructional design strategies for the preparation of pre-service teachers who will deliver integrated STEM lessons. The research objectives were threefold and included identifying a preferred definition of integrated STEM education, developing its purpose statement, and creating a list of instructional design strategies that could be used for designing, planning, delivering, and assessing integrated STEM instruction.

The Delphi method was selected as the optimum approach for data collection, since STEM education is still a growing phenomenon lacking consensus in its interpretations of meaning and practice. Gaining group consensus from expert teacher educators regarding the preferred instructional design strategies for implementing integrated STEM instruction will offer guidance for developing pre-service teacher education courses.

Four rounds of surveys were conducted, which resulted in a proposed definition for integrated STEM education, a proposed purpose statement, and nine instructional design strategies—Plan an integrated STEM lesson, Select design challenges which integrate STEM content, Create solutions to problems using the engineering design process, Develop a project-based lesson, Develop an argument supported by STEM

knowledge integration, Support an experiential-learning environment, Choose multiple examples to demonstrate STEM concepts and connections, Assess student understanding of STEM relationships, and Arrange collaborations to solve problems applying STEM concepts. This study's results should aid teacher preparation programs in the development of future STEM teachers who are capable of designing, planning, delivering, and assessing instruction that will strengthen student's learning through integrated content and processes needed to solve complex societal problems.

DEDICATION

This dissertation is dedicated to my loving husband and best friend, Ryan. It was through his persistent encouragement and confidence in me that this work was completed with far less grief than had I done it without him. Thank you, my love, for your help around the house, for your patience with lost weekends, and your care for our children when I was working. Thank you for your friendship and for absorbing my passions as though they were your own.

And to Claire, Cate, and Wynn, it is my hope your education will inspire you to higher thinking and greater things. I love you all.

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CHAPTER I

INTRODUCTION

The Space Age, initiated by the launch of Sputnik I in 1957, has propelled American society into the 21st century. This is evidenced by technological advancements discovered through NASA's research which has reached everyday lives of Americans (Garrett, 2008). From programming household appliances to entering a job market increasingly dependent upon science, technology, engineering, and mathematics (STEM) related knowledge, students must be prepared for a different society from that of former generations. When considering the growing impacts of STEM on business and industry it follows that students trained in STEM education would have an advantage over students without knowledge and skills in STEM related content (Breiner, Harkness, Johnson, & Koehler, 2012; Fantz & Katsioloudis, 2011). Therefore, schools are attempting to transition to meet students' evolving needs.

An integral component of educational progress has been a revolution in curriculum design with emphasis on the STEM fields. Strategies for STEM education revitalization are warranted in order for the United States to stay competitive in the global market (Business-Higher Education Forum, 2011). This lends credibility to the work being completed by educators. However, despite efforts to promote curriculum change, students are not excelling as much as anticipated. The 2009 PISA scores indicated the United States placed 24th in mathematics literacy, 10th in reading literacy, and 19th in science literacy (OECD, 2010). Among the more accepted reasons for these shortcomings is the lack of access to adequate resources, including qualified teachers (Garrett, 2008).

As it is expected 1.6 million teachers will retire throughout the next decade (DOE, 2011), the opportunity to replace veteran teachers with highly-qualified, beginning instructors dictates a review of current educational preparation programs. The National Council for Accreditation of Teacher Education (NCATE) would like to seize this moment to turn current methods of teacher education "upside down" (NCATE, 2010). NCATE endorsed a transition from "an evaluation system oriented to the curriculum, to a system oriented to candidate performance" (Young, Grant, Montbriand, & Therriault, 2001, p. 13). NCATE (2010) states,

> To prepare effective teachers for 21st century classrooms, teacher education must shift away from a norm which emphasizes academic preparation and course work loosely linked to school-based experiences. Rather, it must move to programs that are fully grounded in clinical practice and interwoven with academic content and professional courses. (p. ii)

The mutual emphasis of content and pedagogical skill in teacher preparation is a needed reform (Shulman, 1986), and STEM education advocates suggest STEM is the intended means to that end. STEM education reform initiatives which specifically emphasize instructional strategies for integrated curriculum would serve to better prepare pre-service teachers in the STEM subjects. However, before these initiatives can be developed, there should be established a definitive purpose for STEM education. This research will seek to suggest an acceptable definition of integrated STEM education, propose a core purpose statement, and identify preferred instructional design strategies which explicitly address teaching strategies for pre-service teachers of integrated STEM content.

Purpose Statement

The purpose of this study was to identify the preferred instructional design strategies central to the preparation of pre-service teachers who may wish to teach integrated STEM lessons to students. The results of this study should aid teacher preparation institutions in the development of future pre-service STEM teachers who are capable of designing and planning instruction that can be subject specific but also to strengthen student learning through integrated content and processes needed to solve complex problems.

Research Questions

The following research questions were developed to provide the framework to guide this research:

RQ_1: For pre-service STEM teacher educators, what is a preferred definition of integrated STEM education?

RQ_2: For pre-service STEM teacher educators, what is a preferred purpose statement for integrated STEM education?

RQ_3: For pre-service STEM teacher educators, what are the preferred instructional design strategies central to delivering an integrative approach to the teaching of STEM?

Background and Significance

In 1983, the publication of *A Nation at Risk* (National Commission on Excellence in Education [NCEE], 1983) returned Americans' emphasis to science, technology, engineering, and mathematics curriculum (Mahoney, 2010). It warned America was not producing the competitive workforce necessary for continued economic prosperity.

> The time is long past when American's destiny was assured simply by an abundance of natural resources and inexhaustible human enthusiasm, and by our relative isolation from the malignant problems of older civilizations. The world is indeed one global village. We live among determined, well-educated, and strongly motivated competitors. We compete with them for international standing and markets, not only with products but also with the ideas of our laboratories and neighborhood workshops. America's position in the world may once have been reasonably secure with only a few exceptionally well-trained men and women. It is no longer. (NCEE, 1983, p. 10)

In response to *A Nation at Risk* (1983), President George H. W. Bush gathered the United States' governors in 1988 to design a plan to improve education in the United States (Ritz, 2009). The plan was entitled *America 2000*, and it established a 10-year proposal to revive America's education system. Ambitious goals, such as making the United States first in science and mathematics education and ensuring every American adult was literate and possessed the necessary knowledge and skills to compete in a global economy, were used to guide the United States' governors in their efforts to improve America's school system.

Following the establishment of *America 2000*, educators and professional organizations began to develop educational standards to meet these goals. With the exception of engineering, whose standards have yet to be defined, individualized subject standards were created by representative groups for each of the STEM subjects: the National Council of Teachers of Mathematics (NCTM) in 1989, the National Committee on Science Education Standards in 1996, and the International Technology Education

Association (ITEA) in 2000. While each set of standards were distinct in nature, all suggested integration in an effort to enhance student learning (Basista & Mathews, 2002; Mahoney, 2010). STEM education is intended to fulfill that suggestion. It is designed to serve as a means to prepare America's students for improved performance in the business and industry sectors through increased understanding of mathematics, science, technology, and engineering (Brown, Brown, Reardon, & Merrill, 2011). Central to the concept of STEM education is contextualization of learning. Contextual learning, which is rooted in the Constructivist Movement, is an educational theory which presumes individuals learn by constructing meaning through interacting with and interpreting their environments (Imel, 2000). Curriculum developers expect transfer of learning occurs when students are able to associate, through hands-on learning projects, knowledge in such a way as to gain deeper understanding of its concepts and principles (Berry, Reed, & Ritz, 2004; Luca & Oliver, 2002).

Given the potential toward improved learning, and thus economic stature with STEM content, proposals to implement STEM education are being instituted. Federal and state governments have increased funding for STEM related projects, organizations such as the National Science Foundation are focusing research on STEM initiatives, and K-12 curriculums are being developed all in hopes to improve STEM knowledge (Dugger, 2010). Suggested methods for curriculum integration between the STEM subjects have taken several forms. "Programs, modules, packaged curriculums, and even charter schools have aligned themselves with proposed models of what STEM educational programs should represent" (Mahoney, 2010, p. 24).

Despite these efforts, a review of the STEM initiatives reveals a majority of inadequate performances. Sanders (2009) explains the deep-rooted sovereign territories of the independent STEM subjects will not be easily moved. Therefore, even with the significant contributions made by government and private organization funds, there has been little gain in new STEM practices. The work has been largely uncoordinated and ill-defined, and teachers are being presented with integrated curriculum which they are unprepared to teach (Williams, 2011). This promotes frustration and low self-efficacy among STEM educators; whereas teachers who are prepared to teach integrated material enjoy greater satisfaction in the classroom (DeChenne, 2010).

Therefore, efforts are being made to remedy the situation. Initiatives including "leading companies, foundations, non-profit organizations and science and engineering societies to form part of the 'Race to the Top' programme" (Williams, 2011, p. 27) have compounded these efforts. Yet, without proper research and training in appropriate instructional practices, continued performances will remain inadequate (Mahoney, 2010). Creating a consensus of a mission statement, goals, and requirements for integrated STEM education may be the essential key to building a successful STEM literate society (Paige, Dugger, & Wolansky, 1996).

Limitations

The limitations of this study included the following:

1. This was a descriptive study which relied on survey research, in the form of the Delphi method, to identify the opinions of experts (Leedy & Ormrod, 2010). Each participant was regarded as a leading authority on STEM education. They were selected

based on their literature contributions to the education field. Additionally, each participant was a practicing educator of pre-service teachers in an American university.

2. The preferred instructional design strategies would be focused on teaching strategies for integrated curriculum and would be applicable to pre-service education programs.

3. There is no one universally accepted definition of integrated STEM education. The researcher relied on a commonly accepted definition and purpose statement to conduct the initial survey (Breiner et al., 2012).

4. The Delphi method requires communication and supervision. A panel of university education professors served as a review board to minimize research bias and ensure proper interpretation of data.

Assumptions

The assumptions of this study included:

1. STEM education programs will increase in demand necessitating educational reform in their design, implementation, and assessment.

2. Individual participants in this study would not be content experts in every field of the STEM subjects. Participants would value the promise for enhanced transfer of learning potential through an integrated curriculum. Collectively, participants would represent the science, technology and engineering, and mathematics fields.

3. Technology and engineering educators were combined into one group. While engineering education is growing in interest, there was an insufficient number of engineering educators alone to constitute a group by themselves. As the technology

standards have incorporated engineering principles within their content, it was assumed technology educators would represent engineering education as well.

4. As panelists were members of the STEM education community, participants would have an interest in the development of instructional design strategies applicable to integrated STEM education. They would be capable of identifying an instructional design skill set for pre-service STEM teacher candidates to learn to provide instruction through an integrated K-12 curriculum.

5. Panelists would not communicate with each other during the collection of data. This communication would be entrusted to the researcher.

Procedures

As STEM education is an evolving field with much groundwork still to be laid, it was determined the research would be conducted through the Delphi survey method. The Delphi research method builds "consensus among knowledgeable participants" (Paige et al., 1996, p. 15) by eliciting opinions of a panel of experts in order to create a group response to a given issue (Brown, 1968).

The research procedures were as follows. Leading experts from each of the STEM subjects, science, technology and engineering, and mathematics, were identified based on the pre-determined criteria. Letters of invitation were E-mailed to prospective participants until 21 members (seven from each subject area) agreed to participate. It was anticipated that through the acquisition of an equal number of participants from each STEM school subject, namely seven from each field, uniform representation for each subject area would be ensured.

Upon completion of the panel, the Round 1 survey was created and distributed. Following a brief demographic section, participants were asked to rate their degree of satisfaction with a provided general definition of integrated STEM education and its purpose statement on a five-point Likert scale. They were instructed to provide improvements to the integrated STEM definition and purpose statement, if needed. Finally, panelists were asked in an open-ended question format to list one instructional design strategy pre-service teachers of integrated STEM education would need to master in order to be an integrative STEM teacher. They were also asked to provide a description of their strategy.

After the Round 1 survey was completed, a review board, which consisted of three pre-service education faculty members who were not affiliated with the study, was asked to examine the suggested strategies. The review board used the Round 1 input to create the list of suggested strategies which formed the basis of the Round 2 and Round 3 surveys (Delbecq, Van de Ven, & Gustafson, 1975).

The Round 2 survey asked participants to consider the proposed changes and to rate their degree of satisfaction for the definition of integrated STEM education and the purpose statement for integrated STEM education on a five-point Likert scale. In part two of the Round 2 survey, each participant rated their degree of satisfaction with the list of preferred instructional design strategies for pre-service STEM teacher preparation. Participants then resubmitted their responses, and the study progressed to Round 3.

With the results from the Round 2 survey, the Round 3 survey was created to obtain consensus. Each participant was asked to once again rate their degree of approval for the given definition of integrated STEM education and the purpose statement.

Finally, each participant reviewed the list of instructional design strategies and rated their degree of satisfaction with each strategy. Participants then resubmitted their responses.

The Round 4 survey asked participants to rate each item based on whether it was perceived to be a suitable instructional design strategy for integrated STEM education. Those items which were viewed as suitable strategies were distinguished from the others.

Upon completion of Round 4 of the Delphi study, a definition for integrated STEM education and a purpose statement for integrated STEM education were written. Additionally, a list of preferred instructional design strategies for a pre-service STEM education program was presented.

Definition of Terms

To aid in the reader's comprehension of the terms used in this research, special terms are defined as follows:

Content Knowledge: "knowledge about the actual subject matter that is to be learned or taught" (Mishra & Koehler, 2008, p. 4).

Instructional Design: "systematic and reflective process of translating principles of learning and instruction into plans for instructional materials, activities, information resources, and evaluation" (Smith & Ragan, 1999, p. 2).

Instructional Strategy: a "set of systematic activities used by a teacher that contains explicit steps to achieve a specific student outcome" (Albus, Thurlow, & Clapper, 2007, p. 3).

Integrated Curriculum: explicit assimilation of concepts from more than one subject (Satchwell & Loepp, 2002).

Pedagogical Knowledge: "deep knowledge about the processes and practices or methods of teaching and learning and how it encompasses (among other things) overall educational purposes, values and aims" (Mishra & Koehler, 2008, p. 6).

Silo Instruction: intra-disciplinary approach to teaching and learning through compartmentalized subjects (Fiore, 2011).

STEM Education: an approach to education which integrates science, technology and engineering, and mathematics through an instructional method which utilizes project-based problem-solving, discovery, and exploratory learning, and requires students to actively engage a situation to find a solution to a problem (Fioriello, 2010).

Summary

The purpose of this study was to determine a preferred definition of integrated STEM education and create a purpose statement for integrated STEM education. Using this foundation, the researcher sought to identify the preferred instructional design strategies necessary to prepare a pre-service teacher of integrated STEM education.

STEM education, as a phenomenon, grew in response to the 1983 publication of *A Nation at Risk.* This report issued a warning to the American people that global societies within direct competition to the United States were no longer at a distant second to America. Rather, they were surpassing current American students. This resulted in an urgent push to reassess the value of the American education system and align the curriculum to next generation demands, so curriculum standards were drafted for science, mathematics, and technology education.

These efforts were significant in that they redirected curriculum developers to focus on current STEM related content and evolved instructional strategies to include more project-based learning activities. However, the work remained inadequate due to a lack of camaraderie between the school subjects. Most maintained an isolated approach to instruction by failing to integrate content. Students continued to struggle to draw application from the content being taught to improve their overall understanding of the major concepts and principles.

Additional buy-in from federal and state initiatives as well as private research organizations has continued the push for improved integrated STEM education. Funding has increased, instructional activities and kits have flooded the market, schools have endorsed integrated STEM programs, and research is being conducted to validate various hypotheses regarding integrated STEM education. Still, the most significant tool toward successful integrated STEM education implementation, the trained teacher, has yet to be adequately addressed. Consequently, this research is being conducted to determine the preferred instructional design strategies necessary to guide pre-service teacher education for an integrated STEM classroom.

To conduct the study, it was advisable to make several assumptions. First, it was assumed STEM education programs will continue to increase in demand. This necessitates a call for educational leadership qualified to ensure the successful design, implementation, and evaluation of STEM education. Furthermore, it was assumed those who chose to participate would not be content experts in every subject that composes STEM education. Each participant would be an expert educator of pre-service teachers within their individual school subject. However, they would value the potential for a

student's enhanced transfer of learning through an integrated curriculum and consequently appreciate the possibilities for integrated STEM education. This would be noted and observed through their publications and contributions to STEM education. Additionally, as engineering education is an emerging educational field, it was assumed technology and engineering education would be best represented by a combination of the subjects. Finally, it was assumed participants would not share correspondence regarding the study with each other throughout the duration of the research.

For the purpose of this study, research was conducted through the Delphi method. Leading educators were identified to create an authoritative panel of STEM education experts. Following the creation of the expert panel, members developed their preferred definition for integrated STEM education and a list of instructional design strategies for preparation of pre-service teachers of integrated STEM curricula. In Rounds 2 and 3 of the Delphi method, members were asked to reach a consensus on the preferred instructional design strategies for preparation of pre-service teachers of integrated STEM curricula. Finally, in Round 4, the items created were rated to distinguish between those which were deemed suitable strategies for integrated instruction from those which would be less suitable for integrated instruction.

Key terms were identified to clarify the reader's interpretation of the study. Pedagogical knowledge refers to the "deep knowledge about the processes and practices or methods of teaching and learning and how it encompasses (among other things) overall educational purposes, values and aims" (Mishra & Koehler, 2008, p. 6). Pre-service teachers are trained to use their pedagogical knowledge within their instructional design. Instructional design is defined as the "systematic and reflective process of

translating principles of learning and instruction into plans for instructional materials, activities, information resources, and evaluation" (Smith & Ragan, 1999, p. 2). As teachers implement their instructional designs, they rely on instructional strategies to communicate learning to students. Instructional strategies are defined as a "set of systematic activities used by a teacher that contains explicit steps to achieve a specific student outcome" (Albus, Thurlow, & Clapper, 2007, p. 3).

Furthermore, while no formal definition of integrated STEM education exists, it was important that a working definition be provided to help guide the research. Therefore, a definition summarized from Fioriello (2010) was selected. Accordingly, STEM education is an approach to education by integrating science, technology and engineering, and mathematics through an instructional method which utilizes project-based problem-solving, discovery, and exploratory learning, and requires students to actively engage a situation to find a solution.

Chapter II will provide a review of literature relevant to the development of integrated STEM education. It will offer an explanation for the purpose of integrated STEM education and propose a definition for integrated STEM education. Additionally, it will describe how integrated STEM education is considered an alternative approach, as opposed to the traditional approach, to education in the United States. Advantages and disadvantages to teaching integrated STEM education will be addressed. Finally, the purpose for the proposed instructional design strategies for STEM pre-service teachers will be provided.

Chapter III will describe the research procedures. It will explain the population, Delphi method, instrument design, methods of data collection, and data analysis.

Chapter IV will present the findings of the study. The researcher will identify the proposed definition of integrated STEM education and its preferred purpose per the panelists' recommendations. Finally, the researcher will list the preferred instructional design strategies for pre-service integrated STEM teacher preparation.

Chapter V will discuss the summary and conclusions. Additional suggestions for implementation of the findings and recommendations for future studies will be provided.

CHAPTER II

REVIEW OF LITERATURE

While teaching STEM content is not a revolutionary approach to education and instructional strategies commonly adopted to instruct various concepts of STEM subjects are not new, the phenomenon of integrated STEM education may be viewed as a fresh approach to education. Thus, it is important to become familiar with recent developments of integrated STEM education. One should understand why integrated STEM education is distinguished from the coursework of the individual STEM school subjects and how some might describe the purpose of integrated STEM education. The reader should understand how integrated STEM education might be practiced and its perceived benefits and challenges. Finally, the reader should understand that determining the preferred instructional design strategies for teaching integrated STEM content might benefit future teachers of STEM content. Chapter II will seek to address these issues to provide a greater understanding of integrated STEM education and its implementation.

Historical Overview of STEM Education

In the 1980s, national education report cards, including *A Nation at Risk: The Imperative for Educational Reform* (NCEE, 1983) and the *Science and Engineering Education for the 1980s and Beyond* (National Science Foundation & Department of Education, 1980), made Americans take notice. The writers of these documents revealed growing inadequacies in the current United States' education system (Breiner et al., 2012) which had to be addressed. American students were being outperformed by their international contemporaries in every academic subject (NCEE, 1983). The federal government and educational leaders perceived that the educational system of the 1960s,

which still governed instruction in the 1980s, would not suffice to prepare the necessary workforce of the 21st century (Coleman, 2005; Gitomer, Lathman, & Ziomek, 1999). Therefore, the National Science Board created a commission to address these issues. The purpose of the commission was to suggest solutions and estimate the cost for their proposed plan (Coleman, 2005). Diverse remedies addressing highly-qualified teachers, improved curriculum, and incorporation of information technologies were among the suggested solutions provided by the commission. They proposed by 1995 the nation would supply the finest mathematics, science, and technology education in the world (Coleman, 2005).

Throughout the 1990s, organizations focused on creating measures to address this challenge. The Boyer Commission (1998) called for a major overhaul of undergraduate education, especially among research universities. The National Committee on Science Education Standards and Assessment (NCSESA) and the National Research Council published the National Science Standards in 1996. Shortly thereafter, in 2000, the National Council of Teachers of Mathematics (NCTM) published an updated version of the 1989 National Mathematics Standards (Burris, 2005). Likewise the technology education standards were published in 2000 by the International Technology Education Association (ITEA), now known as the International Technology and Engineering Educators Association (ITEEA). Additional publications by the National Science Teachers Association, the National Council of Teachers of Mathematics (NCTM), and the International Technology and Engineering Educators Association (ITEEA) sought to improve instructional strategies in their respective school subjects of science, mathematics, and technology (SMET) education (Breiner et al., 2012; ITEA, 2003).

However, efforts to reform curriculum and instructional practices had witnessed minimal improvements at best (Breiner et al., 2012).

Then the National Science Foundation entered the arena and adopted the educational reform platform. They began a strenuous campaign to renew the significance of science, technology, engineering, and mathematics education. Initially, it was referred to as SMET, with the emphasis on science and mathematics, but the term was expected to eventually invoke offense due to the similarity between "smut" and "SMET" (Sanders, 2009). Therefore, in 1999, the NSF rearranged the acronym to form STEM.

In the beginning, STEM was to instill a concentrated effort into renewed science and mathematics programs. However, determined attempts from the technology and engineering profession and technology and engineering organizations, such as the International Technology and Engineering Educators Association (ITEEA), began working to increase awareness for the value that technology and engineering curriculum provides toward student success (Starkweather, 2011). These continued efforts are increasing the perceived significance of technology and engineering education. Yet, technology and engineering educators would confess there remains significantly more work to be done to establish the equality of these curriculums in comparison to the perceived importance of science and mathematics curriculums (Daugherty, 2009).

The National Science Foundation's increased funding, coupled with greater federal funding, and some states' integration of technology and engineering curriculum resulted in the growth of STEM education throughout the 2000s (Dugger, 2010). Yet, the *Trends in International Mathematics and Science Study* (NCES, 2003) following the

United States' 'No Child Left Behind' Act (2001) revealed the need for continued reform of science and mathematics education in the United States (Thompson, 2009).

Through the National Science Foundation, STEM education acquired its name and continues to be recognized for its potential to improve K-12 education, as evidenced by funding and legislation (Dugger, 2010; Williams, 2011). However, a general consensus for the definition of STEM education has yet to be adopted (Bybee, 2010; Ostler, 2012). This is clarified by Breiner et al. (2012) who explain that there are a variety of stakeholders invested in STEM education. They include: government officials, STEM educators, businesses, parents, and students. The authors suggest each stakeholder has their own perspective of what STEM education is thereby making one single definition difficult to obtain. For example, STEM teachers might say STEM education is the implementation of problem-based instruction to develop creative thinkers prepared to generate innovative ideas to real-world problems. Whereas, parents might describe STEM education as the creation of a new subject by integrating coursework between all STEM subjects, and business leaders may argue STEM education is graduating professionals who are prepared to enter the STEM pipeline. Yet, close consideration of these varied definitions for STEM education may reveal that they are not three distinct definitions, but rather a progressive list of the characteristics of integrated STEM education as a whole. If that is the case, then it might be possible to align the characteristics, build a purpose statement, and create a single definition for integrated STEM education.

