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Defining Characteristics of an Integrated STEM Curriculum in K-12 Education

Vinson Robert Carter
University of Arkansas, Fayetteville

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Defining Characteristics of an Integrated STEM Curriculum in K-12 Education

Defining Characteristics of an Integrated STEM Curriculum in K-12 Education

A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy in Curriculum and Instruction

By

Vinson Robert Carter
University of Arkansas
Bachelor of Science in Vocational Education, 2002
University of Arkansas
Master of Arts in Teaching in Vocational Education, 2003

August 2013
University of Arkansas

This dissertation is approved for recommendation to the Graduate Council.

Dr. Michael K. Daugherty
Dissertation Chair

Dr. Betsy Orr
Committee Member

Dr. Cathy Wissehr
Committee Member

Abstract

The purpose of the study was to obtain consensus concerning the defining characteristics of integrated STEM (Science, Technology, Engineering, and Mathematics) curriculum. This study utilized a three round modified Delphi study to solicit recommendations from experts of STEM education in order to: 1) create a set of categorical and defining curricular components needed to develop and implement appropriate integrated STEM curriculum; 2) identify the characteristics that set integrated STEM education curriculum apart from single-discipline curricula; 3) discuss the components necessary to gauge whether an initiative, project, or curriculum should be referred to as integrated STEM education; and 4) examine whether significant differences exist from the defining characteristics based on the disciplinary grounding of panelists in science, mathematics, or technology and engineering. Results indicate that it is essential that STEM education be problem- or project-based, although other considerations are essential in providing students with the most authentic learning experiences. The panel agreed that the majority of STEM curricula are not integrated, but discipline-specific curricula and that many STEM programs have a narrow educational focus that includes a collection of activities and specific products that may not be developed using sound pedagogical practices. The results from the study add to the literature on the definitive attributes of STEM education.

Table of Contents

Chapter 1: Introduction	1
Background	1
Context of the Problem	2
Statement of the Purpose	3
Statement of Research Questions	3
Assumptions of the Study	3
Significance of the Study	4
Conceptual Framework	4
Chapter 2: Review of the Literature	5
Introduction	5
Early Integration Research and Curriculum Development in STEM Education	6
Setting the Stage for Integrated STEM Curriculum	12
The Case for Integrated STEM Curriculum	16
Functional/Operating Models of Integrated STEM	17
Chapter 3: Methodology	29
Introduction	29
The Delphi Research Method	29
Delphi Panel Selection	30
Research Design	30

Data Collection.....	32
Data Analysis	33
Summary	34
Chapter 4: Results	35
Delphi Study Participants.....	35
Data Collection Results	37
Round One.....	37
Round One Analyses	38
Round Two	43
Round Two Analyses	44
Round Three	51
Round Three Analyses	52
Summary	77
Chapter 5: Summary, Findings, Limitations, and Recommendations	78
Summary of the Study.....	78
Findings.....	79
Conclusions for Practice.....	98
Study Limitations	100
Recommendations for Future Research	101
Summary	102

References	104
Appendix A: IRB Approval	110
Appendix B: Prospective Letter to Participants	111
Appendix C: Round One Letter to Participants	113
Appendix D: Round One Instrument	115
Appendix E: Round Two Letter to Participants	120
Appendix F: Round Two Instrument	121
Appendix G: Round Three Letter to Participants	136
Appendix H: Round Three Instrument	137

Chapter 1: Introduction

Background

STEM (science, technology, engineering, and mathematics) education is vital to the future of our nation. The citizens who make up our STEM workforce are essential in providing the innovations and changes that will continue to transpire into the 21st century (“Innovation America”, 2007). According to the National Governors Association:

In the new global economy, states need a workforce with the knowledge and skills to compete. A new workforce of problem solvers, innovators, and inventors who are self-reliant and able to think logically is one of the critical foundations that drive innovative capacity in a state. A key to developing these skills is strengthening science, technology, engineering, and math (STEM) competencies in every K–12 student (2007, p. 1).

However, the acronym STEM has various connotations and denotations among teachers, researchers, politicians, and government agencies. Many educators use the STEM acronym when describing initiatives, projects, and curricula without clearly addressing all four disciplines of science, technology, engineering, and mathematics in an integrated effort. According to Sanders (2009), educators should refer to ‘STEM’ as ‘STEM education’ to clearly differentiate from the individualized science, technology, engineering, and mathematics disciplines in the workforce. There is also a common misunderstanding in regard to STEM education that the definition of the ‘T’ in STEM implies the use of computing technology or computers (Daugherty, 2010; Sanders, 2009). Salinger and Zuga (2010) agreed that “there is still confusion about the meaning of STEM education. Some people believe erroneously that technology is really about instructional technologies, but this would put three subjects—science, mathematics and engineering—in parallel with a tool—instructional technology” (p. 8). Technology

education is a discipline devoted to the study of the modification of the natural world by humans and the process of design (Dugger & Naik, 2001). Most believe that the proper use of the ‘T’ in STEM should refer to the discipline of technology education (Daugherty, 2010; Sanders, 2009; Salinger and Zuga, 2010).