Proposed Purpose and Definition of Integrated STEM Education

While each of the stakeholders for STEM education envisions it through slightly different perspectives, there remains a common purpose for STEM education among most stakeholders. A suggested purpose for integrated STEM education is to prepare students through learning experiences using problem-based learning strategies to develop a population of learners who are literate in STEM knowledge and abilities and prepared to apply it to future education and employment.

From this purpose statement, a proposed definition of integrated STEM education can be generated. Integrated STEM education may be defined as an approach to education which integrates science, technology and engineering, and mathematics through an instructional method which utilizes project-based problem-solving, discovery, and exploratory learning, and requires students to actively engage a situation to find a solution to a problem (Fioriello, 2010).

Traditional Approach to Education

Approaching education through integrated STEM instruction may appear to be revolutionary to the American school system which has operated under segregated curriculum and instruction for over 100 years. The tradition of non-integrated instruction, or silo instruction, was established with the Committee of Ten in the late 1800s (Morrison, 2006). The Committee outlined suggested course patterns which would best prepare all students for tertiary education. While the Committee's proposal was designed to address secondary education, primary education curriculums were impacted as well (Center for the Study of Mathematics Curriculum, 2004). At that time, the prevailing belief of committee members was to increase knowledge which would

generate judgment (Morrison, 2006). The Committee created sub-committees for each subject necessary for college preparatory academics. Each sub-committees' purpose was to establish frameworks and timelines for their assigned subject (Center for the Study of Mathematics Curriculum, 2004). This ultimately led to the traditional style of compartmentalized, subject instruction which continues to be practiced in much of the United States today (Morrison, 2006).

As independent subjects taught through silo instruction, STEM is readily accepted as necessary to generate student success and improve the United States' economy (NSB, 2007). After all, it is the tradition. Yet, the challenge to STEM teachers is to create situations in which students have considerable opportunities to take charge of their own learning (Morrison, 2006). Integrated STEM education is not intended to be considered isolated instructional content (Dugger, 2010; Morrison & Bartlett, 2009; NGA, 2007). This is what prompts the need for the term integrated STEM education. It distinguishes STEM subjects taught collectively from STEM subjects taught separately.

Integrating material across subjects embellishes content and provides a greater context from which students can learn. Instruction becomes integrated when content from more than one subject area has been purposefully assimilated (Satchwell & Loepp, 2002). In an integrated STEM education program, equal attention is given to the standards and objectives for a minimum of two of the STEM content areas-science, technology, engineering, and mathematics (Laboy-Rush, 2011). The instructor then evaluates and assesses each of the objectives equally (Sanders, 2009). The National Governors Association's (2007) *Innovation America: Building a Science, Technology,*

Engineering, and Math [STEM] *Agenda*, describes STEM education through its definition of STEM literacy. They state:

> STEM literacy is an interdisciplinary area of study that bridges the four areas of science, technology, engineering, and mathematics. STEM literacy does not simply mean achieving literacy in these four strands or silos. Consequently, a STEM classroom shifts students away from learning discrete bits and pieces of phenomenon and rote procedures and toward investigating and questioning the interrelated facets of the world. (NGA, 2007, p. 7)

Proponents of integrated STEM education are excited for the potential this method of instruction may have on economic growth and educational development. Many advocates who may push for STEM reform might argue some of the following benefits to an integrated STEM education approach.

Arguments from STEM Professionals for Integrated Education

The perceived benefits of integrated STEM education may be categorized into two areas: academic and affective. However, it can be difficult to distinguish these two categories as often learning is increased when it is perceived by the learner as enjoyable and useful. Consider the proposed academic benefits of integrated STEM education.

Integrated instruction is beneficial when attempting to create curricular connections for students in order to enhance understanding of concepts (Gallant, 2010). Linking content through application of knowledge improves students' understanding when bridging the gap between STEM subjects. The integration of science and mathematics is integral to building a depth of understanding in both subjects because they complement and enhance the understanding of each other (Basista & Mathews, 2002).

Likewise, the incorporation of engineering concepts into students' curriculum offers supplemental improvements in students' understanding as well. According to the National Academy of Engineering and the National Research Council (Katehi, Pearson, & Feder, 2009), benefits of incorporating engineering education into K-12 education will include an overall improvement in the following: achievement in mathematics and science education, understanding and ability in engineering design, and technological literacy. Supplemental to these benefits is an increased awareness of engineering concepts.

Satchwell and Loepp (2002) indicate there is significant potential for increased learning when content is taught through STEM-based projects. The Integrated Mathematics and Science through Technology (IMaST) (2002) project revealed increased scores in higher-level mathematics problem solving and scientific process skills among students who participated (Laboy-Rush, 2011). This is not surprising as STEM education instruction through integrated curriculum often employs a variety of instructional strategies to appeal to several learning modalities (Salinger & Zuga, 2009).

Similarly, Thompson (2009) reported standards-based instruction as practiced by the P^3 Model (Preparation, Practice, and Performance) reflected a positive systematic change in mathematics and science education as opposed to the non-standards based instructional methods. According to Thompson (2009), the standards-based instruction model was described as including hands-on, inquiry, connections, communications, and problem-solving activities. Alternatively, the non-standards based instruction was defined as teacher-driven, lecture-based instruction with the incorporation of quizzes and tests for assessments.

Research provided by Fortus, Krajcikb, Dershimerb, Marx, and Mamlok-Naamand (2005) suggests students who are presented with a design-based problem show some promise in knowledge transfer skills. This demonstrates the potential for students to retain and apply knowledge in new situations when introduced to content through problem-based instruction.

In addition to academic benefits, affective attributes are likely as well. Gallant (2010) explains STEM education is believed to increase interest once students become involved in working together in a cooperative group on a real-world problem. Additionally, Fantz and Grant (2013) and Stohlman, Moore, and Roehrig (2012) point to studies which indicate integrated mathematics and science courses improve students' attitudes and interests toward school in general.

Advocates of problem-based learning argue "it engages learners, promotes higher order thinking, and is effective in conveying factual information" (Drake & Long, 2009, p. 2). Whereas critics would suggest its emphasis on thinking skills belittles the necessity for course content (Drake & Long, 2009), Havice (2009) suggests it encourages students to investigate the world around them in the context of course material. It moves from a primarily lecture-based lesson to one which is inquiry-based.

Laboy-Rush (2011) adds problem-based learning provides evidence of increased student motivation and interest. Age appropriate activities meet the innate needs students have to nourish their abilities (Laboy-Rush, 2011). Morrison and Bartlett (2009) add experiential learning as advocated by John Dewey, which is characteristic of problem-based instruction, increases value to a student's educational development. They state it increases students' interest which then motivates the desire for additional learning.

Other benefits of increased student interest may include the potential for more candidates to enter STEM related fields following graduation from secondary institutions. Proponents argue there is a pressing need to address the lack of homegrown STEM contributors in the United States (BHEF, 2011; Daugherty, 2009; Lantz, 2009). Stirring interest and building increased understanding in STEM subjects may generate the numbers in the STEM workforce necessary to return the United States to the top of international rankings (Brown et al., 2011).

Additionally, Havice (2009) explains STEM education, when conducted through instructional strategies such as problem-based instruction, incorporates team-work and instruction in soft-skills applicable to real-world situations. The distinction here is to teach students how to work in groups as opposed to placing students in groups to complete their work. By assigning jobs and facilitating production in groups, teachers can instruct students in the finer skills of group work. This is different from asking students to complete their work in groups and not demonstrating to them how to accomplish their tasks effectively. When left uninstructed, some students may be inclined to allow the strongest student to complete the work while they ride on that student's coattails. This is not effective instruction for group work. Havice (2009) states problem-based instruction requires team-work and creativity. It also forces students to work within time constraints due to tight schedules at the secondary level. Students are pushed to be effective and efficient. This scenario forces students to establish roles, such as group leader or design manager, and build highly demanded soft-skills and business traits as they work with partners to meet a goal (Luca & Oliver, 2002).

Finally, proponents of integrated STEM education also state prolific STEM curriculums will serve to create a technologically literate society that are capable of functioning in the 21st century (Frueh, 2011). As technology has inundated society, its members must be educated to adapt. Frueh argues a STEM literate population benefits individuals in simple ways such as promoting knowledgeable conversations with doctors to ensure understanding of medical diagnoses or asking appropriate questions of pharmacists. Similarly, a STEM literate population benefits communities through intelligent voters who can serve as an effective constituency as they are informed on environmental issues, political issues, etc. These skills can be acquired through a universal STEM education program regardless of the professional track a student chooses.

Despite the many evidences of the potentials an integrated STEM curriculum can provide to students, there are those who remain unconvinced it is the preferential method of instruction. Some may argue integrated STEM education is an educational fad which ought not to have influence toward significant change.

Arguments from STEM Professionals Against Integrated Education

Alternative perspectives on STEM education serve to balance the discussion on the potentials of integrated STEM instruction. While many critics of integrated STEM education would not argue against the benefits highlighted by its proponents, they suggest the arguments against integrated STEM education outweigh the benefits for integrated STEM education. The majority of arguments rest on the feasibility and necessity for a shift in current educational practices toward integrated STEM education applications. That is to say, is it necessary to transition from traditional, lecture and

activity-based instruction, to more integrated, problem-based instruction centered on STEM integration in order to create a STEM literate society?

Some critics observe adopting STEM educational practices requires additional resources to include teacher training, curriculum, professional development activities, classroom equipment, and scheduling issues (Sanders, 2009). This is no small task as curriculum is rooted in deep traditions. Consequently, proposals to alter curriculum are often met with resistance. It is not widely accepted to consent to change (Williams, 2011).

Additionally, despite many efforts to persuade teachers that student-centered instruction is ideal for student learning, the curriculum "does not address the environments and structures that faculty work within, which typically favor traditional instruction" (Henderson, Finkelstein, & Beach, 2010, p. 19). Teachers are provided an integrated curriculum which they cannot adequately instruct due to limitations in their classrooms; this causes teachers to revert back to the traditional method of instruction.

At the secondary level, many teachers become less willing to integrate courses. Stohlman et al. (2012) explain to promote a successful integration of science and mathematics, teachers' understanding of the subject matter must be fully developed. As many teachers have holes in their understanding of their own subject content area, to ask them to incorporate a second subject area may create increased knowledge gaps and challenges.

Williams (2011) agrees and adds that some teachers feel inept and ill-prepared to instruct an integrated subject. To compromise, they may choose to instruct using the silo approach to STEM education. In other words, each individual S.T.E.M. curriculum is

offered and taught, but it is not integrated. Therefore, students miss the necessary transfer of learning to benefit from a truly integrated, STEM curriculum (Salinger & Zuga, 2009).

Critics may further suggest moving toward integrated STEM education is a rather substantial commitment when there is a lack of sufficient proof of a legitimate need for additional STEM professionals. Some even suggest "that direct federal investment in R&D in the physical sciences and engineering and in STEM education would distort markets" (Gonzalez, 2011, p. 3).

Other criticisms involve the nature of STEM education to segregate populations. It does not attract women and minorities by content alone (Greene, DeStefano, Burgon, & Hall, 2006). STEM fields require effective marketing and instructional techniques to pull a wide variety of population representation into potential STEM careers (Purdue University, 2011).

Finally, some suggest lecture-based learning is more effective than problem-based learning, particularly on standardized tests (Schwerdt & Wuppermann, 2011; Stinson, Harkness, Meyer, & Stallworth, 2009). Despite arguments which suggest hands-on learning through problem-based instruction offers variety and self-paced learning opportunities, critics suggest problem-based learning is less efficient than allowing students to master content through instructor-led lectures. Additionally, there is the potential students may learn incorrect or misleading information from their peers, which could complicate and delay the learning process (Schwerdt & Wuppermann, 2011).

Schwerdt and Wupperman (2011) observed a negative correlation between problem-based learning and student performance as opposed to the positive correlation

seen through the instructor-led approach on student learning. This study is contrary to a number of other studies which have observed a positive correlation between student learning and problem-based instruction, such as the IMaST (2002) study. However, Schwerdt and Wupperman suggest the negative correlation between problem-based instruction and student learning creates a question. "Is it worth the effort and cost to train and prepare STEM educators?" Such contradictions suggest further research on effective instructional design is needed.

Despite the cautions critics offer in regard to adopting the philosophies of integrated STEM education, it remains a growing trend and a hopeful remedy to necessary educational and economic recovery (BHEF, 2011). The endorsement of the nation's governors for improved efforts in innovation and invention continue the push for increased efforts in integrated STEM education (NGA, 2007).

The Perceived Need for STEM Teachers

The anticipation of a sweeping reduction in the teacher workforce is looming with the onslaught of the retirement of many baby boomer teachers (DOE, 2011). Immediate impacts include the increased demand for highly-qualified, highly-effective educators. Some argue STEM teachers are a likely remedy to meet these impending deficiencies. For example, in his 2011 State of the Union address, President Obama said, ". . . over the next 10 years, with so many baby boomers retiring from our classrooms, we want to prepare 100,000 new teachers in the fields of science and technology and engineering and math" (NPR, 2011, p. 5). Likewise, the National Science Board (2007) stipulates one of the two central challenges to building a strong coordinated STEM education system is securing a sufficient supply of well-prepared and highly effective STEM educators.

This predicted teacher shortage, coupled with the continuous fight against teacher attrition rates within the first five-years of teaching, is a significant concern for the education community (Young et al., 2001). Young et al. explain "It is extremely important for the educational community and policymakers to carefully reflect and strategically set forth action plans" (p. 3) to confront these issues facing education today.

In addition to the continuous, rapid retirement of teachers, the nation is faced with the need to increase recruitment of minority teachers. With a growing diversity of cultures in America's schools, appealing to minority groups to pursue education careers is more important than ever. There are efforts "underway to recruit teachers who more accurately reflect the ethnic and linguistic diversity present in schools" (Young et al., 2001, p. 3). These efforts are most significant to the poor urban and rural schools whose student populations are more likely comprised of minorities (Gitomer et al., 1999).

In conjunction with the shortage of qualified teachers, technological advancements coupled with the interdependent global economy have generated a sense of urgency which suggests significant changes are appropriate for 21st century education practices within the United States. The state of Maryland has taken a proactive approach to implement such changes. They have created a definition of STEM education and STEM education standards for students in grades K-12, which emphasize an integrated STEM curriculum (MSDE, 2003a). Table 1 provides an overview of the Maryland definition of STEM education and its STEM education standards. Maryland in-service teachers are being trained in the processes of developing integrated lesson plans and implementing STEM integrated curriculum (MSDE, 2003b). Through hands-on, inquiry

based learning strategies, teachers are beginning to practice integrated STEM lessons which are aligned to the STEM curriculum content.

Maryland is not alone in its efforts toward integrated curriculum. The *Framework for K-12 Science Education* and the newly released *Next Generation Science Standards* (NGSS), ask teachers to integrate engineering concepts into the science curriculum as well (Achieve, 2013; National Research Council, 2011). This is evidence of educators striving to evolve with the new demands of a global society.

Table 1

Maryland STEM Initiatives

STEM education: "an approach to teaching and learning that integrates the content and skills of science, technology, engineering, and mathematics" (MSDE, 2003a, para. 2).
STEM Standards of Practice
1. Learn and Apply Rigorous Science, Technology, Engineering, and Mathematics Content 2. Integrate Science, Technology, Engineering, and Mathematics Content 3. Interpret and Communicate STEM Information 4. Engage in Inquiry 5. Engage in Logical Reasoning 6. Collaborate as a STEM Team 7. Apply Technology Appropriately

Proponents of STEM education advise its potential to address these pertinent issues warrant exploration into the development of future STEM teachers (BHEF, 2011; Breiner et al., 2011). For it is only with teachers who are trained to instruct integrated STEM content that legitimate information regarding the value of integrated STEM

education can be accrued. Nadelson, Seifert, Moll, and Coats (2012) explain many teachers who are not trained in instructional strategies for teaching integrated STEM content or are uncomfortable with the content itself may struggle to obtain the greatest possible effects on student learning. This might occur because teachers choose to avoid STEM instruction or cover STEM material superficially. Insufficient instruction would have an influence on the results of any study which sought to determine the true worth of integrated STEM education. Consequently, without proper instructors, it would be difficult to assess the true value integrated STEM education may or may not offer to education.

In light of these calls to action, it would appear addressing the process to prepare integrated STEM classroom instructors is timely. Efforts to create models of teacher preparation for integrated instruction may serve as key examples for developing STEM teacher preparation programs. For instance, some teacher preparation programs are experimenting with teacher development workshops centered on the Technological, Pedagogical, and Content Knowledge (TPCK) model which Mishra and Koehler (2008) developed from Shulman's (1986) Pedagogical Content Knowledge (PCK) model (Chai, Koh, & Tsai, 2010). The emphasis is placed on preparing pre-service teachers to integrate technology, particularly communication and information technology, into classroom instruction. While the model is focused on the integration of instructional technology into other content areas, the theory driving the process of pre-service teacher preparation for integrated teaching provides an effective example which may be applied to integrated STEM instruction.

The Technological Pedagogical Content Knowledge Model

In 1986, Shulman asked "how might we think about the knowledge that grows in the minds of teachers, with special emphasis on content?" (p. 9). To answer this question, he proposed three categories of content knowledge. They included: subject matter content knowledge, pedagogical content knowledge, and curricular content knowledge.

Subject matter content knowledge refers to not only a familiarity and understanding of the basic concepts of a subject matter, but a deep understanding of the truths of the domain. Teachers must be able to "explain why a particular proposition is deemed warranted, why it is worth knowing, and how it relates to other propositions, both within the discipline and without, both in theory and in practice" (Shulman, 1986, p. 9).

Pedagogical content knowledge refers to the subject matter knowledge for teaching. Essentially, Shulman (1986) suggests this knowledge includes the discernment to select the most useful forms of representation, powerful analogies, illustrations, and examples of the most regular topics taught in one's subject area. Pedagogical content knowledge also includes an understanding of what makes the learning of specific topics easy or difficult, the conceptions and preconceptions that students of different ages and backgrounds bring with them to learning and strategies to reorganize the understanding of learners.

Finally, Shulman (1986) states curricular knowledge is the intimate familiarity with a subject's curriculum such that the teacher can identify a variety of alternative means of study for a single topic. The teacher must know what the students should have

learned the year prior and will learn the year to come in the same subject area. Likewise, teachers must be familiar with the content students are learning in other subjects to draw applications across the curriculum.

Building from Shulman (1986), Mishra and Koehler (2008) introduced a framework for Technological, Pedagogical, Content Knowledge (TPCK). Essentially, they suggest there are seven key areas of knowledge at the heart of good teaching using instructional technology. There are the core components of knowledge: content, pedagogy, and instructional technology. Then there are the blended relationships between these components: pedagogical content knowledge, instructional technology pedagogical knowledge, and instructional technology content knowledge. The mixture of all six components of knowledge form instructional technology, pedagogical content knowledge. See Figure 1.

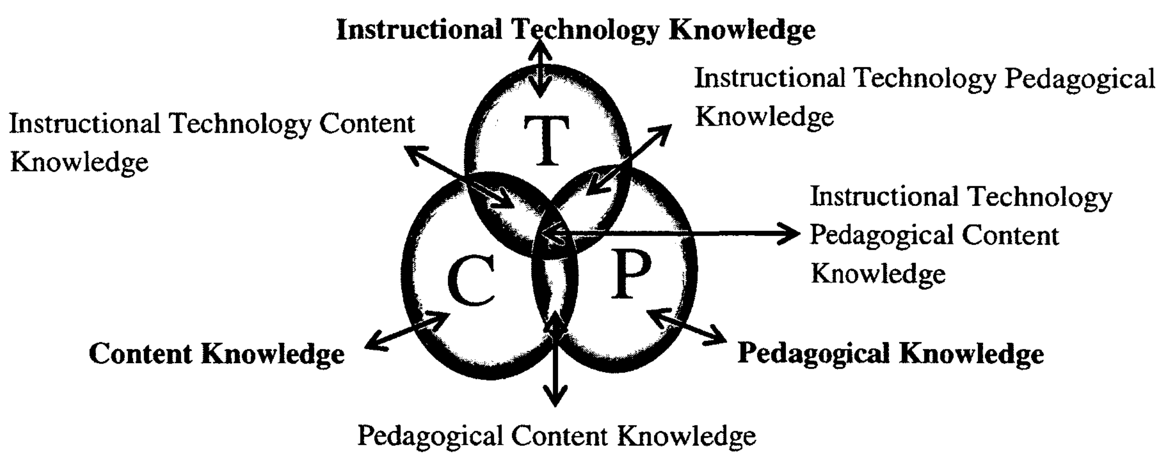

Figure 1. Adapted from the TPCK framework and knowledge components as presented by Koehler and Mishra, 2008.

When instructing pre-service teachers under this model, it is expected they would develop connections between the various areas of knowledge (Chai, Koh, & Tsai, 2010). For example, pre-service teachers would recognize once instructional technology and content are blended to form instructional technology content knowledge, it requires an

understanding of the influence and constraint they practice on each other (Mishra & Koehler, 2008). Mishra and Koehler explain teachers are not only accountable to master the content knowledge of their subject, but they must also master the implications of the integration of instructional technology on that subject through instruction.

In a similar fashion, when considering how content and pedagogy blend, the question becomes how subjects differ from each other and whether subjects can or should be taught through similar instructional strategies (Mishra & Koehler, 2008). Mishra and Koehler suggest teachers must "interpret subject matter, find multiple ways to represent it, and adapt instructional materials to alternative conceptions and students' prior knowledge" (p. 7). They add, the teacher's choice of instructional method (coupled with students' prior learning) will emphasize the important knowledge or skill desired to be learned in a lesson.

Learning to effectively blend content and pedagogy as Mishra and Koehler (2008) have described is a skill to be acquired. However, while integrating instructional technology is relatively new to education, the skills it requires are not entirely new knowledge. Science and mathematics have laid a significant foundation for the integration of their content.

Science and Mathematics Findings on Skillful Integration

The science and mathematics school subjects lend themselves to a seamless blend of instruction. These connections demonstrate the motivations of science and mathematics educators to implement integrated instruction. While examining instructional practices regarding integration, Douville, Pugalee, and Wallace (2003) reported four reasons to connect science and mathematics education as cited by McBride

and Silverman (1991). They were: science and mathematics closely relate systems of thought, science relates concrete examples of mathematics ideas, mathematics enhances a deeper understanding of science concepts through quantification and explanation of patterns, and science activities provide relevancy for learning mathematics. Since science and mathematics education has employed some strategies for integrated learning, they have been able to determine some skills essential for profitable integration. The knowledge gained from research regarding integrated instruction for science and mathematics now serves as an asset for further gains in an integrated STEM program.

Essential to successful integration is the teachers' knowledge of subject matter content (Stohlman et al., 2012). This is reflected in Shulman's (1986) Pedagogical Content Knowledge model. However, pedagogical practices also play a significant role in effective integrated instruction. Zemelman, Daniels, and Hyde (2005), as cited in Stohlman et al. (2012), provide a list of ten best practices for implementing integrated science and mathematics lessons. The best practices are provided in Table 2.

The skills to promote integration between science and mathematics described above are similar to the skills Lee (2007) proposes to enhance teachers' pedagogical strategies for effective mathematics instruction. In his study, Lee discovered professional development which emphasized teaching across the curriculum, hands-on learning activities, group work, inquiry-based and student-centered instruction, and portfolio assessment were innovative and creative instructional approaches to mathematics education which enhanced teacher instruction and improved their personal satisfaction.

Table 2

Ten Best Teaching Practices of Integrated Science and Mathematics

1. Use manipulatives and hands-on learning	6. Promote writing for reflection and problem solving
2. Include cooperative learning	7. Incorporate problem solving approaches
3. Incorporate discussion and inquiry	8. Integrate technology
4. Utilize questioning and conjecture	9. Practice teaching as a facilitator
5. Use justification of thinking	10. Include assessment as part of instruction

Note. As cited in "Considerations for teaching integrated STEM education," by M. Stohlman, T. Moore, & G. Roehrig. (2012). *Journal of Pre-College Engineering Education Research,* 2(1), 28-34.

The successful integration of science and mathematics, coupled with the increased attention toward engineering education, which four states □ Indiana, Massachusetts, Minnesota, and Oregon □ have now introduced into their science standards, implies the potential to successfully integrate all STEM subjects is feasible (Murphy & Mansini-Samuelson, 2012). Yet, acquiring skills for the purpose of integrated instruction requires specified training. This training is necessary. Murphy and Mansini-Samuelson advocate improved teacher education programs through STEM education in order to address critical issues such as: teachers' lack of knowledge of content, limited pedagogical experiences, and limited confidence in their ability to teach content.

However, there continues to be a lack of consensus as to how STEM education should be implemented. Consequently, many educators of STEM content continue to receive their training through traditional pre-service education programs.

Current Pre-Service Education Practices

Presently, a common curriculum among post-secondary institutions for the preparation of teachers does not exist (Ball & Forzani, 2011). Many post-secondary

institutions rely on the *Framework for Teaching* (The Danielson Group, 2011) as a guide for program development. It is aligned with the standards developed by the Interstate Teacher Assessment and Support Consortium (InTASC) (Danielson, 2009). These standards serve to guide program developers in what pre-service educators should know and be able to do when they instruct students in grades K-12 (CCSSO, 2011).

The Council of Chief State School Officers (CCSSO), through the Interstate Teacher Assessment and Support Consortium (InTASC), created a set of pre-service teacher training standards designed to ensure that every K-12 student would be prepared to enter college or the workforce following the completion of the secondary program (CCSSO, 2011). Such knowledge would include a mixture of academic and global skills. The CCSSO describes these to include: "problem solving, curiosity, creativity, innovation, communication, interpersonal skills, the ability to synthesize across disciplines, global awareness, ethics, and technological expertise" (CCSSO, 2011, p. 4). Additionally, the standards should attend to interdisciplinary themes and promote the teacher's proficiency to create learning experiences that incorporate multiple disciplines (CCSSO, 2011).

The teacher training standards are not program specific; they are applicable across all subject areas and grade levels. The vision of the standards is to describe how effective teaching that leads to improved student achievement would look (CCSSO, 2011). The general pre-service education program standards were divided into four categories: The Learner and Learning, Content, Instructional Practice, and Professional Responsibility (CCSSO, 2011). Each category then addresses standards associated with its core concept.

Unique to these standards is that they were not designed only for pre-service teacher preparation. These standards were created to assist in the development of professional practice standards. Therefore, it is reasonable to assume in-service teachers could be held to similar expectations as those proposed for pre-service teachers (CCSSO, 2011).

Four Categories of InTASC Standards

The following is a summary of each of the components as described in the Interstate Teacher Assessment and Support Consortium (InTASC) teacher training standards (CCSSO, 2011). Additionally, a synopsis of each standard's description is provided with emphasis placed on those standards and descriptions which align specifically with instructional practices.

The Learner and Learning. Effective teachers should understand that learning and developmental patterns vary from student to student. Teachers must hold high expectations for each student, but these expectations must align with the abilities of the individual learner. Instruction to this level is achieved through a combination of professional knowledge with the recognition that each learner will enter the classroom bringing their personal backgrounds and prior learning experiences with them (CCSSO, 2011). Table 3 provides an overview of the standards for teacher preparation which the Council of Chief State School Officers (CCSSO) (2011) aligned with the Learner and Learning component.

Table 3

Summary of Teaching Standards for the Learner and Learning as Stipulated by the CCSSO (2011)

Standard	Description
Standard 1: Learner Development	The teacher understands how learners grow and develop.
	The teacher recognizes that development varies according to individuals and implements appropriate and challenging learning experiences accordingly.
Standard 2: Learning Differences	The teacher uses their understanding of learning differences and diverse cultures to ensure inclusive learning environments which promote optimum student learning.
Standard 3: Learning Environments	The teacher works with the learning community to support individual and collaborative learning which encourages active engagement and learning and self-motivation.

Table 4 is a selection of those performances through which pre-service teachers demonstrate mastery knowledge of the standards aligned with the Learner and Learning and are applicable to instructional technique. It also addresses examples of the essential knowledge affiliated with these performances.

Table 4

Abridged Version of Descriptors Pertaining to Instructional Strategies for Teaching Performance and Essential Knowledge for the Learner and Learning Standards as Stipulated by the CCSSO (2011)

Standard	Performances	Essential Knowledge
Standard 1: Learner Development	The teacher creates developmentally appropriate lessons by considering learners' strengths and interest	The teacher knows how to use instructional strategies to promote student learning
Standard 2: Learning Differences	The teacher designs and delivers instruction to diverse student's strengths	The teacher understands, identifies, and develops differing instructional practices
	The teacher designs instruction to build on learner's prior knowledge	The teacher understands students with exceptional needs and uses strategies to address these needs

Table 4 (continued)

Standard 3: Learning Environments	The teacher develops learning experiences that engages learners through collaboration	The teacher uses strategies that build learner self-direction
	The teacher uses a variety of methods to engage learners	The teacher knows how to help learners work productively
	The teacher promotes responsible learner use of interactive technologies	The teacher knows how to guide learners to use technologies

Content. Teachers must acquire a deep and flexible understanding of their content areas. They must also be able to draw on additional content knowledge when necessary as they work with diverse learners. In addition to understanding content areas, teachers must display mastery in multiple means of communication, including digital media and information technology. Teachers must integrate cross-disciplinary skills such as critical thinking, problem solving, and communication when helping students to use content as they develop new knowledge. Finally, teachers will make the content relevant to current local, state, national, or global issues (CCSSO, 2011). Table 5 provides an overview of the standards for teacher preparation which the Council of Chief State School Officers (CCSSO) (2011) aligned with the Content component.

Table 5

Summary of Teaching Standards for Content as Stipulated by the CCSSO (2011)

Standard	**Description**
Standard 4: Content Knowledge	The teacher understands the concepts and tools of inquiry for their discipline. They create learning experiences that make the discipline meaningful for the learner.
Standard 5: Application of Content	The teacher understands how to connect new concepts and use a variety of different perspectives to engage the learners in critical thinking, creativity, and collective problem solving strategies related to current issues.

Table 6 is a selection of only those performances which require the use of instructional skills to demonstrate mastery knowledge of the standards aligned with

content. It also addresses examples of the essential knowledge affiliated with these performances.

Table 6

Abridged Version of Descriptors Pertaining to Instructional Strategies for Teaching Performance and Essential Knowledge for the Content Standards as Stipulated by the CCSSO (2011)

Standard	Performances	Essential Knowledge
Standard 4: Content Knowledge	The teacher effectively uses multiple representations and explanations that guide learning through inquiry	The teacher understands major concepts of inquiry
	The teacher uses supplementary resources and technologies	The teacher knows and uses academic language of the discipline
Standard 5: Application of Content	The teacher develops and implements projects that guide learners in analyzing an issue from varied disciplines and cross-disciplinary skills	The teacher understands how to know their discipline, how it relates to other discipline approaches to inquiry, and the strengths and weaknesses of each approach
	The teacher engages learners in applying content knowledge to real world problems through interdisciplinary themes	The teacher understands the demands of accessing and managing information as well as how to evaluate issues of ethics
	The teacher facilitates learners' use of current tools and resources to maximize content learning	The teacher understands creative processes and how to engage students to produce original work

Instructional Practice. Teachers implement effective instructional practices through an integration of assessment, planning, and instructional strategies in structured and enjoyable ways. Teachers systematically plan effective instruction by beginning with their goal for student learning and assigning student objectives which will help students to meet the goal. Teachers will also include a variety of formative and summative assessments throughout the learning process to assess the progress of student learning, reinforce student learning, and modify instructional practices where needed. Table 7 provides an overview of the standards for teacher preparation which the Council of Chief State School Officers (CCSSO) (2011) aligned with the Instructional Practice component.

Table 7

Summary of Teaching Standards for Instructional Practice as Stipulated by the CCSSO (2011)

Standard	**Description**
Standard 6: Assessment	The teacher understands and uses a variety of methods of assessment to engage learners, monitor progress, and guide the teacher and learner's decision making.
Standard 7: Planning for Instruction	The teacher plans instructional activities that encourage every learner to meet rigorous learning goals by pulling from content area knowledge, curriculum, cross-disciplinary skills, and pedagogy.
Standard 8: Instructional Strategies	The teacher understands and uses a variety of instructional strategies to develop deep understanding of content areas and build skills in applying knowledge in meaningful ways.

Table 8 is a selection of the performances which employ the use of instructional skills to demonstrate mastery knowledge of the standards aligned with Instructional Practice. It also addresses examples of the essential knowledge affiliated with these performances.

Table 8

Abridged Version of Descriptors Pertaining to Instructional Strategies for Teaching Performance and Essential Knowledge for the Instructional Practice Standards as Stipulated by the CCSSO (2011)

Standard	**Performances**	**Essential Knowledge**
Standard 6: Assessment	The teacher engages learners in multiple ways of examining their own thinking	The teacher knows when and how to engage learners in their own assessment
Standard 7: Planning for Instruction	The teacher selects and creates learning experiences that are appropriate for curriculum goals	The teacher integrates cross-disciplinary skills to engage learners

Table 8 (continued)

Standard 8: Instructional Strategies	The teacher uses appropriate strategies to adapt instruction to learner needs	The teacher understands cognitive processes associated with various kinds of learning
	The teacher continuously monitors student learning, engages learners in assessing their progress, and adjusts instruction according to student needs	The teacher knows how to apply a range of developmental, cultural, and linguistic instructional strategies
	The teacher collaborates with learners to design and implement relevant learning experiences	The teacher knows when and how to use instructional strategies to differentiate instruction
	The teacher varies their instructional processes	The teacher understands multiple forms of communication conveys ideas
	The teacher provides multiple models and representations of concepts with opportunities for learners to demonstrate their knowledge	The teacher knows how to use a wide variety of resources
	The teacher engages all learners in developing higher order questioning skills	The teacher understands content and skill development is supported by media and technology
	The teacher engages learners in using a range of learning skills and technology tools to access, interpret, and apply information	
	The teacher uses a variety of instructional strategies to support learners communications	
	The teacher asks questions to stimulate discussion	

The Professional Learning and Leadership standards were not affiliated with instructional practices. Therefore, no table was provided to describe performances and essential knowledge skills associated with these standards.

The Council of Chief State School Offices (2011) explains as they developed the standards, they considered what characteristics provide evidence of effective teaching. This is the purpose of standards. They provide broad direction toward student outcomes which can be operationalized in order to evaluate and assess student progress (Oosterhof, 2009).

Generating highly-qualified transition teachers for 21st century classrooms is a difficult job. Despite high standards such as those set by the CCSSO, Chesley and Jordan (2012) found many pre-service teachers observed their university preparation programs were inadequate. Unfortunately, teachers reported feeling ill-prepared for classroom instruction. Among the reasons listed, three key areas were: how to plan for instruction, strategies for building student engagement, and methods to integrate technology. Young, Grant, Montbriand, and Therriault (2001) further add:

> Expectations for teachers are high in today's educational reform and policy agendas. Teachers need to be experts in one or more specific subjects. They also must be prepared to effectively handle the challenges of a growing diverse population of students with a variety of multicultural, multilinguistic, and multiability needs. (p. 1)

Consequently, pre-service teacher education programs will need to play a significant role in the development of highly-qualified teachers and should consist of a lengthy process filled with quality learning experiences and sound theoretical principles (Young et al., 2001). Specific instructional design strategies for teacher education are a part of that process.

Pre-service teacher education standards, such as the InTASC standards, are used to build the accreditation system which organizations such as the National Council for Accreditation of Teacher Education (NCATE) apply to endorse such programs (Young et al., 2001), and therefore, carry significant influence. An NCATE endorsement is noteworthy. Not only do NCATE approvals imply rigorous program requirements are being fulfilled, but as Gitomer et al. (1999) explain students who graduate from an

NCATE approved teacher preparation program are more likely to pass the Praxis licensing test than those who do not complete such a program.

In addition to the benefits of ensuring effective teacher preparation through rigorous standards, Ball and Forzani (2011) explain developing pre-service teachers around education standards eliminates the concern that teaching is a "gift" and therefore only achievable by the ones who have the "gift". Rather, teaching should be perceived as a skill which can be learned. While there are those who may have a "natural ability" to teach, and therefore, perhaps excel in teaching, it does not mean others may not also master quality teaching strategies and perform their job well. Successful pre-service educator programs will generate this confidence in their graduates and produce teachers with greater self-efficacy (DeChenne, 2010). The InTASC standards were written in an effort to accomplish these goals. With the move toward integrated instruction, as evidenced in Maryland and the Next Generation Science Standards, instructional design strategies for integrated curricula, such as those called for by the InTASC standards, become obligatory.

Distinctions for a Pre-Service STEM Educator

As previously stated, integrated STEM education will emphasize planning strategies which integrate a minimum of two of the STEM content areas. Therefore, teachers of integrated STEM education will practice their profession slightly different than those who instruct a single content subject. Two distinctions a pre-service integrated STEM teacher must master include the development of a variety of instructional design strategies which complement integrated instruction and an appreciation for the necessity of teamwork among STEM teachers.

Use Instructional Strategies for Integrated Planning

In 2001, teams of deans from both colleges of education and colleges of engineering met to revisit work previously begun in 1988 toward the implementation of collaborative instruction with the intent to address STEM education initiatives (Garrett, 2008). They investigated solutions to three goals. First, they sought suggestions which would improve K-12 teachers' abilities to prepare students to live in a technologically complex world. Second, they desired to generate a collaborative outreach program to K-12 schools. And third, they wanted to improve pedagogical skills within the college of engineering (Garrett, 2008). Garret describes some of the benefits which were born from this collaboration. They included: the addition of problem-based learning to K-12 curriculum standards, the development of an engineering-based lesson plan bank, and the creation of an in-service education program for teachers.

While the team's efforts created helpful strategies toward improved instruction, pre-service teachers were forced to continue to tolerate inadequate teacher preparation. This distinction is made clear by Merrill (2001) who explains there is a difference between determining what to teach and how to teach. Instructional strategies describe how a lesson will be taught. They are teaching techniques used during instruction to "assist students in the acquisition of the desired knowledge and skill" (Merrill, 2001, p. 294). Albus, Thurlow, and Clapper (2007) further clarify instructional strategies as a "set of systematic activities used by a teacher that contains explicit steps to achieve a specific student outcome" (p. 3). Garrett (2008) explained despite significant ground gained in determining what to teach, there was more work to be done in order to adequately instruct pre-service teachers in how to teach it.

With the rise of improved understanding of meeting students' needs, efforts are being made toward educating teachers in a greater variety of instructional strategies. For example, Maccini and Gagnon (2005) specifically address strategy instruction for students with learning disabilities in mathematics courses at the middle school level. They provide examples of techniques to help students solve word problems, follow procedures, and carry out a plan. Likewise, Albus et al. (2007) address instructional strategies to improve reading skills for English as a Second Language (ESL) students in general education classrooms.

However, addressing pre-service teachers' needs to understand and practice instructional strategies for integrated content is not being fully realized (Chesley & Jordan, 2012). Just as in years past, the majority of current pre-service teachers continue to be products of the traditional, lecture-based, silo instruction schools. These instructional strategies are less effective for integrated curriculum than the hands-on, problem-based activities which are typically needed in integrated STEM classrooms (Gallant, 2010; Havice, 2009; Laboy-Rush, 2011). Since many pre-service teachers have minimal personal experience with integrated coursework presented through problem-based instruction, it becomes difficult for them to transition to instructional strategies which may differ from those they experienced as students. Put differently, teachers will often instruct in manners that mirror the methods in which they were taught (Kennedy, 1999). Thus, it is advisable to train pre-service teachers in appropriate methods of instruction for an integrated STEM education classroom (NSB, 2007).

When operating under the definition of STEM education through integrated, problem-based instruction (Dugger, 2010; Fioriello, 2010), integrated STEM education

becomes distinct from the traditional method of teaching in its content objectives and purpose. The InTASC standards endorse the theme of cross-curricular integration and argue teachers should instruct integrated coursework. To meet this stipulation, future teachers of integrated STEM education curriculum must be prepared with instructional design strategies which promote integrated learning and align with the InTASC standards. Thus, defining the preferred instructional design strategies for integrated STEM content will serve to fulfill this need.

Examples of Instructional Strategies Affiliated with STEM Education

Where a non-integrated classroom teacher emphasizes instruction directed toward a single subject, an integrated classroom teacher must blend content from at least two subjects within their lesson. They must also teach students to think across the subjects. Therefore, instructing through an integrated approach requires instructional design strategies which shift teachers from the transmission perspective (which emphasizes teacher-led lecture and transmission of necessary content) to the constructivist perspective (which "sees knowledge as being constructed in students' minds as they draw on their prior knowledge to make sense of new experiences") (Hewson, Zeichner, & Tabachnick, 2001, p. 2).

One common instructional design strategy affiliated with the constructivist approach to learning is problem-based instruction. Drake and Long (2009) describe problem-based instruction as a situation given to a group of students who must use their resources to deliver a potential answer. It involves presenting students with a real-world problem, which becomes the context for instruction. Students identify what they know, what they need to know, and where to go to find it as they work through the scientific

research process. Teachers act as facilitators throughout the process and students collaborate to reach a conclusion.

Inquiry-based teaching and learning is a second approach to a constructivist method of instruction. This strategy can be scaffolded from confirmatory, to structured, to guided, and to open-inquiry (Lantz, 2009). Oliveiria (2009), as cited by van Zee (2009), defines inquiry-based instruction as "teacher-student verbal exchanges that take place in classroom settings where pupils learn science by posing questions, proposing and revising evidence-based explanations and solutions, and using the language of science processes" (p. 848). While this definition is related to science instruction, the process can be achieved through other course content. When applied to science education, students progress through a five-step process which mirrors the scientific method. Students would be engaged with a question, either asked by the student or the teacher. Students then provide responses which prioritize evidence. They propose explanations based on the evidence, evaluate their proposals in light of scientific knowledge, and then justify their decision (van Zee, 2009).

A third instructional design strategy which may be applied to the constructivist approach to education would be performance-based instruction (Lantz, 2009). Brethower and Smalley (1992) define performance-based instruction as "instruction during which learners perform in ways that approximate and progressively approach the ways they will perform on-the-job using what they have learned" (p. 1). The concept behind performance-based instruction is a continuum from simple, on-demand tasks to open-response work. It asks the students to demonstrate proficiency and understanding through completion of a task, which they have chosen, to reveal adequate transfer of

learning through a problem-solving situation (Jones, 2001). Teachers trained in instructional strategies like these and others are better prepared to enter a STEM education classroom, and with a call for an increased number of STEM educators it becomes the responsibility of higher education to prepare such teachers.

STEM Teachers Must Work in Teams

A second distinction of a STEM educator is the necessity to work in teams. Fulton and Britton (2011) explain, in addition to developing appropriate instructional strategies for an integrated curriculum, STEM educators must become comfortable with interaction among fellow STEM teachers. This interaction is distinguished through personal, professional development activities. STEM Professional Learning Communities provide an opportunity for STEM teachers to collaborate on effective strategies for teaching STEM content as well as to enhance personal content knowledge (Fulton, Doerr, & Britton, 2010). STEM teachers who plan together, provide instructional critiques, improve each other's lesson plans, and at times teach together report a stronger satisfaction with work performance than those educators who do not. This type of camaraderie among STEM teachers is often preferable, especially at the secondary level, since many STEM teachers do not believe themselves to be adequately prepared in all STEM subjects to teach an integrated course (Williams, 2011). However, this type of professional interaction is not easily attained in schools. Many teachers are hesitant to develop such a close working relationship as it may reveal weaknesses within their personal performance. Encouraging pre-service teachers to understand the importance of life-long learning is beneficial to the teacher and student alike (Fulton & Britton, 2011).

Henderson and Dancy (2011) explain there is no shortage of STEM instructional material, and there is no lack of knowledge regarding effective teaching. "The biggest barrier to improving undergraduate STEM education is that we lack knowledge about how to effectively spread the use of currently available and tested research-based instructional ideas and strategies" (Henderson & Dancy, 2011, p. 1). Pre-service teachers of STEM education should benefit from a structured system which guides their development in execution of instructional strategies for an integrated STEM curriculum.

The Outcomes of Pre-Service STEM Teacher Preparation

Nadelson and Farmer (2012) suggest that the new *Framework for Next Generation Science Standards (NGSS)* (NRC, 2011) relied heavily on the anticipated future of STEM education. As Nadelson and Farmer (2012) explain, the new science standards will require teachers to include engineering concepts into their instruction. Yet, engineering is not typically a part of pre-service teacher training, and consequently, there are not standards which address instructional strategies for science and engineering education (Nadelson & Farmer, 2012).

While there has yet to be a consensus reached for the definition and purpose of integrated STEM education, there is notable existing and developing STEM curriculum and programs which emphasize integrated learning activities (e.g., Engineering by Design, Louisiana Tech's College of Engineering and Science, IMaST, PLTW). This indicates an inclination to perceive integrated STEM education as distinct from the independent STEM subjects. Integrated STEM education involves at least some degree of integration between course content. This was endorsed by the National Committee on Science Education, National Committee of Teachers of Mathematics, and the

International Technology Education Association, which recommended integration to enhance content understanding (Mahoney, 2010).

Seeking to create a teacher who offers a general, broad-based understanding of a minimum of two of the STEM subject in conjunction with the proper training to instruct an integrated course is distinct from creating a STEM instructor who is prepared to teach in-depth knowledge of a single STEM discipline. Ostler (2012) states,

> The specialized training that teachers receive in a given content discipline is important to be sure, but teachers need better integrated content models from their preparation programs. In short, a degree in a STEM discipline would have the option to be highly specialized while a STEM education degree will require a somewhat broader general understanding of the interrelatedness of STEM topics. (p. 29)

This does not imply that pursuing only a generalist degree of knowledge is sufficient for everyone. Certainly, developing learners who have specialized knowledge is essential as well. However, the building blocks for specialized learners can be laid through STEM education, while at the same time serving the general population with well-developed general knowledge of STEM content (Ostler, 2012).

While it has not been written explicitly, the idea of integrated STEM education is to practice two distinct attributes. This is instructing integrated concepts and using instructional design strategies which promote integrated learning. This begins to outline the purpose for STEM education. However, further clarification needs to be made. For example, some may ask, “What constitutes integration?”, “How much integration is

necessary?", and "Are engineering standards necessary or are they sufficiently covered in technology education?"

Despite needing to further clarify distinctions of integration, this does not limit an organization from making long term goals as it is clear STEM education is about integration. The first step will be to create an acceptable definition and purpose for integrated STEM education and then to state the preferred instructional design strategies necessary for training those who will implement integrated STEM education. These steps will lead to answers for the more specific questions about the implementation of STEM education.

Summary

Chapter II provided an overview of STEM education. While the necessity for improved science and mathematics education was discussed through reports published in the 1980s, it was not until 1999 that the National Science Foundation adopted STEM education, created its name, and began to provide significant funding for its development.

Although there is not a universal definition for STEM education, Chapter II provided a proposed purpose statement for STEM education based on the integrative use of science, technology, engineering, and mathematics content. Through this suggested purpose statement, integrated STEM education was then defined as an approach to education which integrates science, technology and engineering, and mathematics through instructional methods which utilize project-based problem-solving, discovery, and exploratory learning, and requires students to actively engage a situation to find a solution to a problem (Fioriello, 2010).