The acronym “STEM” has also been politicized and is often attached to initiatives simply to attract attention and perhaps funding. Numerous conflicting working definitions of integrated STEM may be damaging the effort put forth in educational programs and practices. Therefore, it is important that the STEM community resolve what the STEM acronym signifies (Bybee, 2010). Many researchers have proposed that STEM education be implemented using an integrated approach to better serve students (Atkinson & Mayo, 2010; Mahoney, 2010; Sanders, 2009; Satchwell & Loepp, 2002). However, the label “STEM” is often attached to curricula and programs that primarily focus on a single discipline. In practice, curriculum projects that are clearly not integrated are often referred to as STEM, even though a great number of research studies have suggested that an interdisciplinary or integrated curriculum provides students with a more meaningful classroom experience that enhances understanding (Bybee et al., 1991; Furner & Kumar, 2007; LaPorte & Sanders, 1993; Loepp, 1999; Sanders, 1999; Satchwell & Loepp, 2002).

Context of the Problem

Understanding the need to bring integrated STEM education into our nation’s schools has become a significant concern for educators and policymakers. However, defining the characteristics of what comprises an integrated STEM curriculum can be a challenge for educators due to the fact that the interpretation of STEM education and the goals and outcomes are defined by different organizations in different ways. There are many programs that use the

term STEM to define their intended purposes or goals; yet, a definitive integrated model for K-12 STEM education curriculum as well as a clear definition of what makes a curriculum “STEM” could not be located by this researcher.

There is a need to gain consensus concerning the defining characteristics of integrated STEM curriculum. This study solicited the expertise of science, technology and engineering, and mathematics educators to determine the defining characteristics necessary for developing integrated STEM curriculum.

Statement of the Purpose

The purpose of this study was to obtain consensus concerning the defining characteristics of integrated STEM curriculum through the implementation of a modified Delphi study.

Statement of Research Questions

1. What are the defining characteristics that set integrated STEM education curriculum apart from single-discipline curricula according to a panel of experts?
2. How might a set of categorical and defining curricular components be established for an integrated STEM education curriculum?
3. What defining components or characteristics can be used to gauge whether an initiative, project, or curriculum should be referred to as integrated STEM education?
4. Do significant differences exist from the defining characteristics based on disciplinary grounding in science, mathematics, or technology and engineering?

Assumptions of the Study

This study accepts the following assumptions. The expert panel will reflect that technology and engineering education will be treated as one discipline because technology and engineering classes are primarily taught in the technology education classroom in K-12

education. A nomination process made up of qualified, renowned, and respected individuals was used in the selection process of participants in the Delphi study (Ludwig, 1997); however, this study does not take into account the philosophical differences that may exist within the disciplines of science, technology and engineering, and mathematics education. In addition, the Delphi panelists may not be entirely representative of all of those involved in K-12 integrated STEM education.

Significance of the Study

This study laid the groundwork to create a framework in which integrated STEM education may be developed. It was essential that the defining characteristics of integrated STEM curriculum be clear to ensure that there was a clear and definitive basis through which students are introduced to concepts used in STEM fields.

Conceptual Framework

An essential yet missing component in integrated STEM education was a framework for developing curriculum materials. Without a prescriptive guide of defining characteristics for curricula, the sustainable progress of STEM education might be delayed, possibly impeding its appropriate implementation and advancement.

This research provided classroom teachers, teacher educators, and curriculum developers with the final component needed to address integrated STEM education literacy in K-12 education. The purpose was to establish a list of the characteristics needed to develop integrated STEM education curriculum materials. A consensus was established employing a panel of experts who participated in a three-round modified Delphi study. The panel's progression through the Delphi process determined these defining characteristics of integrated STEM education curriculum.

Chapter 2: Review of the Literature

Introduction

During the past decade, educators, researchers, and politicians alike have discussed STEM (Science, Technology, Engineering, and Mathematics) preparation and the role it plays in American education and the global economy. Calls to action, reports, and speeches and ultimately reform in STEM education have been made by disciplinary groups, politicians, associations, and national commissions. Among these various reports, including *Technically Speaking* (National Research Council (NCR), 2002), *Successful K-12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics* (2011), *Preparing the Next Generation of STEM Innovators: Identifying and Developing Our Nation's Human Capital* (National Science Board (NSB), 2010), *Invention and Impact: Building Excellence in Undergraduate Science, Technology, Engineering and Mathematics (STEM) Education* (American Association for the Advancement of Science (AAAS), 2004), and *The Overlooked STEM Imperatives: Technology and Engineering* (The International Technology Education Association (ITEA), 2010), each have suggested that the effectiveness of our nation as a global leader is reliant upon a solid educational curriculum that prepares students in STEM disciplines.

Despite the overwhelming consensus among the aforementioned, which all promoted STEM education at the forefront of K-12 educational programs, there was little consensus on the precise path to pursue. The confusion and dissonance reveal the underlying impression that the very definition of STEM lacked clarity and precision (Sanders, 2009). The STEM acronym, originally used by education-related programs and its development as a term by authors of reports and surveys as well as its use by politicians is never explicitly defined other than an

acronym for the independent disciplines it represents (Sanders, 2009). Brown, Brown, Reardon, and Merrill (2011) found in their survey of public school teachers and administrators that there continued to be a general “lack of understanding of STEM education in schools,” despite its overwhelming support and recognition (p. 8). Numerous organizations viewed STEM education in differing ways, leading to common misperceptions among K-12 educators. As a result, these educators may have become burdened by their role in preparing students for a future in STEM careers, which many consider essential to the overall success of the United States’ economic future (Tsupros, Kohler, & Hallinen, 2009). A major concern in STEM education was how to prepare future educators to integrate STEM education learning into the current curriculum at all stages of K-12 education (Stohlmann, Moore, & Roehrig, 2012).