There are several perceived benefits, academic and affective, which are associated with STEM education. Research conducted to date demonstrates STEM education offers the promise to improve students' overall knowledge and understanding of STEM related content. Additionally, STEM education increases student interest which in turn offers added benefits such as increased attendance, increased graduation rates, and lower attrition rates. Furthermore, when integrated STEM instruction is implemented through instructional strategies such as problem-based learning and performance-based activities, students demonstrate an increased development of creativity, improved social skills, and improved self-efficacy. Students also demonstrate increased motivation in classroom activities which then translates to a greater potential for additional learning.

However, there are those who are hesitant to accept STEM education without reservation. There is concern students may fail to grasp true understandings of mathematical or scientific theory if it is only taught through a generalized, integrated curriculum. Additionally, critics fear the cost integrated STEM education would require. They suggest such a cost is not justified when there remains insufficient evidence STEM education would in fact produce improved academic results over the traditional methods of education.

Currently, many pre-service teachers of STEM education are trained under the traditional methods of teacher preparation. Most teachers graduate from programs which align with the teacher preparation standards developed by InTASC. The most current standards were identified. It was observed that those standards call for teachers to be prepared to integrate course content, develop creative thinkers, and address global issues. In order to comply with the stipulations set by the InTASC standards, it was noted

teachers of integrated STEM curricula would need to be furnished with compatible instructional design strategies. Instructional strategies were defined as techniques used during instruction to "assist students in the acquisition of the desired knowledge and skill" (Merrill, 2001, p. 294). Additionally, a teacher of integrated STEM course material must be prepared with a broad overview of course content and impressed upon the importance of teamwork and camaraderie in order to ensure the greatest success.

Finally, Chapter II addressed the perceived promise of preparing a STEM pre-service teacher to join the current teachers of STEM content. The pre-service teachers would be equipped with the necessary skills to instruct an integrated course. They would have a broad general knowledge of STEM content, which should enhance the foundational knowledge and skills of their students. Their understanding of the two aspects of STEM education, namely the integrated curriculum and the need for specialized instructional design strategies, strengthens their potential effect on the future generation of students.

Next, Chapter III will describe the research procedures. It will explain the population, Delphi method, instrument design, methods of data collection, and data analysis.

CHAPTER III

METHODS AND PROCEDURES

This chapter discusses the methods and procedures for this study. It provides the general information regarding the population used to conduct the study. Additionally, it defines the research variables and provides an explanation of the design of the study. A description of the procedures and data analysis process will be provided.

Population

The population for this study was selected through purposive sampling to ensure experts from the field of STEM education contributed to the research (Leedy & Ormrod, 2010). They represented each subject area for STEM education, that is: science, technology and engineering, and mathematics education. The population was gathered through a selection process based on the following criteria. Each participant was a teacher education faculty member of a minimum four-year college or university which prepared teachers in the individual STEM school subjects. Additionally, each participant displayed interest in the development of integrated STEM education through their publication contributions and conference presentations on the topic. Participants were identified through their recent publications in STEM related journals. A sample of the invitation E-mail sent to each nominee is provided in Appendix A. It was anticipated the panel would be complete at 21 members from across the United States by approximately January 21, 2013. The group size is not affected by statistical power, but rather emphasis is placed on arriving at consensus among the group experts (Okoli & Pawlowski, 2004). Delbecq, Van de Ven, and Gustafson (1975, p. 89) suggest "with a homogeneous group of people, ten to fifteen participants might be enough" as they have witnessed "few new ideas are generated within a homogeneous group once the size exceeds thirty well-chosen

participants" (p. 89). They further caution the larger the number of participants, the more effort for analysis. "Therefore, staff would do well to hold the number of participants in the Delphi study to a minimally sufficient number of respondents and seek verification of results through follow-up survey research" (p. 89). Thus, the researcher worked to create a panel of 21 members, seven representing each of the STEM school subjects.

Design

This was a non-experimental, descriptive study. The purpose was to collect the opinions of expert STEM educators regarding a preferred definition for integrated STEM education, a purpose statement describing this construct, and instructional design strategies to be used for the preparation of pre-service integrated STEM education teachers. The Delphi method was most appropriate for data collection, as opposed to a meta-analysis, because the ultimate purpose of this study was to identify strategies specific to integrated instruction. Preparing pre-service teachers for integrated education is still in its infancy. Therefore, it is possible that not all instructional design strategies profitable for integrated instruction have been identified at this time; thus, increasing the likelihood of insufficient data for a meta-analysis. So where a meta-analysis would collect data gathered from many studies and interpret the results; the Delphi method builds potential data by identifying and creating consensus of expert opinions regarding an issue which has yet to be sufficiently studied (Brown, 1968; Harris & Rogers, 2008; Leedy & Ormrod, 2010; Paige et al., 1996). Van de Ven and Delbecq (1974), as cited in Rowjewski and Meers (1991), state, the Delphi method "is a surveying procedure that provides for systematic solicitation and collation of judgments on a particular topic

through a set of carefully designed, sequential questionnaires interspersed with controlled feedback" (p. 4).

The Delphi method originated from the RAND Corporation in the 1950s. The technique was designed to allow researchers to develop the most reliable consensus of opinions of leading authorities regarding a particular issue (Okoli & Pawlowski, 2004). Linstone and Turoff (1975) describe the Delphi method "as a method for structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem" (p. 3). As Brown (1968) explains, the Delphi method is a meticulously planned, sequential program of interviews typically through a series of surveys. Each panelist is provided the opportunity to offer explanation for their responses on each item of the survey. Throughout the series of rounds, with the exception of the first round, the panelists are asked to critique each other's remarks through their surveys. The technique enables the results to generate informed judgments by allowing experts to improve suggestions while avoiding face to face contact and confrontation. Thus, the characteristics of the Delphi method become (a) anonymity, (b) iteration with controlled feedback, and (c) statistical group response (Dalkey, 1968).

Delbecq et al. (1975) explain there are three key groups of people who participate in the Delphi study method. The first are the *Decision Makers*. They develop the surveys, analyze the responses, appraise the usefulness of the information, and revise additional surveys. The second group is referred to as the *Staff*. They function to guide and support the work of the Decision Makers. Finally, there are the *Respondents*. They are the ones whose opinions are being sought. For the purpose of this research, the

researcher will act as the Decision Maker. To aid in the control of research bias, a review board comprised of three university faculty members who instruct pre-service education students will serve as the Staff. Finally, the nominated, expert STEM educators who agree to participate in the study will serve as the Respondents.

Research Variables

The research variables were based on the research questions. There were three dependent variables. They were: a proposed definition for integrated STEM education, a proposed purpose statement for integrated STEM education, and the preferred instructional design strategies for a pre-service teacher of integrated STEM education developed by the panel of STEM education experts. The independent variables were the suggestions of the panel members. They are each leading authorities and representative of the varying subjects within the fields of STEM education.

Procedures and Data Analysis

The research for this study will be gathered using the Delphi method. The chief purpose for selecting the Delphi method was to collect the opinions of integrated STEM education teacher training experts (Harris & Rogers, 2008). Seven stages were designed to organize the compilation of data. The stages were to create the Round 1 survey; identify and invite potential participants in the study; E-mail the Round 1 survey, collect and analyze the data; E-mail the Round 2 survey, collect and analyze the data; E-mail the Round 3 survey, collect and analyze the data; E-mail the Round 4 survey, collect and analyze the data; and then write the results. These are illustrated in Figure 2. The purpose for organizing the data collection process was to promote continuity of participation among members (Pisel, 2001).

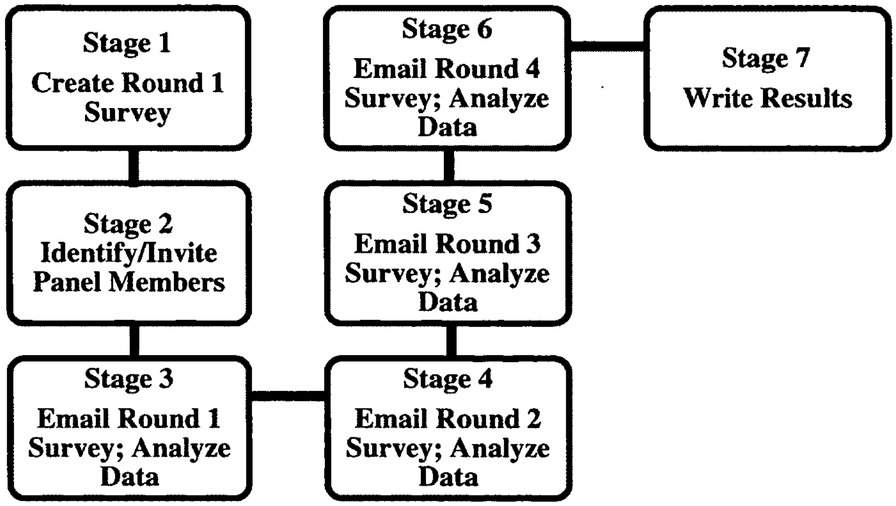

Figure 2. Stages for data research through the Delphi method.

Stage 1-Creating the Round 1 Survey

The items within the Round 1 survey were designed to define a definition and purpose statement of integrated STEM education. Establishing an agreed upon definition and purpose statement for integrated STEM education would help panel members to draw consensus for the instructional design strategies for pre-service teachers of integrated STEM education. The instructional design strategies would be proposed by the panel members. The Round 1 survey provided an open-ended directive requesting each panel member to supply one instructional design strategy for the preparation of pre-service teachers of integrated STEM education. Reliability of the survey design was enhanced by review of an inter-rater board. Teacher educators, independent of the study, assessed the survey to ensure it would be accurately interpreted by the panel members.

Stage 2-Inviting the Panelists

After Stage 1 was completed, panel members for the Delphi study were identified based on the following criteria:

- They were university faculty members of a teacher preparation department.

- They were representative of science, technology and engineering, or mathematics education.
- They were actively engaged in the furtherance of the STEM integrative concepts through publications and conference presentations.

It was anticipated 21 members would agree to participate. Therefore, the researcher sought to contact potential candidates through an invitation letter via E-mail until seven from each discipline agreed to participate. See Appendix A for the invitation letter.

Stage 3-Round 1 Survey

Once the 21members agreed to participate, each was E-mailed a letter thanking them for their time and potential contributions. See Appendix B for the letter. Two supplemental documents were attached to this E-mail. The first attachment was a summary of the purpose of the study. This provided necessary background information for the study to assist participants in their contributions. See Appendix C. The second attachment was the Round 1 Survey. Participants were asked in Round 1 to examine and critique a proposed definition for integrated STEM education and a proposed purpose statement for integrated STEM education. Also, participants were asked to identify one instructional design strategy critical for the preparation of a pre-service teacher to enable them to teach integrated STEM content. After they had created their strategy statement, each participant was asked to include a description of their statement. This would ensure the review board and panel members had a clear understanding for the purpose of each proposed strategy. See Appendix D for a copy of the Round 1 Survey.

Once the Round 1 survey was completed, the data were collected. The demographic data were compiled.

Regarding the definition of integrated STEM education in Part 1 of the survey, each panelist was asked to rate their level of satisfaction with the provided definition of integrated STEM education on a five-point Likert scale. Those scores were then translated to a numeric value (i.e., most satisfactory = 5 points, satisfactory = 4 points, uncertain = 3 points, dissatisfactory = 2 points, and most dissatisfactory = 1 point). The mean score, median, standard deviation, and interquartile range were calculated to determine the degree of satisfaction among the panelists for the prescribed definition of integrated STEM education. Additionally, panelists' recommendations for improvement to the integrated STEM education definition were compiled and presented to the review board. The review board used this data to code the suggested corrections and compile a revised definition of integrated STEM education based on the participant's feedback.

As with the proposed definition of integrated STEM education, each panelist was asked to rate their level of satisfaction for the suggested purpose of integrated STEM education. The data regarding the panelists' opinions for the proposed purpose for integrated STEM education were compiled. A five-point Likert scale was used. The mean score, median, standard deviation, and interquartile range were calculated to determine the degree of satisfaction for the proposed purpose statement of integrated STEM education. Additionally, panelists' recommendations for improvement to the integrated STEM education purpose statement were compiled and presented to the review board. The review board coded the suggested corrections and compiled a revised purpose statement for integrated STEM education based on the participants' feedback.

Finally, Part 2 of the survey asked each panelist to write a proposed instructional design strategy that would direct instruction for the preparation of a pre-service teacher of

integrated STEM education. Additionally, each panelist was asked to describe the intent of the strategy. Upon completion of the Round 1 survey, the researcher removed all personal identifiers and numerically labeled the responses.

Once the data were compiled, the researcher then assembled a review board. Appendix E is a copy of the letter sent to each member of the review board. The researcher adjusted the definition based upon panel members' feedback. The same was done with the purpose statement. The review board evaluated the proposed instructional design strategies. Those strategies which were of a similar nature were combined to form a single strategy. Those strategies which were unique to the others were left as they were written. When the panel completed their tasks, they created a single list of instructional design strategies for the preparation of a pre-service teacher of integrated STEM education.

Stage 4-Round 2 Survey

Following completion of Round 1, data were used to create the Round 2 survey which was distributed through an E-mail for each panelist to review. See Appendix F. Prior to beginning the study, the researcher determined that an item must achieve a minimum mean score of 3.50 on the five-point Likert scale to be considered significant. A score of 3.50 or higher was equivalent to satisfactory or most satisfactory. Although all data were kept confidential and reported to each panelist in aggregate, the researcher distributed the Round 2 survey to each panelist individually with their respective Round 1 responses for the definition and purpose statement of integrated STEM education displayed next to the group responses. This enabled each participant to compare their responses to those of the group.

During Round 2, participants were asked to respond to the data collected in the Round 1 survey. All survey contents were kept in the same order as presented to the participants in the Round 1 survey. Part 1 of the Round 2 survey asked participants to rate their level of satisfaction on a five-point Likert scale for the amended definition of integrated STEM education and the amended purpose statement of integrated STEM education. Members were permitted the opportunity to see group responses, in aggregate, regarding the definition of integrated STEM education and its purpose statement. These responses were posted next to each participant's original responses. This allowed each participant the opportunity to revise their proposed definition and purpose statement for integrated STEM education, if needed, and then again to note their agreement with these statements.

Finally, panelists were asked to rate each proposed integrated STEM education instructional design strategy on a five-point Likert scale. Round 2 of the Delphi was designed to begin building consensus among the panelists on the instructional design strategies.

Stage 5-Round 3 Survey

Following Round 2 of the Delphi study, data were analyzed. The mean score, median, standard deviation, and interquartile range were calculated for the proposed definition and purpose statement of integrated STEM education. The final part of the Round 2 survey asked participants to rate each proposed instructional design strategy for the preparation of a pre-service integrated STEM education teacher. The mean, median, standard deviation, and interquartile range was assessed for each strategy.

Using the Round 2 data, the Round 3 survey was developed. See Appendix G. The purpose of the Round 3 survey was to verify the degree of consensus of the data collected. The data from the Round 2 survey were reported to each participant in the Round 3 survey to assist them in reviewing their ratings.

In Round 3, each panelist was E-mailed their personal survey which displayed their responses from the Round 2 survey next to the group responses. They were asked to review the revised definition of integrated STEM education and the revised purpose statement. Given a five-point Likert scale, panelists were asked to rate their level of satisfaction for the revised definition and purpose statement of integrated STEM education provided. Each panelist also rated the prescribed list of instructional design strategies for a pre-service integrated STEM education program.

After completing the Round 3 survey, the mean score, median, standard deviation, interquartile range, and the coefficient of variance were calculated for each response. The coefficient of variance was used as it serves to indicate the degree of consensus among group members. A coefficient of variance between 0.00 and 0.50 indicates a strong consensus among group members.

To demonstrate a strong group consensus, a response must have a mean score of at least 3.51, an interquartile range of 2.00 or lower, and a coefficient of variance between 0.00 and 0.50 (English & Keran, 1976). Any response which did not meet these criteria would be classified as not achieving group consensus, therefore not a preferred instructional design strategy for the preparation of pre-service teachers of integrated STEM content.

Stage 6-Round 4 Survey

Following the Round 3 survey of the Delphi study, consensus was achieved for the definition of integrated STEM education, its purpose statement, and a list of instructional design strategies for a pre-service teacher of integrated STEM education. However, it was necessary to analyze the instructional design strategies developed in order to ensure that each item was in fact suitable for teaching integrated STEM education.

The Round 4 survey was E-mailed to participants in the same fashion as the previous surveys. See Appendix H. Participants were provided the list of instructional design strategies, their associated statistics, and a set of directions asking them to analyze each strategy according to whether it was suitable for instruction of an integrated STEM curriculum. They would determine if each strategy could be converted into a course objective and taught to pre-service teachers of integrated STEM content. The percentage of participant agreement for each item was determined. An item must achieve a minimum of 51% of the participants' agreement to be rated as a suitable strategy. Upon completion of the Round 4 survey, members had created a list of the preferred instructional design strategies useful in the preparation of pre-service teachers of integrated STEM education.

Stage 7-Write the Results

Once the items reached consensus, the researcher reported the information. The list of instructional design strategies for integrated STEM pre-service teacher preparation was created along with an acceptable definition and purpose statement for integrated STEM education.

Summary

Chapter III provided a description of the methods and procedures for the study. Data were collected through the Delphi method. This technique was selected as it is a reliable method to build consensus among a group of leading authorities in a particular subject.

The population for this study relied on experts in the field of STEM education. Each panelist represented a minimum of one of the STEM subject areas and was an expert in the preparation of teachers. A total of 21 members were sought, seven representing each STEM subject.

The study was conducted through four rounds of Delphi surveys. Round 1 collected demographic information on each participant and asked the panelists to critique a provided definition for integrated STEM education and a purpose statement for integrated STEM education. Furthermore, the panelists created a list of preferred instructional design strategies for integrated STEM pre-service teacher preparation.

Rounds 2 and 3 served to establish consensus among the panelists. Descriptive statistics were used to determine agreement of panelists for each strategy provided.

Round 4 of the survey classified the strategies written by the Delphi panel. Members distinguished between those items deemed suitable for integrated STEM instruction from those that were not.

Chapter IV will present the findings of the study. The researcher will identify the proposed definition of integrated STEM education and its preferred purpose per the panelists' recommendations. Finally, the researcher will list the preferred instructional design strategies for pre-service integrated STEM teacher preparation.

CHAPTER IV

FINDINGS

This chapter presents the findings for the study. Four rounds of surveys were presented to the participants throughout the months of February to July, 2013. This chapter will provide a summary of the steps followed during each survey round and the responses gathered from the participants.

Round 1

Prior to beginning the study, the researcher had identified 53 qualified potential panel members to invite to participate in the study according to pre-determined criteria: they were active teacher educators at a minimum of a four-year college or university; they were teacher educators within one of the STEM subject areas; and they had expressed interest in the development of integrated STEM education through their professional publications and/or presentations. The sample of potential panel members was designed to be diverse to allow for a variety of perspectives. Therefore, seventeen potential members were identified from the field of science, 19 from technology and engineering, and 17 from mathematics. Initial invitations were issued to 21 prospective panel members, seven from each subject, on January 22, 2013. As potential candidates were confirmed, the subject area they represented was recorded. If a potential panel member declined to participate in the study, invitations were sent to subsequent names from the initial pool of 53 potential candidates. By February 18, 2013, 21 panel members, seven from each STEM subject area (science, technology/engineering, and mathematics) had responded and accepted the invitation to participate in the study.

Round 1 of the Delphi study was initiated on February 21, 2013, and was to be completed by March 1, 2013. This round was foundational and divided into three sections including demographics, definitions, and design strategies.

The demographic section was intended to validate the variety and expertise of the group of participants. Each was asked to respond to four demographic questions. Participants were asked to identify the following: gender, age, STEM concentration field, and years within the teaching profession.

As there is no universally accepted definition of STEM education, the second section of the Round 1 survey sought to establish a common perspective of STEM education from which each participant could complete the subsequent surveys. To accomplish this task, a definition for integrated STEM education was presented to the participants based on a definition by Fioriello (2010). Panel members were asked to rate, on a five-point Likert scale, their degree of satisfaction for this given definition. They were also encouraged to provide thoughts which might improve the given definition.

In a similar manner, outlining a common perspective for the purpose of STEM education was essential to guide the participants in their feedback for preferred instructional design strategies of integrated STEM education. Following the definition, participants were asked to rate, on a five-point Likert scale, their degree of satisfaction with a given purpose statement of STEM education. The participants were also encouraged to record thoughts which might improve the given purpose statement.

Once the participants had responded to the provided definition of STEM education and its purpose statement, they approached the final section of the Round 1 survey. In this section, the participants were asked to reflect on the essential instructional

design strategies a pre-service teacher of integrated STEM education should know and be able to do. They were to identify the instructional design strategy they believed was most essential for the preparation of a pre-service teacher of integrated STEM education. They were also asked to briefly describe this instructional design strategy to ensure it would be properly interpreted for the subsequent survey rounds. Twenty-one Round 1 surveys were administered, 18 surveys (86%) were completed and returned by March 22, 2013. One science member withdrew from the study citing research conflicts, two members (one from science and one from technology and engineering) failed to send in their response within the designated time frame.

The panel members were evenly distributed between the genders with nine of the 18 members being identified as male. Additionally, the majority of the panel members (fourteen) were described as 41 years old or older. Only four members stated they were between the ages 31 and 40. See Table 9.

Table 9

Panel Member Demographics 1

Gender		**Age**			
Male	Female	≤ 30	31-40	41-50	≥ 51
9	9		4	7	7

The majority (11) of the respondents indicated they had more than 20 years of teaching experience. Six participants recorded they had 21-25 years of experience, two participants had 26-30 years of teaching experience, and three participants stated they had served within the teaching profession for over 31 years. Seven participants stated they had less than 20 years of teaching experience; four indicated they had taught for 16-20 years; two participants stated they had been teaching for 11-15 years. Only one

participant stated they had been teaching less than five years. Although there were no prior criteria set which stipulated a participant must have a required minimum amount of teaching experience, the criteria which were established led to the petition of highly-qualified participants, many of whom had several years of teaching experience. See Table 10.

Table 10

Panel Member Demographics 2

STEM Concentration Field			**Years in Teaching Profession**						
Science	Technology and Engineering	Mathematics	≤5	6-10	11-15	16-20	21-25	26-30	≥ 31
5	6	7	1		2	4	6	2	3

The second section of the Round 1 survey requested participants to reflect on a provided definition for integrated STEM education. The definition stated that STEM Education is an approach to education which integrates science, technology and engineering, and mathematics through an instructional method which utilizes project-based problem-solving, discovery, and exploratory learning, and requires students to actively engage a situation to find a solution to a problem (Fioriello, 2010). They were to rate their degree of satisfaction with this definition of integrated STEM education on a five-point Likert scale. Those scores were then translated to a numeric value (i.e., *most satisfactory* = 5 points, *satisfactory* = 4 points, *uncertain* = 3 points, *dissatisfactory* = 2 points, and *most dissatisfactory* = 1 point). Eighteen participants rated their degree of satisfaction with the definition of integrated STEM education. Descriptive statistics were used to depict the group's degree of satisfaction with the given definition of integrated STEM education at this point in the study. Collectively, descriptive statistics create a visual of the degree of satisfaction among the group members. While the mean

represents the average degree of satisfaction of the group and the median describes the central or "middle" numeric value of the data, the standard deviation represents the spread of those values. The lower the standard deviation the closer the scores were to the mean value. The interquartile range is beneficial as it is not affected by outliers and offers a clear picture of where the majority of the responses lie. For the Round 1 survey, the descriptive statistics were as follows: the mean score was 3.11, median was 3.50, standard deviation (SD) was 1.13, and the interquartile range (IQR) was 2.00. See Table 11.

Table 11

Descriptive Statistics for the Definition of Integrated STEM Education

Item	*n*	*M*	*Mdn*	*SD*	*IQR*
STEM definition	18	3.11	3.50	1.13	2.00

Note. *n* denotes number, *M* denotes mean, *Mdn* denotes median, *SD* denotes standard deviation, and *IQR* denotes interquartile range.

In addition to rating their degree of satisfaction with the given definition, each participant was encouraged to offer suggestions which might improve the definition of integrated STEM education. These suggestions would be collated and used to create a revised definition of integrated STEM education, which the participants would see on the Round 2 survey.

Some of the suggestions were editorial; other suggestions addressed the concept of integrated STEM education. For example, some participants proposed that the definition should reflect that integrated STEM education will pursue student discovery and creativity through authentic, real-world problems. Additionally, they suggested that not every problem has a solution. Others stated that the definition needs to address the connections across the STEM curricula.

Below is an abbreviated list of the sample suggestions offered by the participants. The suggestions provided were used to revise the definition for the Round 2 survey.

- include descriptors such as authentic, real-world problems
- specify that instruction is standards-based
- use the word "include" to ensure the list of instructional strategies is not seen as definitive
- STEM education does not only need to be about finding a solution to a problem; it can encourage discovery and exploration
- this definition is highly prescriptive and constraining
- this definition needs to address instruction and curriculum; it should address how instruction deliberately uses didactic content from each discipline to support the content of others
- this definition assumes there is a solution to every problem
- this definition can be more concise if words such as "design" or "Engineering Design" were used to replace project-based, problem-based, etc.
- it should also acknowledge the arts
- perhaps using the word "practices" would make it more concise

After rating their degree of satisfaction with the given definition of integrated STEM education, each participant was asked to rate their degree of satisfaction with a provided purpose statement of STEM education. This statement proposed that the purpose of STEM education is to prepare students through integrated learning experiences using problem-based learning strategies to develop a population of learners

who are literate in STEM knowledge and abilities and prepared to apply it to future education and employment situations. As with the scores for the definition, each response was given a numeric value. Eighteen participants rated their degree of satisfaction with the purpose statement of integrated STEM education. Descriptive statistics were used to describe the group's degree of satisfaction with the purpose statement of integrated STEM education. They were as follows: the mean score was 3.17, the median was 4.00, the standard deviation (SD) was 1.20, and the interquartile range (IQR) was 2.00. See Table 12.

Table 12

Descriptive Statistics for the Purpose Statement of Integrated STEM Education

Item	***n***	***M***	***Mdn***	***SD***	***IQR***
STEM Purpose Statement	18	3.17	4.00	1.20	2.00

In addition to rating their degree of satisfaction with the provided purpose statement for integrated STEM education, each participant was encouraged to offer suggestions which might improve the purpose statement. The participants mentioned that there were discrepancies with the term "literate", which needed to be addressed. They proposed the purpose statement should clarify that STEM education is student-focused, experiential, and trans-curricular or teaching across the curriculum.

Below is a list of suggestions, which were offered by the participants. These suggestions were used to revise the purpose statement for the Round 2 survey.

- enlarge the definition of "literacy" to include communication of knowledge and make it future pointing—progressive
- literate is too vague—students should be able to evaluate information

- the last line implies more than literacy but also application
- students need to experience content knowledge combined with hands-on applications so they can understand the what and the why
- STEM learning can be offered in the context of teaching 21st century skills
- emphasize the applied and interactive nature of the curriculum
- emphasize it is student focused
- emphasize authentic-learning and real-world problems
- specify literate in the integration and connection between the STEM content areas

Finally, the participants were asked to provide one instructional design strategy a pre-service teacher of integrated STEM education should practice in order to teach an integrated STEM lesson. They were also asked to offer a description of their response to ensure it would be properly interpreted. Below, in no particular order, is a summary of the instructional design strategies provided by each of the participants.

- Implement a learning cycle such as the 5E learning cycle
- Develop, implement, and assess a standards-based STEM curricula using authentic content through hands-on learning experiences
- Teacher communicates effective research procedures through modeling appropriate methodology
- Evaluate data and create evidence-based on scientific argumentation
- Understands the value of experiential learning and develops strategies for students to apply learning

- Identify engineering design challenges that require the application of specific mathematic and scientific principles to create a solution to a design challenge
- Plan an integrative lesson from multiple perspectives and implement that lesson
- Communicate the connections between the individual STEM subjects
- Selecting a design challenge that aligns with student ability
- Incorporates the STEM disciplines as a learning cycle
- Chooses multiple examples to accommodate a variety of learning styles
- Develops project-based lessons to incorporate the engineering design process
- Identify and communicate the connections between the STEM disciplines
- Plan integrative lessons through the Launch, Explore, Summarize approach
- Communicate the importance of planning an integrative lesson
- Incorporate experiential learning into the classroom
- Implement project-based learning activities
- Use engineering design to solve real-world problems

Following the completion of the Round 1 survey, a review board, consisting of three active, teacher educators within the STEM subjects but independent of the research study, was convened to review the data. They were asked to study the 18 responses collected and to combine instructional design strategies they deemed were of a similar nature. They were also asked to add any additional instructional design strategies they

believed might be missing. From their effort, 11 instructional design strategies were created and below is a summary of their suggestions (in no particular order).

- 5E Learning Cycle
- Engineering Design
- Authentic Content
- Use of Statistics
- Problem-based Learning
- Argumentation
- Experiential Learning
- Communication of Information
- Nature of Science
- Application
- STEM Process
- Inquiry
- Collaboration

Once the review board had refined the instructional design strategies into a single list, the study was ready to progress to the second round. The researcher used the list created by the review board, combined with the descriptions provided by the panel members, to build the Round 2 survey. See Appendix F. It was distributed to each of the participants May 28, 2013.

Round 2

One of the advantages of a Delphi study process is the opportunity for expert opinions to be provided and critiqued through a blind review. As the participants reflect

on the answers provided and the descriptive statistics associated with each answer, it causes them to reconsider their own perspective. Ultimately, the hope is to gain agreement from a group of leading experts regarding a particular issue.

The purpose of the Round 2 survey was to begin to create consensus among the expert participants concerning the preferred instructional design strategies for the preparation of a pre-service teacher of integrated STEM education. It was during Round 2, the participants reflected on all 11 of the instructional design strategies created from the Round 1 survey. As there were three members who rescinded their participation during Round 1, the total number of surveys E-mailed was 18. However, upon receiving the Round 2 survey, one participant responded they would no longer be able to contribute to the study. The total number of participants remaining in the study was 17, five from science, six from technology and engineering, and six from mathematics. Of the 17 participants, 16 (94%) responded to the Round 2 survey within the allotted timeframe, five from science, six from technology and engineering, and five from mathematics.

The Round 2 survey was divided into two sections. Section one requested the participants to reflect on the revised definition of integrated STEM education and to rate their degree of satisfaction with this definition on a five-point Likert scale. Using the suggestions for improvement from the Round 1 survey, the revised definition of STEM education on the Round 2 survey stated that Integrated STEM Education is an approach to education where instruction is designed using a combination of knowledge from the individual school subjects of science, technology, engineering, or mathematics. It can be used to enhance student learning of complex concepts through the use of authentic learning experiences. This type of learning emphasizes applying team work/team

building skills and is taught using instructional strategies that incorporate design challenges, experiential learning events, knowledge integration, and collaborative learning.

Sixteen participants responded to this item. The following descriptive statistics regarding the panelists' perspective of the revised definition of integrated STEM education from the Round 2 survey were calculated. It was determined the mean score was 3.56, the median was 4.00, the standard deviation (SD) was 0.96, and the interquartile range (IQR) was 1.00. See Table 13.

After participants rated their degree of satisfaction with the revised definition, they were encouraged to offer any additional revisions they believed might enhance the current definition. At this point, very few suggestions were made that could be considered duplicated by other participants. Some participants offered no additional corrections. Other participants suggested particular phrases, such as "problem-solving" or "research-based" be added to the definition. One participant pointed out that STEM education is both horizontal and vertical in nature. It not only spans across the curriculum, but it also spans across grade bands. Below is a summary of the suggestions offered by the panelists for further improvements to the existing definition of integrated STEM education.

- I have issue with defining engineering as a school subject
- Reword to the "individual school subjects of"
- I am not sure of the importance of "team-building" in the definition
- Include "problem-solving" in the definition
- Educators should work to enhance student creativity and curiosity

- Content is not necessarily only school grade level content. STEM education utilizes the content knowledge from multiple STEM arenas to enhance conceptual knowledge
- Add design process
- STEM should be defined on a continuum as it shifts depending on the situation
- Add learning events to the list
- Add research-based

As with the revised definition of integrated STEM education, the purpose statement of integrated STEM education was edited using the comments from the Round 1 survey and presented to the participants on the Round 2 survey. It now suggested that the purpose of integrated STEM education is to develop a learner who is literate in the connection of STEM knowledge and can successfully interpret, apply, and adapt that knowledge to future education, employment, and life situations. The participants were asked to reflect on these revisions, rate their degree of satisfaction with the current purpose statement on a five-point Likert scale, and then to add any additional comments they felt were necessary.

Descriptive statistics were calculated for the Round 2 survey. Fifteen of the 16 members responded to this item. Based on the participants' feedback, the results for the revised purpose statement were as follows: the mean score was 3.73, the median was 4.00, the standard deviation (SD) was 0.70, and the interquartile range (IQR) was 1.00. See Table 13.

Table 13

Round 2 Summary of Integrated STEM Education Definition and Purpose Statement

Item	*n*	*M*	*Mdn*	*SD*	*IQR*
STEM Education Definition	16	3.56	4.00	0.96	1.00
STEM Education Purpose Statement	15	3.73	4.00	0.70	1.00

Regarding potential improvements to the existing purpose statement, the participants desired to see the term "literate" defined and quantified. They also advised the curriculum emphasis of integrated STEM education be emphasized, that is the purpose statement would indicate STEM education is cross curricular in nature and intent on solving authentic problems. The following suggestions were offered to improve the revised purpose statement for integrated STEM education.

- Add the word "STEM" in front of literate
- Stating both that the student is literate and that the student can interpret, apply, and adapt knowledge is redundant
- Highlight the integration of STEM and that students will be able to integrate concepts across the STEM subjects
- "life situations" has a negative connotation
- What about the creativity generated by STEM
- We'd like more than one learner. . .we need a generation of learners
- Consider having diverse benefits of using an integrated STEM instructional strategy
- STEM pedagogy (curriculum, instruction, and assessment) might be important to add to this purpose. I would add "apply solutions to authentic problems"

- Does this assume the goal is to develop STEM professionals? Or do you mean students can apply STEM to any future career – hair dresser? Firefighter? Etc.
- Include the term "practices"

These suggestions would be used to develop a refined purpose statement for the Round 3 survey. Once the participants had completed the first section of the Round 2 survey, they moved to address the instructional design strategies in section two.

In section 2, the participants were asked to rate their degree of satisfaction with each of the instructional design strategies proposed by them and the other expert panel members, which had been compiled by the review board following Round 1. Each instructional design strategy was presented to the members with a short description following it to aid them in their understanding of the purpose of the strategy. Members were to reflect on the instructional design strategies and then rate them on a five-point Likert scale according to their degree of satisfaction for each strategy. Those scores were then translated to a numeric value. Eleven strategies were presented to the members for consideration.

Eleven strategies were presented to the panel for consideration. During its review, the Review Board categorized the strategies focusing on key words. In the final editing of the strategies, these key words were put into an order as they would be used by teachers. Therefore, the researcher presented the instructional design strategies in a progressive order beginning with the initial stages of planning and preparation, moving to student design and development, and concluding with student evaluation and assessment.

The first instructional design strategy stated that pre-service teachers must be able to plan an integrated STEM lesson, which aligns STEM content standards. Fifteen of the

16 members rated their degree of satisfaction with this strategy. The responses resulted in a mean score of 3.60, a median of 4.00, a standard deviation (SD) of 0.99, and an interquartile range (IQR) of 1.00.

The second instructional design strategy suggested pre-service teachers of an integrated STEM course must be able to select design challenges which integrate STEM content. All 16 members responded. The participants' responses resulted in a mean score of 4.19, a median score of 4.00, a standard deviation (SD) of 0.66, and an interquartile range (IQR) of 1.00.

Next, the members considered the third instructional design strategy. This stated that pre-service teachers must be able to describe the STEM process. It suggested integrated STEM should be seen as a didactic cycle across the content areas. Each of the 16 participants responded. Their scores led to a mean score of 3.19, a median score of 3.50, a standard deviation (SD) of 1.38, and an interquartile range (IQR) of 2.00.

The fourth instructional design strategy stated pre-service teachers should be able to explain connections between the STEM subjects. Each of the 16 participants rated this strategy. The calculations resulted in a mean score of 3.63, a median score of 3.50, a standard deviation (SD) of 1.02, and an interquartile range (IQR) of 1.75.

The fifth instructional design strategy suggested pre-service teachers must be able to create solutions to problems using the engineering design process. Sixteen members rated this strategy. The scores resulted in a mean score of 4.06, a median score of 4.00, a standard deviation (SD) of 1.18, and an interquartile range (IQR) of 1.00.

Each of the sixteen participants scored the sixth instructional design strategy. It read that pre-service teachers should be able to develop project-based lessons, which

allow students to demonstrate their understanding of the specified STEM content. The mean score was determined to be 4.25, the median was 4.00, the standard deviation (SD) was 1.00, and the interquartile range (IQR) was 1.00.

With the seventh instructional design strategy, 15 of the 16 participants scored their responses. It stated that pre-service teachers should be able to develop an argument supported by STEM knowledge integration. The mean score was determined to be 4.13, the median was 4.00, the standard deviation (SD) was 0.74, and the interquartile range (IQR) was 1.00.

The eighth instructional design strategy stated that pre-service teachers will support an experiential learning environment. All sixteen participants responded. The mean score was 4.00, the median was 4.00, the standard deviation (SD) was 0.82, and the interquartile range (IQR) was 0.75.

The next instructional design strategy suggested pre-service teachers should choose multiple examples to demonstrate STEM concepts and connections. All participants responded. The mean score was found to be 4.38, the median was 4.50, the standard deviation (SD) was 0.81, and the interquartile range (IQR) was 1.00.

The tenth instructional design strategy suggested pre-service teachers should be able to assess student understanding of STEM relationships. All sixteen respondents rated their degree of satisfaction. The mean score was found to be 4.25, the median was 4.00, the standard deviation (SD) was 0.86, and the interquartile range (IQR) was 1.00.

Finally, the eleventh instructional strategy was rated by 15 of the 16 participants. It stated that pre-service teachers will be able to arrange collaborations to solve problems by applying STEM concepts. The mean score was 3.80, the median was 4.00, the

standard deviation (SD) was 1.08, and the interquartile range (IQR) was 2.00. Table 14 provides a summary of the data.

Table 14

Round 2 Summary of Instructional Design Strategies

Item	Round 1 Strategy	Round 2 *n*	*M*	*Mdn*	*SD*	*IQR*
1	Plan an integrated lesson	15	3.60	4.00	0.99	1.00
2	Select design challenges which integrate STEM content	16	4.19	4.00	0.66	1.00
3	Describe STEM process	16	3.19	3.50	1.38	2.00
4	Explain the connections of STEM subjects	16	3.63	3.50	1.02	1.75
5	Create solutions to problems using the engineering design process	16	4.06	4.00	1.18	1.00
6	Develop a project-based lesson	16	4.25	4.00	1.00	1.00
7	Develop an argument supported by STEM knowledge integration	15	4.13	4.00	0.74	1.00
8	Support an experiential learning environment	16	4.00	4.00	0.82	0.75
9	Choose multiple examples to demonstrate STEM concepts and connections	16	4.38	4.50	0.81	1.00
10	Assess student understanding of STEM relationships	16	4.25	4.00	0.86	1.00
11	Arrange collaborations to solve problems applying STEM concepts	15	3.80	4.00	1.08	2.00

Note. *n* denotes number, *M* denotes mean, *Mdn* denotes median, *SD* denotes standard deviation, and *IQR* denotes interquartile range.

Round 3

Now that the participants had become familiar with the list of preferred instructional design strategies created in Round 1 and initially rated in Round 2, the study progressed to Round 3. The intent of Round 3 was to achieve consensus among the participants for the revised definition of integrated STEM education, its purpose statement, and the preferred instructional design strategies for the preparation of a pre-service teacher of integrated STEM education. Seventeen members received the Round 3 survey. Of the 17 participants, 16 (94%) responded to the Round 3 survey within the

allotted timeframe, five from science, six from technology and engineering, and five from mathematics.

The format of the Round 3 survey was patterned after the Round 2 survey. It consisted of two sections. The first section requested participants to reflect on the amended definition of integrated STEM education and to once again rate their degree of satisfaction with this exiting definition on a five-point Likert scale. Using the suggestions from the Round 2 survey, the definition of integrated STEM education was changed for the Round 3 survey. It now stated Integrated STEM Education is an approach to education in which the curriculum is built from the combination of the individual learning standards of science, technology, engineering, and mathematics. It uses the context of authentic, real-world problems and is taught through instructional strategies such as project-based, problem-solving, discovery, and exploratory learning for the purpose of developing creative problem solving skills.

All sixteen participants responded to this item. The following descriptive statistics were calculated: the mean score was 4.13, the median was 4.00, the standard deviation (SD) was 0.72, and the interquartile range (IQR) was 0.75. To further demonstrate group consensus, the coefficient of variance (CV) was also assessed and determined to be 0.17. This indicated a group of leading STEM teacher-educators had achieved consensus for the refined definition of integrated STEM education. See Table 15.

The participants were encouraged to state additional ideas they believed might enhance the given definition. Only two suggestions were made, indicating an increase in the degree of satisfaction for the revised definition of integrated STEM education. Below

is a summary of the suggestions to improve the current definition of integrated STEM education.

- STEM needs to be defined on a continuum
- Would like to add the word "practices"

The revised purpose statement of integrated STEM education was also presented to the participants in section 1 of the Round 3 survey. It was important to create a distinction between the definition and purpose statement for integrated STEM education. The former explains what integrated STEM education is, and the latter designates why integrated STEM education exists. Therefore, the researcher needed to filter those suggestions from the panelists which applied to the definition of integrated STEM education from those which were best suited for the purpose statement of integrated STEM education. Additionally, the term "literate" was clarified. The term "literate" indicated that not only would a student of integrated STEM content be able to identify the connections of the STEM subjects, but that they would also be able to appropriately apply that information. Using the suggestions from the Round 2 survey, the purpose statement of integrated STEM education now suggested that integrated STEM education seeks to develop a population of learners who are not only literate in the integration and connections of the STEM subjects but can successfully interpret, apply, and adapt that knowledge to future education, employment, and additional life activities.

The participants were asked to reflect on the revisions and to rate their degree of satisfaction with this revised purpose statement on a five-point Likert scale. Sixteen members responded to this item. The participants were also encouraged to state additional ideas they believed might enhance the given purpose statement. Only two

suggestions were provided, indicating there was a transition to a greater degree of satisfaction for the proposed purpose statement. Below is a summary of the suggestions to improve the current purpose statement of integrated STEM education.

- Ensure STEM is trans-disciplinary
- Remove the word confident

The descriptive statistics for the Round 3 revised purpose statement were as follows: the mean score was 4.00, the median was 4.00, the standard deviation (SD) was 0.63, and the interquartile range (IQR) was 0.00. The coefficient of variance (CV) was also assessed and determined to be 0.16. This verified that group consensus had been achieved for the revised purpose statement of integrated STEM education. See Table 15.

Table 15

Round 3 Summary of Integrated STEM Education Definition and Purpose Statement

Item	*n*	*M*	*Mdn*	*SD*	*IQR*	*CV*
STEM Education Definition	16	4.13	4.00	0.72	0.75	0.17
STEM Education Purpose Statement	16	4.00	4.00	0.63	0.00	0.16

Transitioning to the second section of the Round 3 survey, the participants were asked to reflect on each of the eleven instructional design strategies in connection with the description provided beside it. See Appendix G. They were to use the five-point Likert scale to rate their degree of satisfaction with each strategy. Those scores were then translated to a numeric value. In addition to each of the instructional design strategies and their description, the descriptive statistics from the Round 2 survey were provided. Each participant was also reminded of their personal Round 2 score for each of the instructional design strategies.

As the intent of the Round 3 survey is to establish group consensus, the coefficient of variance (CV) was also calculated for each of the instructional design strategies. A coefficient of variance between 0.00 and 0.50, in connection with an interquartile range (IQR) less than 2.00, indicates group consensus has been achieved. The results of the Round 3 survey are as follows.

The first instructional design strategy stated that pre-service teachers must be able to plan an integrated STEM lesson. Sixteen members rated this standard. The responses resulted in a mean score of 3.69, a median of 4.00, standard deviation (SD) of 0.95, an interquartile range (IQR) of 1.00, and a coefficient of variance (CV) of 0.03.

The second instructional design strategy suggested pre-service teachers of an integrated STEM course must be able to select design challenges which integrate STEM content. Sixteen members responded. The participants' responses resulted in a mean score of 4.44, a median score of 4.00, a standard deviation (SD) of 0.51, and an interquartile range (IQR) of 1.00. The coefficient of variance (CV) was 0.11.

Next, the members rated the third instructional design strategy. This stated that pre-service teachers must be able to describe the STEM process. Sixteen participants responded. The results were as follows: the mean score was 3.13, the median score was 3.00, the standard deviation (SD) was 1.31, the interquartile range (IQR) was 2.00, and the coefficient of variance (CV) was 0.42. With a mean score less than 3.50, this strategy failed to achieve the necessary degree of group satisfaction as pre-determined before the study began. Therefore, this strategy was removed from the study.

The fourth instructional design strategy stated pre-service teachers should be able to explain connections between the STEM subjects. Where all 16 participants rated this

strategy in Round 2, 15 of the 16 participants rated this strategy in Round 3. The mean score was 3.60, the median score was 4.00, the standard deviation (SD) was 1.18, the interquartile range (IQR) was 3.00, and the coefficient of variance (CV) was 0.33. This strategy failed to achieve group consensus as the interquartile range was above 2.00. Therefore, this strategy was removed from the study.

The fifth instructional design strategy suggested pre-service teachers must be able to create solutions to problems using the engineering design process. Sixteen members rated this strategy. The scores resulted in a mean score of 4.31, a median score of 4.50, a standard deviation (SD) of 1.01, an interquartile range (IQR) of 1.00, and a coefficient of variance (CV) of 0.23.

Sixteen participants scored the sixth instructional design strategy. It stated that pre-service teachers should be able to develop project-based lessons. The mean score was determined to be 4.31, the median was 4.50, the standard deviation (SD) was 1.01, the interquartile range (IQR) was 1.00, and the coefficient of variance (CV) was 0.23.

For the seventh instructional design strategy, 16 participants scored their responses. This strategy stated that pre-service teachers should be able to develop an argument supported by STEM knowledge integration. The mean score was determined to be 4.25, the median was 4.00, the standard deviation (SD) was 0.58, the interquartile range (IQR) was 1.00, and the coefficient of variance (CV) was 0.14.

The eighth instructional design strategy suggested that pre-service teachers will support an experiential learning environment. All 16 participants responded. The mean score was determined to be 4.06, the median was 4.00, the standard deviation (SD) was

0.85, the interquartile range (IQR) was 1.00, and the coefficient of variance (CV) was 0.21.

Instructional design strategy nine suggested pre-service teachers should choose multiple examples to demonstrate STEM concepts and connections. Sixteen participants responded. The mean score was 4.56, the median was 5.00, the standard deviation (SD) was 0.81, the interquartile range (IQR) was 1.00, and the coefficient of variance (CV) was 0.18.

The tenth instructional design strategy stated pre-service teachers should be able to assess student understanding of STEM relationships. All 16 respondents rated their degree of satisfaction. The mean score was 4.31, the median was 4.50, the standard deviation (SD) was 0.79, the interquartile range (IQR) was 1.00, and the coefficient of variance (CV) was 0.18.