STEM education advocates believed that students will be more prepared to enter the STEM workforce because of the enhanced mathematics and science skills gained through the application of authentic technology and engineering design (Brown et al., 2011). Student preparation in STEM education that involves problem solving through design and the ability to think critically across disciplinary boundaries is fundamental in supporting the ever-increasing mandate for a STEM workforce capable of adapting to and innovating in the 21st century (Brophy & Portsmouth, 2008; Duderstadt, 2008). Defining STEM education and the characteristics of an integrated STEM education curriculum was paramount in providing the necessary skills for our nation’s students to flourish, ultimately re-establishing the United States as the leader in STEM fields (Atkinson & Mayo, 2010).

Early Integration Research and Curriculum Development in STEM Education

The National Science Foundation (NSF) was established by U.S. Congress in 1950 "to promote the progress of science; to advance the national health, prosperity, and welfare; to

secure the national defense..." (NSF, 2012). As its original mission mandated, the NSF continues to provide support for research and education in the non-medical fields of science and engineering and has evolved throughout its history to meet the diverse needs and challenges faced by the nation, including STEM education. The STEM acronym can be traced back to Judith Ramaley, former director of the NSF's Education and Human-Resources Division from 2001-2004 (NSF, 2012). Previously the NSF used the acronym SMET to refer to science, mathematics, engineering, and technology. In addition to the coining of the term "STEM," the focus of the NSF "moved toward educational research and evaluation to know what works, with whom, and under what circumstances" (Salinger & Zuga, 2010, p. 5).

The roots of STEM education in the United States were often traced to the launch of Sputnik by the former Soviet Union in 1957. The Sputnik launch initiated many changes in educational reform and funding in the United States, including the 1958 legislation of the National Defense Education Act (NDEA) and the National Aeronautics and Space Act (NASA) (Fleming, 1960). The NDEA provided \$1 billion dollars to be spent on funding students interested in pursuing a college education to help improve the nation's competitiveness in STEM disciplines (Fleming, 1960; DOE, 2012).

The operational origins of STEM education can be traced to the 1983 National Commission on Excellence in Education report, *A Nation at Risk*. Among the research outlined in the oft-cited report, Mahoney (2010) offers a succinct interpretation of the reports' significance and outcome:

The influence of this report and its recommendations are echoed in the feverish development of national standards produced by academic organizations such as the National Council of Teachers of Mathematics (NCTM), the National Research Council

(NRC), AAAS, and ITEA. It is within this process that the history of STEM can be traced. NCTM (2000), AAAS (1989), NRC (1996) and ITEA (2000) documents all suggest the combination or integration of their respective subjects in an attempt to enhance student learning and STEM preparation (p. 24).

The emergence of standards-based curricula and integration models became the trend after the issuance of the *A Nation at Risk* report.

Early efforts to establish standards-based curricula through an integration model include the *Unified Science and Mathematics for Elementary Schools* (USMES), Biological Sciences Curriculum Study (BCSC), and Project 2061. Each of these efforts included inquiries of real-world challenges that emphasized a more active and applied approach to how students learn about science, mathematics, and technology (Salinger & Zuga, 2010).

Another influential stride in STEM education was the Integrated Mathematics, Science, and Technology (IMaST) Program. Established in 1992 by Illinois State University, IMaST was headed by Dr. Franzie Loepp and Dr. Robert Fisher (Satchwell & Loepp, 2002). The IMaST program was funded by the NSF and was primarily developed as an integrated curriculum model to “promote experientially based, hands-on learning for students and teaming among teachers from three or more disciplines” (IMaST; Center for Mathematics, Science and Technology, 2012). The IMaST curriculum model, which promotes all national standards in mathematics, science, and technology education for the middle school grade levels, was still being used in public schools 20 years after its development.

Furthermore, in the early 1990s, the AAAS presented the publication *Science for All Americans* to serve as a guide for what all students should know about STEM after high school by evaluating content knowledge and student understanding. It was apparent that to properly

assess the objectives addressed in *Science for All Americans*, a set of guidelines would need to be developed (Salinger & Zuga, 2010). To address this need, the AAAS developed the *Benchmarks for Science Literacy* (1993) and the National Research Council (NRC) developed the *National Science Education Standards (NSES)* (1995), and although they are separate documents, both were consistent with one another and include standards for technology.

Another plan to encompass standards-based curricula through an integration model was the Technology, Science, and Mathematics (TSM) Project, funded by the NSF in 1990. TSM activities were designed to be taught collaboratively by technology, science, and mathematics teachers (LaPorte & Sanders, 1993). LaPorte and Sanders developed these middle school activities to include the direct application of science and mathematics to classroom challenges that required students to design, construct, and evaluate solutions to technological problems.

Following the movement in standards-based integration, the Math/Science/Technology (M/S/T) initiative was developed in the early 1990s in New York. The M/S/T alignment of science, mathematics, and technology education standards at all grade-levels created an integrated framework that was collaborative and supportive of these typically individual disciplines. The M/S/T learning standards also included the use of the term ‘engineering design’ as a core problem solving method (Kelley, 2010). Kelley emphasized that a strong case can be made that the M/S/T efforts of the 1990s paved the way for the recent STEM education initiatives.