Finally, the eleventh instructional design strategy was rated by 16 participants. It stated that pre-service teachers will be able to arrange collaborations to solve problems by applying STEM concepts. The mean score was 3.88, the median was 4.00, the standard deviation (SD) was 1.02, the interquartile range (IQR) was 1.50, and the coefficient of variance (CV) was 0.26. Table 16 provides a summary of the data.

As each of the instructional design strategies, with the exception of strategy 4, achieved a coefficient of variance (CV) between 0.00 and 0.50 as well as an interquartile range (IQR) less than 2.00, group consensus had been reached. This ensured that the study could progress to the final stage of research.

Table 16

Round 3 Summary of Instructional Design Strategies

Item	Round 1 Strategy	Round 3 *n*	*M*	*Mdn*	*SD*	*IQR*	*CV*
1	Plan an integrated lesson	16	3.69	4.00	0.95	1.00	0.03
2	Select design challenges which integrate STEM content	16	4.44	4.00	0.51	1.00	0.11
3	Describe STEM process	16	3.13	3.00	1.31	2.00	0.42
4	Explain the connections of STEM subjects	15	3.60	4.00	1.18	3.00	0.33
5	Create solutions to problems using the engineering design process	16	4.31	4.50	1.01	1.00	0.23
6	Develop a project-based lesson	16	4.31	4.50	1.01	1.00	0.23
7	Develop an argument supported by STEM knowledge integration	16	4.25	4.00	0.58	1.00	0.14
8	Support an experiential learning environment	16	4.06	4.00	0.85	1.00	0.21
9	Choose multiple examples to demonstrate STEM concepts and connections	16	4.56	5.00	0.81	1.00	0.18
10	Assess student understanding of STEM relationships	16	4.31	4.50	0.79	1.00	0.18
11	Arrange collaborations to solve problems applying STEM concepts	16	3.88	4.00	1.02	1.50	0.26

Note. *n* denotes number, *M* denotes mean, *Mdn* denotes median, *SD* denotes standard deviation, and *IQR* denotes interquartile range.

Round 4

During the Round 1 survey each participant was asked to provide one instructional design strategy they believed was essential to the preparation of a pre-service teacher to instruct integrated STEM content. The Round 2 and Round 3 surveys "forced" participants to rate their degree of satisfaction with the strategies provided by them and their peers. They were provided a list of instructional design strategies to rate. However, they were not given the opportunity to state that they did not believe such a strategy was essential for integrated STEM education. During the Round 4 survey, they were provided such an opportunity. The significance of this final round of the Delphi study is to allow each participant to state whether an item should or should not be listed. Therefore, the purpose of the Round 4 survey was to determine which of the instructional

design strategies would in fact be suitable for the preparation of pre-service teachers of integrated STEM content.

As consensus for the definition of integrated STEM education and its purpose statement during the Round 3 survey had been achieved, it was not necessary for the participants to address those topics during the Round 4 survey. They would only address the instructional design strategies during this round. To help the participants quantify their degree of preference for each strategy, they were asked to reflect on each of the instructional design strategies and consider if it could be written as a course objective. The participants were reminded a course objective should include three components. It should specify first, what the student would know about the instructional design strategy. Second, it should denote what the student would be able to do. Third, it should state the degree of competency required to demonstrate an adequate understanding of the objective.

Seventeen members received the Round 4 survey. Of the 17 participants, one participant withdrew from the study, leaving sixteen participants. All sixteen (100%) participants responded to the Round 4 survey within the allotted timeframe, five from science, six from technology and engineering, and five from mathematics.

The Round 4 survey was presented in a table format. Along with each instructional design strategy and its description, the descriptive statistics (mean, median, standard deviation, interquartile range, and coefficient of variance) from the Round 3 survey were provided. The participant was also reminded of how they had personally scored each strategy. Each participant was asked to rate the nine instructional design strategies based upon its suitability for the preparation of a pre-service teacher of

integrated STEM content by stating "yes" or "no" next to the strategy. Any strategy which received a simple majority vote of "yes" votes, or 51%, would be deemed suitable for the preparation of a pre-service teacher of integrated STEM education.

The first instructional design strategy stated that pre-service teachers must be able to plan an integrated STEM lesson. Sixteen members responded. Fourteen of the sixteen members (87%) said "yes". This strategy is suitable for the preparation of pre-service teachers; two (13%) participants said "no".

The second instructional design strategy suggested pre-service teachers of an integrated STEM course must be able to select design challenges which integrate STEM content. Fifteen members responded. Fifteen (94%) stated "yes" it was suitable for the preparation of pre-service teachers of integrated STEM content; one (6%) participant did not respond.

The third instructional design strategy suggested pre-service teachers must be able to create solutions to problems using the engineering design process. Fifteen members rated this strategy. Thirteen (81%) stated they agreed this strategy should be viewed as suitable for the preparation of pre-service teachers; two (13%) stated "no"; one participant (6%) declined to answer.

Sixteen participants scored the fourth instructional design strategy. It stated that pre-service teachers should be able to develop project-based lessons. Fifteen (94%) agreed that this strategy was suitable for the preparation of pre-service teachers; one (6%) of the participants disagreed.

The fifth instructional design strategy was rated by 16 participants. It stated that pre-service teachers should be able to develop an argument supported by STEM

knowledge integration. Thirteen participants (81%) agreed this strategy was suitable for the preparation of pre-service teachers; three (19%) participants stated they did not believe this strategy was suitable for the preparation of pre-service teachers.

The sixth instructional design strategy suggested that pre-service teachers will support an experiential learning environment. All 16 participants responded. Eleven participants (69%) were in agreement that this strategy was suitable for pre-service teacher preparation, but five members (31 %) did not agree this strategy was suitable for pre-service teachers.

Instructional design strategy seven suggested pre-service teachers should choose multiple examples to demonstrate STEM concepts and connections. Sixteen participants responded. Thirteen (81%) members agreed with that this strategy was suitable for pre-service teachers of integrated STEM content. Three (19%) of the members did not agree.

The eighth instructional design strategy stated pre-service teachers should be able to assess student understanding of STEM relationships. All 16 participants (100%) responded in agreement with this instructional design strategy.

Finally, the ninth instructional strategy was rated by 15 participants. It stated that pre-service teachers will be able to arrange collaborations to solve problems by applying STEM concepts. Fourteen members (88%) stated they agreed with the suitability of this instructional design strategy for the preparation of pre-service teachers; one member (6%) declined to agree; one member (6%) did not respond. See Table 17.

Table 17

Round 4 Summary of Instructional Design Strategies

Item	Strategy	*n*	Yes (%)	No (%)	NR (%)
1	Plan an integrated lesson	16	14 (87)	2 (13)	
2	Select design challenges which integrate STEM content	15	15 (94)		1 (6)
3	Create solutions to problems using the engineering design process	15	13 (81)	2 (13)	1 (6)
4	Develop a project-based lesson	16	15 (94)	1 (6)	
5	Develop an argument supported by STEM knowledge integration	16	13 (81)	3 (19)	
6	Support an experiential-learning environment	16	11 (69)	5 (31)	
7	Choose multiple examples to demonstrate STEM concepts and connections	16	13 (81)	3 (19)	
8	Assess student understanding of STEM relationships	16	16 (100)	0(0)	
9	Arrange collaborations to solve problems applying STEM concepts	15	14 (88)	1 (6)	1(6)

Note. NR denotes no response. A simple majority (51%) of yes votes would indicate the instructional strategy was preferred by panel members.

Summary

The purpose of this Delphi study was to identify the preferred instructional design strategies pre-service teachers of integrated STEM education content should be able to implement when teaching an integrated STEM course. Through four survey rounds, a panel of teacher education experts representing the STEM subjects identified and validated these instructional design strategies.

Following the Round 1 survey, the participants were able to refine a working definition and purpose statement of integrated STEM education. From this foundation, the members could identify one instructional design strategy essential to teaching integrated STEM content. With the assistance of a review board, data were collected and filtered to create a list of eleven instructional design strategies for teaching integrated STEM content.

The second and third round surveys were used to build and establish group consensus respectively regarding the definition of integrated STEM education, its purpose statement, and set of instructional design strategies essential for the preparation of pre-service teachers of an integrated STEM course. Descriptive statistics, including the mean, median, standard deviation, interquartile range, and coefficient of variance were used to validate if the experts achieved consensus on these items.

The final round of the Delphi study provided participants the opportunity to adjust their ratings of those strategies they believed were less suitable for the preparation of pre-service teachers to teach integrated STEM content. Any strategy which obtained a simple majority of approval (51%) was identified as a preferred instructional design strategy for teaching integrated STEM content. Upon completion of the Round 3 survey, it was determined that nine of the 11 instructional design strategies achieved both a satisfactory mean score and group consensus as preferred instructional design strategies for the preparation of pre-service teachers for integrated STEM instruction.

Chapter V will present the summary and conclusions of this research study. Based upon the findings of this study, the researcher will provide recommendations for actions which may improve future STEM education courses and their delivery by teachers.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

This study sought to identify the preferred instructional design strategies essential to the preparation of pre-service teachers of integrated STEM content. This chapter will summarize the substance of the study, draw conclusions based upon the data collected, and offer recommendations for further action based upon those conclusions.

SUMMARY

During the 20th century, the evolution of transportation and communication industries on transcontinental trade resulted in a move toward a single global economy. As a result, the United States is no longer assured its abundant natural resources and productive workforce will be able to sustain its place as an economic leader in this single global economy (NCEE, 1983). Competition has increased among developed nations and the United States should turn their attention to necessary improvements in education in order to remain a significant influence among global economic leaders. After all, it is through invention and innovation that economies thrive, and education is the means to building invention and innovation (BHEF, 2011; NGA, 2007).

Yet the United States is struggling to adequately prepare a workforce capable of sustaining the economic goals of the 21st century. Research has shown that enthusiasm for education is dwindling among K-16 students (BHEF, 2011; Havice, 2009). Significant shortages in students studying STEM related majors across the United States are generating an alarm among the nation's leaders (BHEF, 2011; CLS, 2010). Efforts to remedy this situation through curriculum and programs designed to motivate students and further STEM education have resulted in minimal positive effects. It has been suggested

that one reason these efforts have been short-changed is that teachers have not been adequately prepared to implement these changes (Garret, 2008).

With the anticipation of the retirement of 1.6 million teachers from the baby-boomer generation over the next 10 years, now is an ideal time to capitalize on essential education reform (DOE, 2011). Preparing teachers who are highly-qualified for STEM education is necessary to meet these demands. Shulman (1986) argues reform in pedagogical knowledge as well as content knowledge is the key to preparing such teachers.

At present, the Council for the Accreditation of Educator Preparation (CAEP) [formed by the merger of National Council for Accreditation of Teacher Education (NCATE) and Teacher Education Accreditation Council (TEAC)] accredits many American university pre-service teacher education programs, of which several implement the InTASC standards for the preparation of pre-service teachers. These InTASC standards advocate for integrated instruction across the curriculum; this obligates pre-service teacher preparation programs to train their teachers in effective instructional design strategies for integrated curriculum. The intent is to reverse the current stagnate cycle of traditional classroom instruction, which has perpetuated a mediocre education system, and move to reinvigorated student-led instruction. Advocates of the constructivist approach to education herald the personal involvement of the student in their learning experience. Hands-on activities, group-work, authentic learning environments, and real-world issues are seen as vital to developing the logical, critical thinkers the National Governors Association stipulates is essential to America's future economy (CLS, 2010; Frueh, 2011; Havice, 2009; Laboy-Rush, 2011).

Others argue that it is not worth the additional cost, confusion, or frustration to prepare teachers for integrated STEM education (Sanders, 2009). Many teachers find they struggle with feelings of low self-efficacy when asked to teach content with which they are not comfortable, and teachers may demonstrate a lack of proficiency when working with unfamiliar content (Stohlman et al., 2012). Furthermore, others suggest student performance is sufficient when instructed through the traditional, teacher-led instructional methods as evident by standardized test scores (Schwedrt & Wuppermann, 2011).

Despite these objections, there has been a general call to excite students toward education through hands-on, authentic problem solving strategies (Havice, 2009). When school is perceived as relevant, students become engaged, and Havice suggests highly-qualified teachers are needed to motivate students' enthusiasm for learning. However, it is necessary to identify what constitutes a highly-qualified STEM teacher. What is the essential knowledge a STEM teacher must be equipped with prior to entering a STEM education classroom? Therefore, the purpose of this study was to identify the preferred instructional design strategies central to the preparation of pre-service teachers who may wish to teach integrated STEM lessons to students. Three research questions were developed to guide the research process. They were:

RQ_1: For pre-service STEM teacher educators, what is a preferred definition of integrated STEM education?

RQ_2: For pre-service STEM teacher educators, what is a preferred purpose statement for integrated STEM education?

RQ$_3$: For pre-service STEM teacher educators, what are the preferred instructional design strategies central to delivering an integrative approach to the teaching of STEM?

Through the identification of the preferred instructional design strategies, pre-service teacher education programs of integrated STEM content will be able to prepare future teachers to instruct students using integrated instructional strategies. As pre-service teachers perfect methods of presenting cross-curricular content through in-depth questioning and real-world issues, their students will develop creative, critical thinking skills and be able to draw knowledge from each of their core courses to identify potential solutions to authentic problems.

There were several limitations to this study. First, this was a descriptive study which relied on survey research, in the form of the Delphi method, to identify the opinions of experts (Leedy & Ormrod, 2010). The Delphi method was the ideal method of research as it solicits expert opinions and then refines those opinions in order to achieve group consensus on the preferred instructional design strategies for a pre-service teacher of integrated STEM content. Second, the preferred instructional design strategies would be focused on teaching strategies for integrated STEM curriculum and would be applicable to pre-service teacher education programs. Third, there is no one universally accepted definition of integrated STEM education. However, it was necessary to ensure participants were approaching the instructional design strategies from a common understanding of STEM education. Therefore, the researcher relied on a commonly accepted definition (Fioriello, 2010) and purpose statement of integrated STEM

education from which participants could begin to develop group consensus on the effective skills of an integrated STEM teacher (Breiner et al., 2012).

Finally, the successful Delphi method requires communication and supervision. In order to reduce research bias, a panel of post-secondary pre-service STEM education professors, who were independent of the study, served as a review board which consolidated the Round 1 data.

One significant benefit of conducting research through the Delphi process is the ability to gather expert opinions and refine those opinions through group interaction without fear of potential peer intimidation. Each expert panelist offers legitimate opinions to be considered, and since the Delphi study protects the anonymity of each participant, they are free to give their opinion without concern of what their counter-parts may say. Furthermore, since the survey process is so in-depth, consisting of four-rounds, it is not necessary to gather a large population to add validity to the study. Typically, 10-15 members are ideal, with no more than 30 members necessary (Delbecq et al., 1975).

Therefore, for this research study, 21 experts (seven from science education, seven from technology and engineering education, and seven from mathematics education) were approached to participate. This number allowed for a potential 50% withdraw rate, while maintaining the integrity of the study with a minimum of 15 participants contributing. The participants for this study were chosen based on three criteria. Each participant was a practicing educator of pre-service teachers in an American university. They worked with pre-service teachers from one of the STEM subjects. Finally, they were regarded as leading authorities on STEM education and were

actively developing knowledge about integrated STEM education through professional literature contributions and conference presentations.

Following the initial invitation to the study, the Round 1 survey was distributed to a panel of 21 members: seven from science, seven from technology and engineering, and seven from mathematics. The research instrument for this Delphi study was a survey distributed to each member electronically. Following the Round 1 survey, each subsequent survey was developed using the data from its prior survey and distributed electronically.

The Round 1 survey was divided into three sections. The first section sought to establish participant demographic information. The second section asked the participants to reflect on a provided definition for integrated STEM education and its purpose statement. The participants were to rate their degree of satisfaction with these statements on a five-point Likert scale (*1 = most unsatisfactory, 2 = unsatisfactory, 3 = uncertain, 4 = satisfactory, and 5 = most satisfactory*) and suggest improvements to each item if they desired. Finally, the third section was an open-ended statement. Each participant was to write one instructional design strategy they believed was preferred for pre-service teachers of integrated STEM content to master and include a description of their strategy to ensure accuracy of its interpretation. Eighteen participants responded to the survey within the allotted time frame (five from science, six from technology and engineering, and seven from mathematics).

The Round 2 survey was designed to begin building group consensus for a list of preferred instructional design strategies of a pre-service teacher of integrated STEM education. Sixteen participants responded within the allotted time (five from science, six

from technology and engineering, and five from mathematics). The Round 2 survey was divided into two parts. The first part requested each participant to reflect on the revised definition of integrated STEM education and its purpose statement. To aid in their reflective process, they were provided the group descriptive statistics (the mean, median, standard deviation, and interquartile range) generated from the Round 1 survey. Additionally, they were reminded of their original score when asked how they would rate these items on a five-point Likert scale. They were asked to rate the revised definition on a five-point Likert scale and make any suggestions for improvements they felt were necessary. In a similar manner, the purpose statement of integrated STEM education was addressed.

In section two of the Round 2 survey, each participant was shown the list of the instructional design strategies which were suggested during the Round 1 survey. A description of each instructional design strategy was added to ensure each participant was properly interpreting the response. They were asked to rate their degree of satisfaction with each instructional design strategy on a five-point Likert scale. Following the completion of Round 2, the study progressed to Round 3.

The Round 3 survey served to confirm group consensus for each of the proposed instructional design strategies. Seventeen members were polled; sixteen participants responded within the allotted time (five from science, six from technology and engineering, and five from mathematics). In part one of the Round 3 survey, each participant was asked to reflect on the revised definition of integrated STEM education from the Round 2 survey. They were reminded of their personal response from the Round 2 survey regarding the revised definition of integrated STEM education, and they

were shown the group mean, median, standard deviation, and interquartile range for this revised definition. They were asked to once again rate their degree of satisfaction on a five-point Likert scale with the new definition of integrated STEM education and to offer suggestions for improvements. Likewise, they completed the same steps for the proposed purpose statement of integrated STEM education.

In the second section of the Round 3 survey, each participant was provided the list of instructional design strategies. They were shown the group mean, median, standard deviation, and interquartile range for each strategy in addition to their own personal score from the Round 2 survey. Then they were asked to once again rate their degree of satisfaction with each strategy on a five-point Likert scale.

Following the completion of the Round 3 survey, the statistics were compiled. Using the mean, median, standard deviation, interquartile range, and the coefficient of variance, it was determined that both the final revision of the definition of integrated STEM education and its purpose statement had reached group consensus. Likewise, each of the instructional design strategies had achieved group consensus, with the exception of strategies three and four. Therefore, the Round 4 survey commenced.

Sixteen participants responded to the Round 4 survey within the allotted time (five from science, six from technology and engineering, and five from mathematics). During the Round 4 survey, the participants were no longer asked to address the definition of integrated STEM education or its purpose statement. Rather they were asked to reflect solely on the list of instructional design strategies. They were to determine if in fact each of these strategies was preferred for the preparation of pre-service teachers of integrated STEM education. To aid the participants in their decision,

they were to reflect on each strategy and determine if it could be written as a course objective in a pre-service teacher program. They were to respond with either a "yes" or a "no". The Round 4 survey permitted the participants the opportunity to eliminate those strategies which they believed did not meet the established criteria.

CONCLUSIONS

The purpose of this study was to identify the preferred instructional design strategies central to the preparation of pre-service teachers who may wish to teach integrated STEM lessons to students. To accomplish this outcome, three research questions were developed.

As there is no single, universally accepted definition of integrated STEM education, it was important to establish a common foundation for this study. Thus, RQ_1 was: For pre-service STEM teacher educators, what is a preferred definition of integrated STEM education?

Through the three round Delphi process, the following definition achieved consensus: Integrated STEM Education is an approach to education in which instruction is accomplished using a combination of content knowledge from multiple STEM (science, technology, engineering, and mathematics) subjects and the design process. It can be used to enhance student learning of complex concepts through the incorporation of authentic learning experiences. This type of learning emphasizes applying team work/team building skills and uses research-based instructional strategies that include design challenges, problem solving, experiential learning events, knowledge integration, and collaborative learning. The mean score for the definition was 4.13, the median was 4.00, the standard deviation was 0.72, the interquartile range was 0.75, and the coefficient

of variance was 0.17. This confirmed the group had achieved consensus and was satisfied with this revised definition of integrated STEM education.

The refined definition of integrated STEM education was narrowed in context to highlight key goals of integrative instruction, each of which has been reiterated through the literature. For example, the panel members accentuated the need for cross-curricular instruction within the revised definition. Gallant (2010) and Basista and Mathews (2002) report students experience an increased ability to transfer learning when instruction incorporates cross-curricular content, which students must apply when solving problems in class. Additionally, the panel members' definition emphasizes the need to include project-based learning, the engineering design process, and collaborative learning situations which are all recommendations aligned with integrated instruction (Daugherty, 2009; Havice, 2009; Laboy-Rush, 2011; Stohlman et al., 2012).

In addition to defining what integrated STEM education is, why integrated STEM education exists needed to be clarified. Therefore, RQ_2 sought, For pre-service STEM teacher educators, what is a preferred purpose statement for integrated STEM education? At the conclusion of the Round 3 survey, the revised purpose statement had achieved group consensus. It stated, the purpose of integrated STEM education is to develop learners who are literate in the connection of STEM knowledge. They can creatively and successfully identify and integrate concepts/processes across the STEM subject areas to solve problems. They are able to confidently apply their solutions to authentic problems and adapt their knowledge of STEM in future education, employment, and life circumstances. The mean score for this purpose statement was 4.00, the median was 4.00, the standard deviation was 0.63, the interquartile range was 0.00, and the coefficient

of variance was determined to be 0.16. Thus, the expert panel had achieved group consensus on a purpose statement for integrated STEM education.

The refined purpose statement developed by the Delphi panel members emphasizes the concept of STEM literacy. Since the Delphi panel members are teacher educators, and teachers must promote literacy in their pupils, it stands to reason that the panel members chose to highlight STEM literacy within their definition and purpose statement. The gauge of the degree of students' STEM literacy will determine the degree of proficiency of STEM teacher instruction. Asunda (2012) and Zollman (2012) stipulate, STEM literacy must include instruction across the subjects and promote student knowledge and application. The experts within this Delphi study have concurred. STEM education must not be only delivered through the single subject approach, which may limit student comprehension of cross-curricular applications, but rather STEM education must emphasize a meta-subject which incorporates standards across the curriculum and asks students to apply that knowledge through creative problem-solving techniques which is the aim of STEM education.

Finally, RQ_3 was addressed. It stated, For pre-service STEM teacher educators, what are the preferred instructional design strategies central to delivering an integrative approach to the teaching of STEM?

Following four rounds of data gathering, it was determined that nine of the 11 instructional design strategies (all but instructional design strategies three and four) had achieved both the minimum degree of group satisfaction and consensus as preferred instructional design strategies for the preparation of pre-service teachers of integrated

STEM instruction. See Table 18 for a summary of the approved instructional design strategies.