During the same period, the mathematics education profession correspondingly developed the NCTM *Curriculum and Evaluation Standards* (1989) and later the *Principles and Standards for School Mathematics* (2000), which serve as a guide for mathematical literacy. Mathematical literacy requires much more than computational aptitude to become a

mathematical thinker and problem-solver in a technological world (McComas & McComas, 2010). In spite of this, the mathematics standards were not as explicit in respect to integration as those of science and technology and engineering (Sanders, 2009). Nonetheless, it was suggested that the NCTM standards were designed to nurture the relationship between science, technology and engineering, and mathematics standards through application by solving real-world challenges addressed in the classroom (McComas & McComas, 2010; Sanders, 2009).

Concurrent with the development of the NCTM standards, the International Technology Education Association (ITEA) began discussions on developing the *Standards for Technological Literacy: Content for the study of technology* (2000/2002/2007). The *Standards for Technological Literacy* include a section on how technology education relates to other fields of study and provides a pathway for making “technological connections” with other disciplines (Loepp, 1999). The standards also provided K-12 benchmarks and a vision that “the study of technology is a way to apply and integrate knowledge from many other subject areas,” including mathematics, science, and engineering (pp. 5-6).

Despite the fact that engineering distinctively connects the individual disciplines of mathematics, science, and technology education engineering, notably, does not have a traditional place in K-12 education (Daugherty, 2010). Daugherty examined the corresponding history and relationship of technology and engineering and highlighted that “the recent public emphasis on K-12 engineering has served to strengthen the bond and provide incentives for the two fields to complement one another” (p. 21). Wicklein (2006) advocated that by moving toward an engineering design focus in technology education, teachers would be required to focus on mathematics and science, thus providing “an ideal platform for integrating STEM” (p. 26). In 2010, ITEA’s membership voted to change its name to the International Technology and

Engineering Educators Association (ITEEA), further cementing the relationship between technology education and engineering at the K-12 level.

In 2010, the National Governors Association Center for Best Practices introduced the *Common Core State Standards for Mathematics*. The NRC publication *Successful K-12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics* (2011) theorized that the shift toward *Common Core State Standards for Mathematics* will allow curricula to address topics such as STEM more comprehensively; therefore, enabling students to develop proficiency and greater achievement in mathematics.

Another example of standards-based curriculum integration is Project Lead the Way (PLTW). PLTW is designed as a hands-on, project-based engineering and biomedical sciences curriculum for grades 6-12. PLTW introduced its “Pathway to Engineering” program in 12 New York high schools in 1997. They proceeded to partner with the *High Schools That Work* initiative of the Southern Regional Education Board (SREB), bringing PLTW programs to an additional 30 states. PLTW has been recognized by the U.S. Department of Education as an exemplary STEM program (PLTW, 2012).

In the same way, ITEEA developed its Engineering by Design (EbD) program to promote a standards-based STEM curriculum for grades K-12. The EbD model is based on the *Standards for Technological Literacy*, the *Principles and Standards for School Mathematics*, and the *Project 2061: Benchmarks for Science Literacy*. The EbD program utilizes constructivist strategies to build knowledge and skill and was intended to be used by schools that are developing STEM models of instruction. The EbD curriculum was currently in use by schools in 19 states by the end of 2012 (ITEEA).

Setting the Stage for Integrated STEM Curriculum

The development of standards-based curricula and integration models was indispensable for developing quality STEM education materials in K-12 education (NRC, 2011). A surprising amount of research has concluded that an interdisciplinary or integrated curriculum provided students with a relevant, comprehensive, and more stimulating experience in the classroom (Bybee et al., 1991; Furner & Kumar, 2007; LaPorte & Sanders, 1993; Loepp, 1999; Sanders, 1999; Satchwell & Loepp, 2002). Moreover, current research in curriculum development indicated, “much of the newest and most valuable knowledge involves more than one subject” (Stohlmann et al., 2012, p. 32). Stohlman and his colleagues endorsed an integrated approach to STEM education that could inspire students’ future success and interest in STEM disciplines. The ability to attract students into the STEM workforce is a chief component in advancing the sustainability and success of the U.S. innovation economy (Atkinson & Mayo, 2010). Stohlmann et al. also reported that “effective STEM education is vital for the future success of students.... the preparation and support of teachers of integrated STEM education is essential” (p. 32). Thus, to properly implement STEM education into public schools, learning must be connected and appropriately situated for students, which in turn, will prepare them for future accomplishments in STEM fields.

Resnick and Klopfer (1989) investigated the perception that students who develop *habits of mind* throughout the learning process would benefit both in the classroom and the real world. This publication argued that traditional curricula teach content and process separately. Their work *Toward the Thinking Curriculum*, however, mirrored how content was utilized through processes encountered in real-world situations.

Accordingly, there began a shift from the established theory of specific and contextual skill preparation toward a thinking curriculum that was based in integrative learning using higher-order thinking to gain technical and academic skills (Herschbach,1998; Loepp, 1999). Herschbach (1998) stated that, “the integration of academic and technical skills can be achieved in ways that engage students in the construction, use, and reformulation of knowledge across fields of inquiry” (p. 1). Loepp (1999) supported the belief that the trend of integrated curricula is supported by the premise “that the current system of discipline-based education is not as effective as it must be” (p. 22). Loepp maintained “the assumption is that most real-world problems are multidisciplinary in nature and that the current curriculum is unable to engage students in real world situations” (p. 22). The challenges that students face in the future will necessitate solutions encompassing the integrative use of multiple STEM concepts (Wang, Moore, Roehri, & Park, 2011).

Stinson, Harkness, Meyer, and Stallworth (2009) found in their examination of mathematics and science integration that due to the increasing demands to assimilate disciplines based on an effort to improve educators’ efficiency and effectiveness, there was a common need to define what it means to integrate disciplines. Although their study concentrated on the effort to integrate mathematics and science, the authors contended that there are several barriers that needed to be addressed in order to characterize a model for content integration. These barriers included a lack of content knowledge in all disciplines (a prerequisite to enabling teachers to integrate content) and a definition of the constructs and parameters for what constitutes integration.

Wang et al. (2011) identified the terms frequently used in reference to integration research as “multidisciplinary” and “interdisciplinary”. Kelley (2010) explained that these

monikers were often muddled and misused by many in contextual application in general education and particularly in STEM education. Mallon and Burton (2005) defined “multidisciplinary” as “individuals from different disciplines working independently on different aspects of a project” (p. 2). Mansilla (2005) defined “interdisciplinary” as understanding that has “the capacity to integrate knowledge and modes of thinking drawn from two or more disciplines to produce a cognitive advancement— for example, explaining a phenomenon, solving a problem, creating a product, or raising a new question—in ways that would have been unlikely through single disciplinary means” (p. 16).

Drake and Burns (2004) additionally identified another curricula approach to integration as “transdisciplinary.” They designated “transdisciplinary” integration as learning that surpassed the narrow scope of disciplines and involved organization around student questions, where concepts and skills are developed through a real-world setting. They defined “interdisciplinary” integration as the generic, all-encompassing concept that included activities that integrated two or more disciplines. In addition, they described “multidisciplinary” integration as placing two or more disciplines side by side or close together (not combined) around a general theme. These methodologies, all used in integrated STEM education, differed from a disciplinary STEM approach historically delineated by departmentalization (silos) of disciplines (Sanders, 2009).

Many scholars and practitioners have proposed that the answer to these discrepancies in integrated curriculum theories was project- or problem-based learning, commonly referred to as PBL. A study by Marx et al. (2004) confirmed that project-based learning has been successful at increasing students’ tests scores compared to traditional practices. Stavery (2006) noted that the fundamental dissimilarity in project-based versus problem-based learning was that project-based learning focused on a final product such as an artifact, model, presentation, or performance as the

learning outcome. In contrast, problem-based learning focused on the processes used to address a given problem. Though differing in application, these pedagogical approaches both used student-centered and teacher-facilitated instruction in which students may work individually or in teams to learn self-directed problem-solving skills along with the real-world application of subject matter (Barron et al., 1998). Project-based learning has been successfully employed in science and technology and engineering classrooms to improve instruction and develop scientific inquiry skills and the use of the engineering design process (Krajcik & Blumenfeld, 2006; Massa et al., 2011).

Established in 2005, the Virginia Tech integrated STEM education program used a different pedagogical tactic similar to project/problem-based instruction referred to as Purposeful Design and Inquiry (PD&I). Sanders (2009) clarified this type of instruction saying, “PD&I pedagogy purposefully combined technological design with scientific inquiry, engaging students or teams of students in scientific inquiry situated in the context of technological problem-solving—a robust learning environment” (p. 20). He further described that through context of a design challenge (a common pedagogical approach in technology and engineering education), problem-based learning “purposefully situates scientific inquiry and the application of mathematics in the context of technological designing/problem solving,” emulating “the design and scientific inquiry routinely employed concurrently in the engineering of solutions to real-world problems” (p. 21).

Katehi, Pearson, and Feder’s (2009) study on engineering in K-12 education found that many of the highly-motivating, integrated design experiments used in the technology and engineering classroom are often lacking in the teaching of mathematics and science. Research also indicated that technicians and engineers in the STEM workforce do not benefit by only

studying science and mathematics (Salinger & Zuga, 2010). These findings supported Cunningham, Lachapelle, and Lindgren-Streicher's (2005) assertion that in order for science and mathematics to be realistic to students, they must study technology and engineering content. Subsequently, the authors reported that in order to prepare students for technical careers; students must study this technical subject matter in schools.

The Case for Integrated STEM Curriculum

In 2010, Bybee remarked that in the near future, the STEM community must resolve what the STEM acronym signifies as it is used in educational guidelines, programs, and practices. In his report on STEM education, he recognized the need to define the purpose of STEM education and stressed that a discerning comprehension of STEM literacy must be established. Bybee defined STEM literacy as “the conceptual understandings and procedural skills and abilities for individuals to address STEM-related personal, social, and global issues” (p. 31). He also stressed that STEM literacy involves the integration of STEM disciplines as “interrelated” and “complementary components.”

In Ray's (2007) address to the National Science Board, he highlighted that “in the next decade, the Nation is going to need 2.2 million new teachers in K-12 schools and community education settings...the greatest need now and into the future is for teachers in the STEM areas” (2007, p. 1). In the report *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* (2007), the authors recommended creating K-12 curriculum materials based on world-class standards and suggested that teacher education programs in colleges of education collaborate with individual STEM discipline programs to develop STEM education and certification programs.

Roberts (2012) proposed that STEM education be defined as an integrative methodology for teaching and learning, and that STEM was best applied when the boundaries between individual disciplines are broken down so that they can be taught as one subject. In this respect, Stohlmann et al. (2012) suggested that STEM education “is an effort to combine science, technology, engineering, and mathematics into one class that is based on connections between the subjects and real-world problems” (p. 30). Although they acknowledged that there are factors that may impede these efforts such as the definitions of STEM, integrated STEM education could involve multiple classes and teachers, and the idea that STEM does not have to always involve all four disciplines, they suggested that as “engineering is becoming more prevalent in K-12 schools.... it can provide great problem solving opportunities for students to learn about STEM while working through the engineering design process” (Stohlmann et al., 2012, p. 30).