Table 18

Instructional Design Strategies for Integrated STEM Instruction

Item	Strategy	Description	*M*	*Mdn*	*SD*	*IQR*	*CV*	*% Agree*
1	Plan an integrated STEM lesson	Pre-service teachers will plan for integrated STEM lessons that will enable students to better understand the knowledge of these school subjects. Planning will use the content standards of these school subjects and incorporate activities that will make the learning meaningful to students. Some educators prefer the use of standardized instructional approaches to lesson planning, such as the 5-E Learning Cycle (engage, explore, explain, extend, and evaluate) or the Launch, Explore, Summarize cycle to ensure that planning is systematic. These approaches can enable teachers to create lessons that integrate STEM knowledge and abilities.	3.69	4.00	0.95	1.00	0.03	87
2	Select design challenges which integrate STEM content	Pre-service teachers should review and select authentic design challenges using available resources. The design challenges should appropriately apply students' prior knowledge of science, technology, engineering, and mathematics relevant to their grade and skill levels. The design challenges should improve students' understanding of the STEM concepts found in real life encounters.	4.44	4.00	0.51	1.00	0.11	94
3	Create solutions to problems using the engineering design process	Pre-service teachers will instruct students to use problem-solving strategies, such as the engineering design process, when seeking to solve authentic design challenges. Students will be able to apply the engineering design process to generate possible solutions to real-world problems through a creative, iterative, cyclical process that uses prior knowledge of the STEM subjects as the basis for their decisions.	4.31	4.50	1.01	1.00	0.23	81
4	Develop a project-based lesson	Pre-service teachers will conduct a project-based lesson, one that uses STEM knowledge to design solutions to real world problems. Their students will investigate a driving research question; design a data collection and data analysis plan; collect, analyze, and represent the data; and communicate their results to their peers.	4.31	4.50	1.01	1.00	0.23	94
5	Develop an argument supported by STEM knowledge integration	Pre-service teachers will help students learn to justify their research findings based upon data collected while proposing ideas to real world problems. They will help their students to create, defend in a civil manner, and analyze the strength of their arguments and those of their classmates. Therefore, knowledge of STEM concepts and principles will be used to support their conclusions.	4.25	4.00	0.58	1.00	0.14	81

Table 18 (continued)

6	Support an experiential learning environment	Pre-service teachers will begin to value the potential benefits of experiential learning that applies STEM concepts and principles. Experiential learning can include the use of simulations, role-playing, model building, projects, and experiments. The environment is designed to help students apply their knowledge and build greater understanding of integrated STEM concepts. As students engage in these learning environments, their knowledge will become more deeply ingrained.					
		M	*Mdn*	*SD*	*IQR*	*CV*	*% Agree*
		4.06	4.00	0.85	1.00	0.21	69
7	Choose multiple examples to demonstrate STEM concepts and connections	To accommodate a variety of learning styles, the pre-service teacher will incorporate several instructional techniques, such as multiple representations, connections and applications, science, technology, and mathematical tools, and problem-solving strategies to ensure students' understanding of the nature and structure of science, technology, engineering, and mathematics.					
		M	*Mdn*	*SD*	*IQR*	*CV*	*% Agree*
		4.56	5.00	0.81	1.00	0.18	81
8	Assess student understanding of STEM relationships	The pre-service teacher will use a variety of instructional tools to engage students in formative and summative evaluations. These will encourage in-depth thought process. Pre-service teachers will learn to create rubrics that help them to critically measure student understanding. Teachers will evaluate and assess students' comprehension of integrated STEM concepts through student created artifacts.					
		M	*Mdn*	*SD*	*IQR*	*CV*	*% Agree*
		4.31	4.50	0.79	1.00	0.18	100
9	Arrange collaborations to solve problems applying STEM concepts	The pre-service teacher will promote team work/team building skills with their students while addressing problems using integrated STEM knowledge. They will help students understand the value of collaboration; students will learn to share ideas when working to solve an authentic design challenge. Teachers will use assigned positions (such as team leader), guided instructions, questions, and class conversations to help students learn to work as a team, thus students share knowledge to strengthen their learning.					
		M	*Mdn*	*SD*	*IQR*	*CV*	*% Agree*
		3.88	4.00	1.02	1.50	0.26	88

When comparing the data collected from this study with that collected by other studies regarding instructional strategies for integrated instruction, the similarities in the instructional design strategies are notable. For example, with the exception of the necessity to promote writing skills for reflection and problem solving, each of the strategies proposed in the Stohlman et al. (2012) study of *Considerations for Teaching Integrated STEM Education* is affirmed through most of the strategies developed by this

study's expert panel. It should be noted, however, this study's strategies were enhanced with the incorporation of the technology and engineering content, specifically the engineering design process. This implies incorporating technology and engineering knowledge and abilities into integrated instruction is not only feasible, but recommended. As proposed by the expert panel from this Delphi study, developing student creativity and ingenuity is desirable. They suggested the incorporation of technology and engineering content can generate these skills which are essential for the development of the 21st century workforce. The participants from this Delphi study also specified the necessity of strategies which addressed the importance of planning an integrated STEM lesson and developing a project-based lesson. Table 19 highlights the connections between the strategies suggested by Stohlman et al. (2012) and those developed through this study. Only the last strategy from the Stohlman et al. study is not aligned with any of the strategies from the Delphi study.

Table 19

Comparison of Integrated STEM Studies

10 Best Teaching Practices for Teaching Integrated Science and Mathematics		**9 Preferred Instructional Design Strategies for Teaching Integrated STEM Content**
Integrate technology	Aligns with	Select design challenges which integrate STEM content
Use manipulatives and hands-on learning	Aligns with	Choose multiple examples to demonstrate STEM concepts
Utilize questioning and conjecture	Aligns with	Choose multiple examples to demonstrate STEM concepts
Include cooperative learning	Aligns with	Arrange collaborations to solve problems
Incorporate discussion and inquiry	Aligns with	Create solutions to problems using the engineering design process
Incorporate problem-solving approaches	Aligns with	Create solutions to problems using the engineering design process
Use justification of thinking	Aligns with	Develop an argument supported by STEM knowledge integration

Table 19 (continued)

Practice teaching as a facilitator	Aligns with	Support an experiential learning environment
Include assessment as part of instruction	Aligns with	Assess student understanding of STEM relationships
Promote writing for reflection and problem-solving	Does not align	Plan an integrated STEM lesson Develop a project-based lesson

Note. 10 best teaching practices as cited in "Considerations for teaching integrated STEM education," by M. Stohlman, T. Moore, & G. Roehrig. (2012). *Journal of Pre-College Engineering Education Research, 2*(1), 28-34.

Similarly, Berlin and White (2012) reported the need for pre-service teachers to be able to discern which lessons should be taught through integration from those which should not. They also emphasized the need for pre-service teachers to learn how to induce their students to communicate the means by which the academic content has been integrated and to incorporate collaboration and teamwork within their lessons and planning. Both of these skills were also addressed through the Delphi study.

With studies which depict related findings, it becomes incumbent upon educators to now respond to the demand for a new kind of pre-service teacher preparation. Pre-service teachers should be trained to instruct integrated content if presented with such an opportunity. With more school systems investigating the potentials of integrated STEM education for their student populations, teachers would more likely experience greater success if they could draw on a skill set aligned with integrated teaching strategies if asked to teach integrated STEM content.

RECOMMENDATIONS

The purpose of this study was to identify preferred instructional design strategies for the preparation of pre-service teachers of integrated STEM education. The findings of this study have led the researcher to make both recommendations for implementing these findings and recommendations for further research.

Federal and state government leaders, together with the private business sector and higher education, assume today's graduates are not properly prepared for further education or the workforce of the 21st century. This has led them to call for an improved education system, one with fully prepared and highly-qualified future teachers. The results of this study list skill sets a pre-service teacher should develop to enable them to teach integrated STEM content. These are practices that can assist teachers to become highly effective STEM teachers within their future classrooms/laboratories. As this study developed a list of preferred methods for instructing an integrated STEM curriculum, it is recommended these strategies be designed into course objectives and activities and be used in preparing pre-service teachers.

As new teachers enter their own classrooms/laboratories, they are likely to emulate the teaching methods practiced by their former professors. Therefore, it is recommended that teacher educators receive appropriate professional development training for teaching STEM concepts through hands-on, authentic learning experiences. Current teacher educators should model the instructional design strategies associated with an integrated STEM curricula. As pre-service teachers experience learning through these strategies, they may recognize the benefits gained through such instruction and desire to implement it in their classroom, thus transferring the benefits these strategies may offer them through their personal learning experiences to their own students. As worth is directly proportional to perceived value, designing personal learning experiences for pre-service teachers using instructional design strategies for integrated STEM subjects may generate a greater degree of belief for the necessity of teaching integrated subjects through such instructional design strategies.

Additionally, providing professional development for teaching integrated STEM content to in-service teachers who would serve as mentors to beginning teachers of integrated STEM would be beneficial. The mentor teachers would be prepared with the essential knowledge necessary to properly support a beginning teacher of integrated STEM content.

In addition, a comparative analysis study, regarding teacher self-efficacy between teachers who have been prepared to teach an integrated STEM curriculum with those who have not been trained in instructional design strategies for integrated instruction will provide insight into determining if teachers' self-efficacy is in fact improved through pre-service preparation programs designed to prepare teachers for integrated STEM instruction.

As pre-service teachers who have been prepared to teach integrated STEM enter their classrooms/laboratories, it is recommended studies be conducted to validate the preferred instructional design strategies for integrated STEM content. One way this could be done is to compare student test scores of those who received instruction in an integrated STEM classroom/laboratory with those students who did not receive their instruction in an integrated STEM classroom/laboratory. This may serve to endorse the use of the preferred instructional design strategies identified through this study. Another study could be undertaken to determine if these instructional design strategies, which were separated into three categories: planning and preparation, design and development, and evaluation and assessment, have remained constant for planning, delivery, and evaluation of integrated instruction.

Finally, studies should be conducted to determine if there is a correlation between having a teacher who is prepared to instruct integrated STEM content and student career choices. This research may validate many presuppositions that integrated STEM instruction through hands-on learning environments will indeed promote creative, critical thinkers who are able to positively impact local, state, national, and international economies. Such students might feel successful in STEM related courses and may pursue careers in STEM related fields.

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APPENDIX A

Letter of Invitation to Participants

January 21, 2013

Dear XXXXXX:

You have made continued contributions to the STEM community and teacher preparation. Because of your scholarly impact, you have been identified as a possible participant in a Delphi study that seeks to reach a consensus for a definition and purpose statement of STEM education. Additionally, if you volunteer to participate, you will be asked to contribute to the creation of a list of instructional design strategies which will serve to guide the development of future pre-service teachers of integrated STEM education.

Your contribution will provide a vital role in this emerging field. While your participation is completely voluntary and you are under no obligation to participate in this study, your opinion is deemed worthy of consideration and would add beneficial input to this work. If you should choose to participate in this study, your identification will remain confidential; all data will be reported as aggregate information.

If you agree to accept this invitation, you will be E-mailed a survey and provided 10 days to complete it. Round 1 of the study will begin directly after the panel has been completed, approximately the second week of February, 2013. This is planned to be a four-round Delphi study and should be completed by July, 2013. Your participation will take about 15 minutes per round. At the conclusion of the study, the panel members should have reached a consensus for a definition of STEM education, a purpose statement for STEM education, and a list of instructional design strategies to guide the education of a pre-service teacher in the implementation of an integrated STEM program.

If you agree to participate, please understand there will be no direct personal benefit for your contribution. If you should choose to participate, please know you are not compelled to remain in the study. You may withdraw at any time without penalty. If you should choose to accept this invitation, please reply to Amanda Roberts by January 31, 2013.

Sincerely,

Amanda Roberts	*John M. Ritz*
Amanda Roberts	John M. Ritz
PhD Candidate, STEM Education	Professor, STEM Education
Old Dominion University	Old Dominion University

APPENDIX B

Letter of Appreciation to Participants

February 21, 2013

Dear XXXXX,

Thank you for agreeing to participate in this Delphi study on the development of Instructional Design Strategies for Preparation of Pre-Service Teachers of Integrated STEM Education. We appreciate your prompt response to our letter of invitation, and we are thankful you are willing to be a contributing member to our study.

You will notice there are two attachments to this E-mail. The first attachment clarifies the purpose for this study and offers additional background information. Additionally, it provides directions for completing the survey. In the final portion of the survey, there is an open-response section for you to provide one integrated STEM instructional design strategy you believe needs to be achieved by candidates being prepared through a pre-service teacher education program. In our efforts to prepare highly-effective teachers of integrated STEM curriculum, emphasis is often placed on best practices such as Inquiry-Based, Project-based, and Problem-solving instruction. However, these terms may be taught and modeled differently among the STEM subjects, which may result in the pre-service teacher only acquiring a vague understanding of these teaching strategies. This survey seeks to identify specific instructional design strategies for integrated STEM education in which pre-service teachers should be trained. Ideally, once the list of instructional design strategies is identified, they could be rewritten in the form of learning objectives for a teacher preparation course on integrated STEM instruction. If you are interested in a sample format to record your answer, there is an example provided on the Round 1 survey. The second attachment is the Round 1 survey.

Please respond directly on the electronic survey attached to this E-mail and submit your response by March 1, 2013, to Amanda Roberts.

We look forward to receiving your response. Thank you in advance for your participation in this study.

Sincerely,

Amanda Roberts
Amanda Roberts
PhD Candidate, STEM Education
Old Dominion University

John M. Ritz
John M. Ritz
Professor, STEM Education
Old Dominion University

APPENDIX C

Summary of the Study for Participants

INSTRUCTIONAL DESIGN STRATEGIES FOR PREPARATION OF PRE-SERVICE TEACHERS OF INTEGRATED STEM EDUCATION: SUMMARY

Purpose: With the growing emphasis placed on STEM education, it is important to properly prepare teachers for integrated STEM instruction. Being able to apply instructional design strategies for integrated STEM teacher preparation would serve as an aid to produce such STEM instructors.

The opportunity to replace veteran teachers with highly-qualified, beginning instructors mandates a review of current teacher preparation programs. This study is designed to help you reflect on the future directions of STEM education. The purpose is to create specific instructional design strategies for pre-service STEM teacher preparation. For the purpose of this research, Instructional Design Strategy will be narrowly defined as: systematic activities used by a teacher which state explicit steps to achieve a specific student outcome (Albus, Thurlow, & Clapper, 2007).

Directions: To begin the study, you will be asked to provide some demographic information. All information will be treated as confidential data. Therefore, when you receive the second round of the Delphi study, all responses will be reported back to you in aggregate. Following the demographic section, you will be asked to consider a definition that is provided for STEM education. Please review it, rate it on the five-point Likert scale, and then provide needed improvements to the definition.

Next, you will be asked to consider a suggested purpose for STEM education. Please review it, rate it on the five-point Likert scale, and provide needed improvements to the purpose statement. Finally, you will be asked to provide an instructional design strategy for pre-service STEM teachers. Please put yourself into the context that you are designing integrated STEM instruction for learners. Then, list the instructional design strategy you believe is most important for a pre-service STEM education program and briefly describe what is meant by the strategy you suggest. The survey contains an example of a strategy with its description from another subject.

When you have completed the survey, please return it via E-mail to Amanda Roberts. Your responses will be assigned a number and all personal identifiers will be removed. Once all participants have responded to the Round 1 survey, the data will be given to an independent panel of university faculty to review and compress. They will code and combine similar answers. They will return the responses to me. At that time, I will create the Round 2 survey and distribute it to you for your reactions.

Thank you for your time and expert contributions. Your participation is appreciated.

Sincerely,

Amanda Roberts

Amanda Roberts
PhD Candidate, STEM Education
Old Dominion University

John M. Ritz

John M. Ritz
Professor, STEM Education
Old Dominion University

APPENDIX D

Round 1 Survey for Participants

Integrated STEM Instructional Design Strategies for the Preparation of Teachers

We appreciate your participation in this study. The purpose of this survey is to ask you to reflect on a definition and purpose of STEM education from the perspective of a STEM teacher educator, and then provide an important instructional design strategy for the development of a pre-service STEM teacher. **Please remember, for the purpose of this study, the instructional design strategy will be used to address integrated instruction of STEM knowledge, concepts, or principles.**

Therefore, we ask following the demographic section of the survey, please rate your degree of satisfaction with the provided definition of STEM education and the purpose statement for STEM education on the five-point Likert scales provided. Then, if you have suggestions to improve the definition or purpose statement, please record those thoughts on the lines provided.

Thank you for your time and contribution.

Round 1 Survey:
Demographics:

Gender: Female ___________ Male _________

Age: 30 or below _____ 31-40 ______ 41-50 _____ 51 and above ______

Your STEM Concentration Field: Science ______

Technology and Engineering ______

Mathematics ______

Years in the Teaching Profession: 0-5 _____ 6-10 _____ 11-15 ______

16-20 ______ 21-25 ______ 26-30 ______ 31 or more ______

Part 1: Identifying a STEM Education Definition and Purpose Statement

STEM Education Definition: It is an approach to education which integrates science, technology and engineering, and mathematics through an instructional method which utilizes project-based problem-solving, discovery, and exploratory learning, and requires students to actively engage a situation to find a solution to a problem (Fioriello, 2010).

To what degree is the sufficiency of this proposed definition of STEM education as stated? *(select one)*

Most Satisfactory	**Satisfactory**	**Uncertain**	**Unsatisfactory**	**Most Unsatisfactory**
______	______	______	______	______

What distinctions would improve the definition of STEM education?

____

____

____

____

The Proposed Purpose of STEM education:

The purpose of STEM education is to prepare students through integrated learning experiences using problem-based learning strategies to develop a population of learners who are literate in STEM knowledge and abilities and prepared to apply it to future education and employment situations.

To what degree is the sufficiency of this proposed purpose of STEM education as stated? *(select one)*

Most Satisfactory	**Satisfactory**	**Uncertain**	**Unsatisfactory**	**Most Unsatisfactory**
______	______	______	______	______

What distinctions would improve the purpose of STEM education?

____

____

Part 2: Developing Integrated STEM Instructional Design Strategies

We ask that you record ONE instructional design strategy for the preparation of a pre-service teacher to instruct integrated STEM content. We have provided an example to possibly guide the format of your response, although we purposefully reported it to represent another teaching area. After you have written your instructional design strategy, please provide a brief description of the statement to ensure the Review Board and Delphi Panel interprets the meaning accurately.

Sample Statement and Description: From the *Information Literacy Standards for Teacher Education* (2011). Retrieved from http://www.ala.org/acrl/sites/ala.org.acrl/files/content/standards/ilstandards_te.pdf

Statement: The information literate teacher education student defines and articulates the need for information and selects strategies and tools to find that information.

The description for this example clarifies the knowledge and skills associated with completing this statement. Thus, the following demonstrates how the information literate teacher education student will model their understanding of the sample statement. They will be able to:

- Identify the purpose for which information is needed
- Determine the factors that influence the information needed
- Explore general information sources to increase familiarity with the scope of the information needed
- Define or modify the information needed to achieve a manageable focus
- Review the initial information needed to clarify, revise, or refine initial impressions and ideas

Place yourself in the context that you are developing instruction for an integrated STEM lesson. What is the most critical instructional design strategy to you for integrated STEM teacher preparation? Please describe your strategy so the Review Board and Delphi Panel will clearly understand its meaning.

Please E-mail your completed survey to Amanda Roberts by March XX, 2013.

APPENDIX E

Letter of Invitation to Review Board

April 1, 2013

Dear XXXXX,

As educators of pre-service teachers, we have a vested interest in ensuring the integrity of the field by developing well-qualified teachers. One measure we can take to promote their success is to teach them strategies they can choose from to instruct their students. With the growing demand for STEM educators, it is becoming necessary to create instructional design strategies which complement a STEM curriculum. Therefore, I will undertake a Delphi study which will seek to elicit expert opinions of fellow educators who prepare pre-service STEM teachers. They will develop a set of preferred instructional design strategies which will aid teachers in integrating STEM curriculum.

We are writing to request your help. In order to follow the proper procedure of a Delphi study method and to escape potential research bias, a review board must be used to analyze the first round of data. Would you agree to serve on this board? It would require a maximum of one morning or afternoon of your time during the week of April 8, 2013. You would be asked to review the suggested changes to a proposed definition of STEM education, a proposed purpose statement for STEM education, and a list of instructional design strategies and their explanations as provided by the study participants. Then you would analyze the strategies and compress the similar statements. Those strategies which are determined to be similar in nature would be combined. Those unique from the others would be listed as they are written. Ultimately, you would work to create a single list of strategies.

If you are willing to serve in this manner, please understand your participation would be voluntary. Your identity will remain confidential to those who are participating in the study, and you will receive no personal remuneration for your time.

We would greatly appreciate your time and service in this research project. Please consider participating. If you should choose to accept this responsibility, please respond directly to this E-mail and submit your response by April 5, 2013, to Amanda Roberts.

We look forward to receiving your response. Thank you in advance for your participation in this study.

Sincerely,

Amanda Roberts	*John M. Ritz*
Amanda Roberts	John M. Ritz
PhD Candidate, STEM Education	Professor, STEM Education
Old Dominion University	Old Dominion University

APPENDIX F

Round 2 Survey for Participants

Integrated STEM Instructional Design Strategies for the Preparation of Teachers

Part I: Building Consensus for an Integrated STEM Education Definition and Purpose Statement

In Part I of this survey, you will see a revised definition of integrated STEM education to which you contributed in developing. It is followed by the Round 1 group statistics and a statement to remind you of your personal response to Round 1. Please reflect on the revised definition of integrated STEM education and rate your degree of satisfaction using the five-point Likert scale provided. Then, if you have suggestions to improve the definition, please record your thoughts on the lines provided.

Integrated STEM Education: An approach to education where instruction is designed using a combination of knowledge from the individual school subjects of science, technology, engineering, or mathematics. It can be used to enhance student learning of complex concepts through the use of authentic learning experiences. This type of learning emphasizes applying team work/team building skills and is taught using instructional strategies that incorporate design challenges, experiential learning events, knowledge integration, and collaborative learning.

Group Results from the Round 1 Survey:

Mean: 3.11 Median: 3.50 St. Dev.: 1.13 IQR: 2.00

You gave the original definition of STEM education a rating of: XXX

To what degree of satisfaction are you with this proposed definition of STEM education?

Most Satisfactory	Satisfactory	Uncertain	Unsatisfactory	Most Unsatisfactory
______	______	______	______	______

What terminology would improve this definition for STEM education?

____

____

Next, you will see a revised purpose statement for Integrated STEM education followed by the Round 1 group statistics and a statement to remind you of your personal response to Round 1. Please reflect upon the revised purpose statement of Integrated STEM Education and rate your degree of satisfaction with it using the five-point Likert scale provided. If you have suggestions to improve the purpose statement, please record those thoughts on the lines provided.

The Proposed Purpose of Integrated STEM Education:

The purpose of integrated STEM education is to develop a learner who is literate in the connection of STEM knowledge and can successfully interpret, apply, and adapt that knowledge to future education, employment, and life situations.

Group Results from the Round 1 Survey:

Mean: 3.17 Median: 3.00 St. Dev.: 1.20 IQR: 2.00

You gave the original purpose of STEM education a rating of: XXX

To what degree are you satisfied with this purpose of STEM education?

Most Satisfactory	Satisfactory	Uncertain	Unsatisfactory	Most Unsatisfactory
______	______	______	______	______

What wording might improve the purpose of STEM education?

____

____

Part 2: Building Consensus for Integrated STEM Instructional Design Strategies

Following is a list of instructional design strategies you and your colleagues identified through Round 1 of this study for the preparation of a pre-service teacher to instruct integrated STEM lessons. We ask you to rate your degree of acceptance for each of the instructional design strategies using the five-point Likert scale.

1. **Plan an integrated STEM lesson.**
   Pre-service teachers will plan for integrated STEM lessons that will enable students to better understand the knowledge of these school subjects. Planning will use the content standards of these school subjects and incorporate activities that will make the learning meaningful to students. Some educators prefer the use of standardized instructional approaches to lesson planning, such as the 5-E Learning Cycle (engage, explore, explain, extend, and evaluate) or the Launch, Explore, Summarize Cycle to ensure that planning is systematic. These approaches can enable teachers to create lessons that integrate STEM knowledge and abilities.

   Do you agree with this instructional strategy?

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
______	______	______	______	______

2. **Select design challenges which integrate STEM content.**
   Pre-service teachers should review and select authentic design challenges using available resources. The design challenges should appropriately apply students' prior knowledge of science, technology, engineering, and mathematics relevant to their grade and skill levels. The design challenges should improve students' understanding of the STEM concepts found in real life encounters.

   Do you agree with this instructional strategy?

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
______	______	______	______	______

3. **Describe STEM process.**
   Pre-service teachers will assist students to see STEM as a didactic cycle where science uses applied mathematics, engineering uses applied science, and technology uses applied engineering. Students will use this understanding to help them create models of physical situations. Students will use the models to contribute unique, potential solutions to real-world problems.