Functional/Operating Models of Integrated STEM

There have been numerous efforts to identify functional educational models that are being used to deliver STEM education in the K-12 classroom (Bayer Corporation, 2010; Berlin & White, 1995; Brophy, Klein, Portsmouth, & Rogers, 2008; National Academy of Engineering and National Research Council, 2009; Stohlmann et al., 2012). The following is a compilation of some of those programs discussed in the literature. Table 1 outlined the grade level, alignment to national standards, and teacher preparation and certification for each of the models detailed below. Table 2 described the discrepancies between the stated goals and outcomes for each of these STEM education models. This is not a comprehensive list. The following information will serve as guide to understanding what is currently taking place and what is missing in K-12 STEM education.

1. Engineering is Elementary

Originally developed by the Boston Museum of Science, Engineering is Elementary (EiE) was a research-based grades 1-5 STEM curriculum designed to focus on students' knowledge of science and engineering to design, create, and improve solutions. EiE was primarily funded by the NSF and matching funds from industry. The EiE curriculum was based on 20 units that are designed to meet the ITEEA *Standards for Technological Literacy* and the Massachusetts' science standards (EiE, 2012).

Purpose

EiE was developed to promote engineering and technological literacy at the elementary level. EiE attempted to create a “research-based, standards-driven, and classroom-tested curriculum that integrates engineering and technology concepts and skills with elementary science topics” (2012). EiE lessons promoted STEM in grades 1-5, through the use of literature based design challenges. EiE reported that over 1.7 million students and 22,000 teachers are currently using their materials in 2012.

Project Goals and Outcomes

According to EiE (2012) the goals and outcomes for the curriculum include:

1. Increase children's technological literacy.
2. Improve elementary educators' ability to teach engineering and technology.
3. Increase the number of schools in the U.S. that include engineering at the elementary level.
4. Conduct research and assessment to further the first three goals and contribute knowledge about engineering teaching and learning at the elementary level.

Teacher Preparation and Certification

The EiE curriculum was not stand-alone curriculum. It was meant to be integrated into the study of science in the elementary classroom. Although anyone can purchase the individual EiE units for use in the classroom, the Boston Museum of Science offered a variety of

professional development opportunities for teachers including workshops and teacher educator institutes.

2. Integrated Mathematics, Science, and Technology (IMaST)

The Center for Mathematics, Science and Technology at Illinois State University's IMaST program was an integrated mathematics, science, and technology curriculum for grades 6-8. IMaST was developed by funding from the NSF, Eisenhower funds from the Illinois State Board of Education, and Illinois State University. The IMaST curriculum consists of theme-based modules based on national standards and state frameworks in mathematics, science, and technology.

Purpose

The IMaST program was developed to provide an integrated curriculum that would promote experientially based, hands-on learning for students working as a team. IMaST strived to promote the use of skill development and application and to allow students to be active learners that can adapt to real world challenges (IMaST; Center for Mathematics, Science and Technology, 2012).

Project Goals and Outcomes

According to IMaST (2012) the goals and outcomes for the curriculum include:

1. Create a standards-based (NCTM, NSES, AAAS, STL) integrated curriculum
2. Enhance student understanding of concepts in mathematics, science, and technology.
3. Use most current pedagogy- Constructivism
4. Learn and apply principles in various contexts
5. Standardize problem solving method (DAPIC - Define, Assess, Plan, Implement, and Communicate)
6. Promote cooperative teaching and learning
7. Include Engineering in definition of "technology"

Teacher Preparation and Certification

The IMaST curriculum is meant to be taught in a teamed approach from three or more disciplines. Although anyone can purchase the individual IMaST modules for use in the classroom, the Center for Mathematics, Science and Technology offers professional development opportunities on integrating mathematics, science, and technology into the classroom.

3. Engineering by Design (EbD)

EbD is a national model program developed by the ITEA-CATTS (International Technology Education Association-Center to Advance the Teaching of Technology and Science) Consortium in consultation with the ITEA Technology Education Advisory Council, ITEA institutional members, and the mathematics, science, and engineering communities (ITEEA, 2012).

Purpose

Engineering by Design was based on constructivist teaching methods to promote problem-based learning. Students are prepared to engage in additional technological study in the high school years and beyond. Students were prepared with content knowledge and skills to help them become informed, contributing citizens in a technological world. The program also promoted the concept that students should use the “technological resources in their own community” (ITEEA, 2012).

Project Goals and Outcomes

According to ITEEA (2012) the goals and outcomes for the curriculum include:

1. Provide a standards-based K-12 program that ensures that all students are technologically literate.
2. Provide opportunities for all students without regard to gender or ethnic origin.
3. Provide clear standards and expectations for increasing student achievement in mathematics, science, and technology.

4. Provide leadership and support that will produce continuous improvement and innovation in the program.
5. Restore America's status as the leader in innovation.
6. Provide a program that constructs learning from a very early age and culminates in a capstone experience that leads students to become the next generation of technologists, innovators, designers, and engineers.

Teacher Preparation and Certification

In grades K–5, the EbD program provided curriculum that could be integrated into additional school subjects. In grades 6–12, the program offers nine individual courses. States were offered the opportunity to join the EbD consortium, allowing all school districts throughout that state to gain access to EbD curriculum. Additionally, individual courses could be purchased from ITEEA for use in classrooms. EbD also provided professional development training for teachers.

4. The Infinity Project

Developed by the Caruth Institute for Engineering Education at Southern Methodist University, the Infinity Project was an engineering curriculum for grades 6-12. The project was funded by the DOE, NSF, Texas Instruments, and numerous other industry partners. It was designed to focus on the preparation of educators and students in STEM fields. The Infinity Project curriculum was in use by 37 states in 2012.

Purpose

The Infinity Project was a mathematics and science-based curriculum designed to provide instructional materials, engineering design projects, and professional development for educators at an affordable price (Infinity Project, 2012).

Project Goals and Outcomes

According to Infinity Project (2012) the goals and outcomes for the curriculum include:

1. A textbook with example problems that contains the core content of the course

2. A set of laboratory exercises that are integrated with the textbook content and that are performed by the students in a computer laboratory setting
3. A low-cost software/hardware laboratory kit that each student uses to perform their experiments and gain immediate feedback
4. Daily lesson plans, a teacher's manual, and in-class lecture slides to support the day-to-day teaching activities of each instructor
5. Summer training institutes for high school mathematics, science, and career and technology teachers to learn how to teach the curriculum
6. A Web-based portal that allows teachers to interact with other instructors and the curriculum designers during the school year and address any day-to-day and week-to-week concerns about their particular course.

Teacher Preparation and Certification

Schools had to apply to become an Infinity Project school and offer the middle and high school engineering curriculum. Teachers were required to be certified in mathematics or science, accepted into the program, and attend a weeklong training during the summer (Infinity Project, 2012).

5. Project Lead the Way (PLTW)

PLTW was initially developed by New York's Shenendehowa Central School District and further expanded by SREB's *High Schools That Work* as a hands-on, project-based engineering and biomedical sciences curriculum for middle and high school students. The initiative was funded by Charitable Leadership Foundation, the Kern Family Foundation, NASA, affiliate universities, and industry partners. PLTW course were offered in over 4,200 schools in 2012.

Purpose

PLTW was created to address the country's need for more leaders in STEM by establishing on-going partnership among school districts, colleges and universities, and industry that would establish and support a pre-engineering education career cluster program in America's

high schools, exciting students about engineering careers and strengthening traditional academic programs with hands-on learning experiences (PLTW, 2012).

Project Goals and Outcomes

According to PLTW (2012) the goals and outcomes for the curriculum include:

1. Increase the number of young people who pursue engineering and engineering technology programs requiring a four or two-year college degree.
2. Provide clear standards and expectations for student success in the program.
3. Provide leadership and support that will produce continuous improvement and innovation in the program.
4. Provide equitable and inclusive opportunities for all academically qualified students without regard to gender or ethnic origin.
5. Reduce the future college attrition rates within four and two-year engineering and engineering technology degree programs.
6. Contribute to the continuance of America's national prosperity.

Teacher Preparation and Certification

Schools had to apply to implement the PLTW program. Teachers were required to meet state licensure and certification requirements and additionally attend a two-week teacher training program for each course that they would teach, as well as attending ongoing professional development (PLTW, 2012).

6. A World in Motion (AWIM)

AWIM was developed by the Society of Automotive Engineers (SAE) as an interdisciplinary STEM curriculum to promote real world application of science in grades 4-10. The program was funded by the NSF and the SAE foundation and was in use in all 50 states and 10 Canadian provinces and territories in 2008.

Purpose

AWIM strived to promote science and mathematics literacy of students in grades K-12 by providing curriculum materials that used engineering design activities in multidisciplinary, cooperative learning environment. The program was interdisciplinary and involved the academic

disciplines of science, mathematics, technology, social studies, and language arts in partnership with engineers and other technical professionals in the local community (AWIM, 2009).

Project Goals and Outcomes

According to AWIM (2009) the goals and outcomes for the curriculum include:

1. Promote science literacy
2. Increase interest in science, math, and technology education
3. Foster curiosity and creativity
4. Encourage a spirit of healthy questioning through the discovery process
5. Provide opportunities for physical science experiences
6. Emphasize cooperative learning (teamwork)
7. Support the roles of girls and minorities in science education and, eventually, in engineering
8. Counteract science and math learning anxiety
9. Provide opportunities to develop and practice measuring skills
10. Provide opportunities to develop problem solving skills
11. Provide models of the scientific approach to problem solving with real world applications

Teacher Preparation and Certification

The AWIM curriculum was taught by classroom teachers, usually in partnership with engineers from their local communities. With the assistance of community partners, the curriculum could be taught using the provided instructions and without additional training. However, AWIM did provide summer professional development for teachers.

Table 1

Functional/Operating Models of Integrated STEM

Model	Grade	National Standards Alignment			
		1. Science	2. Technology	3. Mathematics	
				Teacher Preparation/ Certification Required	
EiE	1-5	1. No	2. Yes	3. No	No
IMaST	6-8	1. Yes	2. Yes	3. Yes	No
EbD	K-12	1. Yes	2. Yes	3. Yes	Yes
Infinity Project	6-12	1. No	2. No	3. No	Yes
PLTW	6-12	1. No	2. No	3. Yes	Yes
AWIM	K-12	1. Yes	2. No	3. Yes	No

Note: National content standards have only been developed for three disciplines in STEM education—science, technology, and mathematics—but not for engineering. However, in 2013, ASEE was exploring the development of engineering standards.