   Do you agree with this instructional strategy?

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
_______	_______	_______	_______	_______

4. **Explain the connections of STEM subjects.**
   Pre-service teachers will select specific standards from each of the individual STEM subjects, which, when combined, are relevant to a designated design challenge lesson. The pre-service teachers will then ask students to communicate ways in which those standards could interact with each other in relation to the design challenge prior to beginning to solve the real-world problem.

   Do you agree with this instructional strategy?

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
_______	_______	_______	_______	_______

5. **Create solutions to problems using the engineering design process.**
   Pre-service teachers will instruct students to use problem-solving strategies, such as the engineering design process, when seeking to solve authentic design challenges. Students will be able to apply the engineering design process to generate possible solutions to real-world problems through a creative, iterative, cyclical process that uses prior knowledge of the STEM subjects as the basis for their decisions.

   Do you agree with this instructional strategy?

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
_______	_______	_______	_______	_______

6. **Develop a project-based lesson.**
   Pre-service teachers will conduct a project-based lesson, one that uses STEM knowledge to design solutions to real world problems. Their students will investigate a driving research question; design a data collection and data analysis plan; collect, analyze, and represent the data; and communicate their results to their peers.

   Do you agree with this instructional strategy?

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
_______	_______	_______	_______	_______

7. **Develop an argument supported by STEM knowledge integration.**
   Pre-service teachers will help students learn to justify their research findings based upon data collected while proposing ideas to real world problems. They will help their students to create, defend in a civil manner, and analyze the strength of their arguments and those of their classmates. Therefore, knowledge of STEM concepts and principles will be used to support their conclusions.

   Do you agree with this instructional strategy?

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
_______	_______	_______	_______	_______

8. **Support an experiential learning environment.**
   Pre-service teachers will begin to value the potential benefits of experiential learning that apply STEM concepts and principles. Experiential learning can include the use of simulations, role playing, model building, and experiments. It is designed to help students apply their knowledge and build greater understanding of integrated STEM concepts. As students engage in these learning environments, their learning will become more deeply ingrained.

   Do you agree with this instructional strategy?

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
_______	_______	_______	_______	_______

9. Choose multiple examples to demonstrate STEM concepts and connections.
To accommodate a variety of learning styles, the pre-service teacher will incorporate several instructional techniques, such as multiple representations, connections and applications, science and mathematical tools, and problem-solving strategies to insure students understanding of the nature and structure of science, technology, engineering, and mathematics.

Do you agree with this instructional strategy?

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
______	______	______	______	______

10. Assesses student understanding of STEM relationships.
The pre-service teacher will use a variety of instructional tools to engage students in formative and summative evaluations. These will encourage in-depth thought processes. Pre-service teachers will learn to create rubrics that help them to critically measure student understanding. Teachers will evaluate and assess students' comprehension of integrated STEM concepts through student created artifacts.

Do you support this instructional strategy?

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
______	______	______	______	______

11. Arrange collaborations to solve problems applying STEM concepts.
The pre-service teacher will promote team work/team building skills with their students while addressing problems using integrated STEM knowledge. They will help students understand the value of collaboration; students will learn to share ideas when working to solve an authentic design challenge. Teachers will use assigned positions (such as team leader), guided instructions, questions, and class conversations to help students learn to work as a team, thus students share knowledge to strengthen their learning.

Do you agree with this instructional strategy?

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
______	______	______	______	______

Thank you for your continued time and support of this study. We appreciate your contributions.

APPENDIX G

Round 3 Survey for Participants

Integrated STEM Instructional Design Strategies for the Preparation of Teachers

Part 1, Establishing Consensus for an Integrated STEM Education Definition and Purpose Statement

In Part 1 of this survey, you will see a revised definition of integrated STEM education to which you contributed in its development. It is followed by the Round 2 group statistics and a statement to remind you of your personal response to the Round 2 definition. Please reflect on the revised definition of integrated STEM education and rate your degree of satisfaction of the definition using the five-point Likert scale provided.

Integrated STEM Education: An approach to education in which instruction is accomplished using a combination of content knowledge from multiple STEM (science, technology, engineering, and mathematics) subjects and the design process. It can be used to enhance student learning of complex concepts through the incorporation of authentic learning experiences. This type of learning emphasizes applying team work/team building skills and uses research-based instructional strategies that include design challenges, problem solving, experiential learning events, knowledge integration, and collaborative learning.

Group Results from the Round 2 Survey:

Mean: 3.56 Median: 4.00 St. Dev.: 0.96 IQR: 1.00

You gave the revised definition of STEM education a rating of: XXX

To what degree of satisfaction are you with this proposed definition of STEM education?

Most Satisfactory	**Satisfactory**	**Uncertain**	**Unsatisfactory**	**Most Unsatisfactory**
________	________	________	________	________

Next, you will see a revised purpose statement for Integrated STEM education followed by the Round 2 group statistics and a statement to remind you of your personal response in Round 2 to the purpose statement. Please reflect upon the revised purpose statement of Integrated STEM education and rate your degree of satisfaction with it using the five-point Likert scale provided.

The Proposed Purpose of Integrated STEM education:

The purpose of integrated STEM education is to develop learners who are literate in the connection of STEM knowledge. They can creatively and successfully identify and integrate concepts/processes across the STEM subjects to solve problems. They are able to confidently apply their solutions to authentic problems and adapt their knowledge of STEM in future education, employment, and life circumstances.

Group Results from the Round 2 Survey:

Mean: 3.73 Median: 4.00 St. Dev.: 0.70 IQR: 1.00

You gave the revised purpose statement of STEM education a rating of: XXX

To what degree are you satisfied with this purpose of STEM education?

Most Satisfactory	**Satisfactory**	**Uncertain**	**Unsatisfactory**	**Most Unsatisfactory**
______	______	______	______	______

Part 2, Establishing Consensus for Integrated STEM Instructional Design Strategies

Following is a list of instructional design strategies you and your colleagues rated in Round 2 for the preparation of a pre-service teacher to instruct integrated STEM lessons. We ask you to once again rate your degree of acceptance for each of the instructional design strategies using the five-point Likert scale. Your individual responses to Round 2 are included.

1. **Plan an integrated STEM lesson.**
   Pre-service teachers will plan for integrated STEM lessons that will enable students to better understand the knowledge of these school subjects. Planning will use the content standards of these school subjects and incorporate activities that will make the learning meaningful to students. Some educators prefer the use of standardized instructional approaches to lesson planning, such as the 5-E Learning Cycle (engage, explore, explain, extend, and evaluate) or the Launch, Explore, Summarize Cycle to ensure that planning is systematic. These approaches can enable teachers to create lessons that integrate STEM knowledge and abilities.

   Group Results from the Round 2 Survey:

   Mean: 3.60 Median: 4.00 St. Dev.: 0.99 IQR: 1.00

   You gave this strategy a rating of: XXX

   Do you agree with this instructional strategy?

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
______	______	______	______	______

2. **Select design challenges which integrate STEM content.**
Pre-service teachers should review and select authentic design challenges using available resources. The design challenges should appropriately apply students' prior knowledge of science, technology, engineering, and mathematics relevant to their grade and skill levels. The design challenges should improve students' understanding of the STEM concepts found in real life encounters.

Group Results from the Round 2 Survey:

Mean: 4.19 Median: 4.00 St. Dev.: 0.66 IQR: 1.00

You gave this strategy a rating of: XXX

Do you agree with this instructional strategy?

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
______	______	______	______	______

3. **Describe STEM process.**
Pre-service teachers will assist students to see STEM as a didactic cycle where science uses applied mathematics, engineering uses applied science, and technology uses applied engineering. Students will use this understanding to help them create models of physical situations. Students will use the models to contribute unique, potential solutions to real-world problems.

Group Results from the Round 2 Survey:

Mean: 3.19 Median: 3.50 St. Dev.: 1.38 IQR: 2.00

You gave this strategy a rating of: XXX

Do you agree with this instructional strategy?

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
______	______	______	______	______

4. **Explain the connections of STEM subjects.**
Pre-service teachers will select specific standards from each of the individual STEM subjects, which, when combined, are relevant to a designated design challenge lesson. The pre-service teachers will then ask students to communicate ways in which those standards could interact with each other in relation to the design challenge prior to beginning to solve the real-world problem.

Group Results from the Round 2 Survey:

Mean: 3.63 Median: 3.50 St. Dev.: 1.02 IQR: 1.75

You gave this strategy a rating of: XXX

Do you agree with this instructional strategy?

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
________	________	________	________	________

5. **Create solutions to problems using the engineering design process.**
Pre-service teachers will instruct students to use problem-solving strategies, such as the engineering design process, when seeking to solve authentic design challenges. Students will be able to apply the engineering design process to generate possible solutions to real-world problems through a creative, iterative, cyclical process that uses prior knowledge of the STEM subjects as the basis for their decisions.

Group Results from the Round 2 Survey:

Mean: 4.06 Median: 4.00 St. Dev.: 1.18 IQR: 1.00

You gave this strategy a rating of: XXX

Do you agree with this instructional strategy?

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
________	________	________	________	________

6. **Develop a project-based lesson.**
Pre-service teachers will conduct a project-based lesson, one that uses STEM knowledge to design solutions to real world problems. Their students will investigate a driving research question; design a data collection and data analysis plan; collect, analyze, and represent the data; and communicate their results to their peers.

Group Results from the Round 2 Survey:

Mean: 4.25 Median: 4.00 St. Dev.: 1.00 IQR: 1.00

You gave this strategy a rating of: XXX

Do you agree with this instructional strategy?

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
______	______	______	______	______

7. **Develop an argument supported by STEM knowledge integration.**
Pre-service teachers will help students learn to justify their research findings based upon data collected while proposing ideas to real world problems. They will help their students to create, defend in a civil manner, and analyze the strength of their arguments and those of their classmates. Therefore, knowledge of STEM concepts and principles will be used to support their conclusions.

Group Results from the Round 2 Survey:

Mean: 4.13 Median: 4.00 St. Dev.: 0.74 IQR: 1.00

You gave this strategy a rating of: XXX

Do you agree with this instructional strategy?

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
______	______	______	______	______

8. **Support an experiential learning environment.**
Pre-service teachers will begin to value the potential benefits of experiential learning that applies STEM concepts and principles. Experiential learning can include the use of simulations, role playing, model building, and experiments. It is designed to help students apply their knowledge and build greater understanding of integrated STEM concepts. As students engage in these learning environments, their learning will become more deeply ingrained.

Group Results from the Round 2 Survey:

Mean: 4.00 Median: 4.00 St. Dev.: 0.82 IQR: 0.75

You gave this strategy a rating of: XXX

Do you agree with this instructional strategy?

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
______	______	______	______	______

9. **Choose multiple examples to demonstrate STEM concepts and connections.**
To accommodate a variety of learning styles, the pre-service teacher will incorporate several instructional techniques, such as multiple representations, connections and applications, science and mathematical tools, and problem-solving strategies to insure students understanding of the nature and structure of science, technology, engineering, and mathematics.

Group Results from the Round 2 Survey:

Mean: 4.38 Median: 4.50 St. Dev.: 0.81 IQR: 1.00

You gave this strategy a rating of: XXX

Do you agree with this instructional strategy?

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
______	______	______	______	______

10. Assesses student understanding of STEM relationships.
The pre-service teacher will use a variety of instructional tools to engage students in formative and summative evaluations. These will encourage in-depth thought processes. Pre-service teachers will learn to create rubrics that help them to critically measure student understanding. Teachers will evaluate and assess students' comprehension of integrated STEM concepts through student created artifacts.

Group Results from the Round 2 Survey:

Mean: 4.25 Median: 4.00 St. Dev.: 0.86 IQR: 1.00

You gave this strategy a rating of: XXX

Do you support this instructional strategy?

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
________	________	________	________	________

11. Arrange collaborations to solve problems applying STEM concepts.
The pre-service teacher will promote team work/team building skills with their students while addressing problems using integrated STEM knowledge. They will help students understand the value of collaboration; students will learn to share ideas when working to solve an authentic design challenge. Teachers will use assigned positions (such as team leader), guided instructions, questions, and class conversations to help students learn to work as a team, thus students share knowledge to strengthen their learning.

Group Results from the Round 2 Survey:

Mean: 3.80 Median: 4.00 St. Dev.: 1.08 IQR: 2.00

You gave this strategy a rating of: XXX

Do you agree with this instructional strategy?

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
________	________	________	________	________

Thank you for your continued time and support of this study. We appreciate your contributions.
Please E-mail your completed survey to Amanda Roberts by Wednesday, July 3, 2013.

APPENDIX H

Round 4 Survey for Participants

Integrated STEM Instructional Design Strategies for the Preparation of Teachers

Greetings everyone! Thank you for your persistence throughout this study. We have arrived at the final round of the Delphi study on Integrated STEM Instructional Design Strategies for the Preparation of Teachers.

As we were able to achieve group consensus for both the definition of integrated STEM education and the purpose statement for integrated STEM education, we will not need to address those topics in this survey. We were also able to reach consensus on each of the instructional strategies you developed with the exception of Instructional Strategy 4, Explain the Connections of STEM Subjects.

The purpose of this Round 4 survey will be to allow you the opportunity to state whether you believe each of these instructional strategies is in fact suitable for the preparation of pre-service teachers of integrated STEM content. In the Round 2 and Round 3 surveys, you were "forced" to rate your degree of satisfaction with the strategies provided. Now, you have the opportunity to rank each strategy according to whether it is preferred for teaching integrated STEM content. To help you quantify your degree of preference for each strategy, reflect on each one of the instructional strategies and ask yourself if it could be written as a course objective. The course objective should include three components. It should specify first, what the student would know about the instructional strategy. Second, it should denote what the student would be able to do. Third, it should state the degree of competency required to demonstrate an adequate understanding of the objective. For example, suppose one of the instructional strategies stated a pre-service teacher of integrated STEM content should be able to "incorporate a variety of informational technologies into their lessons". To determine if this strategy is indeed suitable for teaching integrated STEM content, you should ask yourself, can this instructional strategy be stated as a learning objective in a pre-service teacher course? Can I measure my student's ability to perform this objective? If you are able to measure their ability to practice an instructional strategy, then that strategy will have preference to any strategy that you believe cannot be measured.

On the Round 4 survey, you will see the instructional strategies you developed with their descriptions. You will also see the statistics obtained from the Round 3 survey (including your personal responses). On this survey you will notice "yes" and "no" columns have been added. If you believe the instructional strategy described is suitable for teaching integrated STEM content, please put an "X" in the "yes" column. If you do not believe the instructional strategy is not suitable for teaching integrated STEM content, please put an "X" in the "no" column. When you have finished this survey, you have completed this Delphi study! Please submit your survey to Amanda Roberts by Tuesday, July 23, 2013.

Again, thank you for your thoughts and contributions. Your opinions have made a significant contribution to this study. Might I also add on a personal level, I have learned from the insightful comments you have added in your responses. I wanted to thank you on a personal note for your investment in my improvement as well.

Sincerely,

Amanda Roberts
Ph.D. Candidate
Old Dominion University

Integrated STEM Instructional Strategy Survey

Definition of Integrated STEM Education							
An approach to education in which instruction is accomplished using a combination of both the content knowledge from multiple STEM (science, technology, engineering, and mathematics) subjects and the design process. It can be used to enhance student learning of complex concepts through the incorporation of authentic learning experiences. This type of learning emphasizes applying team work/team building skills and uses research-based instructional strategies that include design challenges, problem solving activities, experiential learning events, knowledge integration, and collaborative learning.							
	M	***Your Response***	***Md***	***Std. Dev.***	***IQR***	***CV***	
	4.13		4.00	0.72	0.75	0.17	

Purpose Statement of Integrated STEM Education							
The purpose of integrated STEM education is to develop learners who are literate in the connection of STEM knowledge(s). They can creatively and successfully identify and integrate concepts/processes across the STEM subjects to solve problems. They are able to confidently apply their solutions to authentic problems and adapt their knowledge of STEM in future education, employment, and life activities.							
	M	***Your Response***	***Md***	***Std. Dev.***	***IQR***	***CV***	
	4.00		4.00	0.63	0.00	0.16	

N	Strategy	Description							
1	**Plan an integrated STEM lesson**	Pre-service teachers will plan for integrated STEM lessons that will enable students to better understand the knowledge of these school subjects. Planning will use the content standards of these school subjects and incorporate activities that will make the learning meaningful to students. Some educators prefer the use of standardized instructional approaches to lesson planning, such as the 5-E Learning Cycle (engage, explore, explain, extend, and evaluate) or the Launch, Explore, Summarize Cycle to ensure that planning is systematic. These approaches can enable teachers to create lessons that integrate STEM knowledge and abilities.							
		M	Your Response	Md	Std. Dev.	IQR	CV	**Yes**	**No**
		3.69		4.00	0.95	1.00	0.03		

N	Strategy	Description							
2	**Select design challenges which integrate STEM content**	Pre-service teachers should review and select authentic design challenges using available resources. The design challenges should appropriately apply students' prior knowledge of science, technology, engineering, and mathematics relevant to their grade and skill levels. The design challenges should improve students' understanding of the STEM concepts found in real life encounters.							
		M	Your Response	Md	Std. Dev.	IQR	CV	**Yes**	**No**
		4.44		4.00	0.51	1.00	0.11		

N	Strategy	Description							
3	**Create solutions to problems using the engineering design process**	Pre-service teachers will instruct students to use problem-solving strategies, such as the engineering design process, when seeking to solve authentic design challenges. Students will be able to apply the engineering design process to generate possible solutions to real-world problems through a creative, iterative, cyclical process that uses prior knowledge of the STEM subjects as the basis for their decisions.							
		M	Your Response	Md	Std. Dev.	IQR	CV	**Yes**	**No**
		4.31		4.50	1.01	1.00	0.23		

N	Strategy	Description							
4	**Develop a project-based lesson**	Pre-service teachers will conduct a project-based lesson, one that uses STEM knowledge to design solutions to real world problems. Their students will investigate a driving research question; design a data collection and data analysis plan; collect, analyze, and represent the data; and communicate their results to their peers.							
		M	Your Response	Md	Std. Dev.	IQR	CV	**Yes**	**No**
		4.31		4.50	1.01	1.00	0.23		

N	Strategy	Description							
5	**Develop an argument supported by STEM knowledge integration**	Pre-service teachers will help students learn to justify their research findings based upon data collected while proposing ideas to real world problems. They will help their students to create, defend in a civil manner, and analyze the strength of their arguments and those of their classmates. Therefore, knowledge of STEM concepts and principles will be used to support their conclusions.							
		M	Your Response	Md	Std. Dev.	IQR	CV	**Yes**	**No**
		4.25		4.00	0.58	1.00	0.14		

N	Strategy	Description							
6	**Support an experiential learning environment**	Pre-service teachers will begin to value the potential benefits of experiential learning that applies STEM concepts and principles. Experiential learning can include the use of simulations, role playing, model building, projects, and experiments. The environment is designed to help students apply their knowledge and build greater understanding of integrated STEM concepts. As students engage in these learning environments, their knowledge will become more deeply ingrained.							
		M	Your Response	Md	Std. Dev.	IQR	CV	**Yes**	**No**
		4.06		4.00	0.85	1.00	0.21		

N	Strategy	Description							
7	**Choose multiple examples to demonstrate STEM concepts and connections**	To accommodate a variety of learning styles, the pre-service teacher will incorporate several instructional techniques, such as multiple representations, connections and applications, science, technology, and mathematical tools, and problem-solving strategies to insure students' understanding of the nature and structure of science, technology, engineering, and mathematics.							
		M	Your Response	Md	Std. Dev.	IQR	CV	**Yes**	**No**
		4.56		5.00	0.81	1.00	0.18		

N	Strategy	Description							
8	**Assess student understanding of STEM relationships**	The pre-service teacher will use a variety of instructional tools to engage students in formative and summative evaluations. These will encourage in-depth thought processes. Pre-service teachers will learn to create rubrics that help them to critically measure student understanding. Teachers will evaluate and assess students' comprehension of integrated STEM concepts through student created artifacts.							
		M	Your Response	Md	Std. Dev.	IQR	CV	**Yes**	**No**
		4.31		4.50	0.79	1.00	0.18		

N	Strategy	Description							
9	**Arrange collaborations to solve problems applying STEM concepts**	The pre-service teacher will promote team work/team building skills with their students while addressing problems using integrated STEM knowledge. They will help students understand the value of collaboration; students will learn to share ideas when working to solve an authentic design challenge. Teachers will use assigned positions (such as team leader), guided instructions, questions, and class conversations to help students learn to work as a team, thus students share knowledge to strengthen their learning.							
		M	Your Response	Md	Std. Dev.	IQR	CV	**Yes**	**No**
		3.88		4.00	1.02	1.50	0.26		

Thank you for your continued time and support of this study. I appreciate your contributions.
Please E-mail your completed survey to Amanda Roberts by Tuesday, July 23, 2013.

VITA

Amanda Roberts

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Academic Degrees

M.S. Old Dominion University	2010	Occupational and Technical Studies
B.S. Liberty University	1997	Social Sciences, Teacher Education

Professional Experience

2013-Present	Liberty Christian Academy, Teacher Information Technology
2012-2013	Staunton River Middle School, Teacher Technology Education
2005-2007	Linkhorne Middle School, Teacher Civics and Economics
2000-2003	Staunton River High School, Teacher World History I and II, Government

Publications

Roberts, A. (2013). Oh, the things you can do with bamboo! *Technology and Engineering Teacher 73*(2), 24-29.

Roberts, A. (2013). STEM is here, now what? *Technology and Engineering Teacher 73*(1), 22-27. Peer Reviewed.

Roberts, A. & Cantu, D. (2012). Applying STEM instructional strategies to design and technology curriculum. In T. Ginner, J. Hallström, & M. Hultén (Eds.), *Technology Education in the 21st Century* (pp. 111-118). Stockholm, Sweden: LiU Electronic Press. Peer Reviewed.

Roberts, A. (2012). A justification for STEM education. *Technology and Engineering Teacher-e.* Retrieved from http://www.iteea.org/mbrsonly/Library/TTT/TTTe/TTTe.htm Peer Reviewed.

Roberts, A. (2012). Technology: New ways for clean water. *Technology and Engineering Teacher, 71*(4), 4-9.

Roberts, A. (2011). Technology and engineering: Sanitary and storm water treatment. *Technology and Engineering Teacher, 70*(7), 4-12.

Roberts, A. (2011). Nanotechnology: The incredible invisible world. *Technology and Engineering Teacher, 70*(6), 10-17.

Presentations

Cantu, D., Roberts, A., & Strimel, G. (2013, March). *Best practices for STEM integration.* Paper session presented at the meeting of the International Technology and Engineering Educators Association (ITEEA), Columbus, OH.

Cantu, D., Roberts, A., & Strimel, G. (2013, March). *Addressing common challenges to STEM integration.* Paper session presented at the meeting of the International Technology and Engineering Educators Association, Columbus, OH.

Ritz, J., & Roberts, A. (2013, March). *An International perspective: Issues confronting technology education.* Paper presented at the meeting of the Council on Technology & Engineering Teacher Education (CTETE), Columbus, OH.

Roberts, A. & Cantu, D. (2012, June). *Applying STEM instructional strategies to design and technology curriculum.* Paper presented at the meeting of Pupils Attitudes Toward Technology (PATT) Conference, Stockholm, Sweden.

Cantu, D. & Roberts, A. (2012, March). *Following STEPS for successful technology & engineering programs.* Paper presented at the meeting of the International Technology and Engineering Educators Association (ITEEA), Long Beach, CA.

Honors and Awards

Darden College of Education Outstanding Technology Education Graduate Student Award, 2013

Maley/FTEE Technology and Engineering Teacher Scholarship, 2013

Donald Maley Spirit of Excellence Outstanding Graduate Student Award, 2013

Iota Lambda Sigma Honor Society, 2013