Table 2

Goals and Outcomes by Functional/Operating Model

Stated Goals and Outcomes	EiE	IMaST	EbD	Infinity Project	PLTW	AWIM
Technological Literacy	X		X			
Improve ability to teach engineering/technology	X					
Increase number of elementary engineering classes	X					
Conduct research	X					
Promote standards-based integrated curriculum		X	X			
Use current pedagogy		X	X			
Learn and apply principles		X				
Standardized problem solving method		X				
Promote cooperative teaching and learning		X				X
Include engineering in definition of “technology”		X				
Provide opportunities for all students/diversity			X		X	X
Restore America's status as the/National prosperity			X		X	
A textbook/ laboratory exercises with core course content				X		
Low-cost software/hardware laboratory kits				X		
Daily lesson plans and supporting materials				X		
Summer training institutes to teach the curriculum				X		
Web-based portal that allows teacher interaction				X		
Increase the number of students who pursue engineering and engineering technology degrees					X	
Provide clear standards/expectations for student success					X	
Provide leadership and support for program.					X	
Reduce the future college attrition rates in engineering					X	
Promote science literacy						X
Increase interest in STEM						X
Foster curiosity and creativity/spirit of discovery						X
Provide opportunities for physical science experiences						X
Counteract science and math learning anxiety						X
Provide opportunities to develop problem solving skills and measuring skills						X
Provide models of the scientific approach to problem solving with real world applications						X

It was apparent from analyzing the information in Tables 1 and 2 that there were differences between each of the integrated STEM education models. The grade level, standards, teacher preparation and certification, and the goals and outcomes addressed by each curriculum model vary greatly.

The EiE curriculum model addresses the elementary classroom. Their primary goal was to build technological literacy and to assist young children in gaining an understanding of the engineering design process. Although the EiE curriculum addressed the integration of STEM disciplines and is specifically aligned with the ITEEA *Standards for Technological Literacy*, the program did not specifically address math and science standards.

In contrast, the IMaST program was closely aligned with all national standards; however, it was only available for middle school students. Both the IMaST and EiE curriculums were available to be ordered and implemented directly into the classroom. The EbD curriculum could also be purchased and implemented into the K-12 classroom, but states are encouraged to become consortium members. In this way, teachers received specific training in each class that they would be teaching. The EbD curriculum was primarily focused on developing technological literacy.

The Infinity Project and PLTW each included curriculum offerings for grades 6-12. Both programs required that teachers be trained to teach each course that was offered in their school. The focus of PLTW was to create a larger pool of students who pursued engineering at the post-secondary level. The Infinity Project concentrated on the development of curriculum materials including textbooks, software, and supporting materials that were aligned with the Texas state standards.

The AWIM curriculum was concentrated on grades K-12. AWIM's major effort was to encourage students to approach problem solving from a scientific approach. The AWIM curriculum supported standards, yet each course was not specifically mapped to the national standards.

In light of these vast differences and discrepancies, a comprehensive set of standards for integrated STEM education curriculum was deemed vital to further STEM education (The National Academies, 2011). Recognizing the need and taking steps toward bringing integrated STEM education into our nation's schools has become a top priority for educators (AAAS, 2004; "Innovation America", 2007; ITEA, 2010; NSB, 2010). Defining integrated STEM education curriculum and its characteristics was an important and necessary ingredient for educators because of the various interpretations of the goals and outcomes of STEM education. The goal of this study was to gain consensus concerning the defining characteristics of integrated STEM curriculum.

Chapter 3: Methodology

Introduction

The purpose for conducting this study was to obtain consensus concerning the defining characteristics of integrated STEM curriculum. A list of core concepts and skills in the fields of science, technology and engineering, and mathematics education was identified by a panel of experts through the implementation of a modified Delphi study. Utilizing the literature on the Delphi method as defined in this study, this chapter described the Delphi research procedure that was implemented, the participants, and a synopsis of the data analyses.

The Delphi Research Method

Developed in the 1950s by the Rand Corporation for the military, the Delphi research method was used to gather significant responses from experts in order to investigate an area of focus (Stitt-Gohdes & Crews, 2004). A challenge that researchers often face was identifying effective methods for gaining consensus when multiple individuals from numerous disciplines and perspectives were utilized in the problem-solving process (Sema & Kasim, 2012). Van DeVen and Delbecq (1974) found that using the Delphi technique was most appropriate “when confronted with a fact finding problem that required the pooled judgment of a group of people” in which “the cost and inconvenience of bringing people together face-to-face is very high, and for problems that do not require immediate solution” (p. 620).

The Delphi research methodology was designed to be used in program development, needs assessment, and resource identification (Meyer & Booker, 1990). Delbecq, Van de Ven, and Gustafson (1975) suggested that the Delphi technique could also be useful to:

Determine or develop a range of possible program alternative; explore or expose underlying assumption or information leading to different judgment; seek out information

which may generate a consensus on the part of the respondent group; correlate informed judgments on a topic spanning a wide range of disciplines; and to educate the respondent group as to the diverse and interrelated aspects of the topic (p. 11).

This study utilized a modified Delphi survey, with variations from the original Rand Corporation model, to solicit recommendations from experts of STEM education and to create a list of core concepts and skills needed to develop appropriate integrated STEM curriculum.

Delphi Panel Selection

To determine the membership of the expert panel for this Delphi study, participants were purposively selected from the fields of science, technology and engineering, and mathematics education based on each individual's published literature and professional activities. The participants were identified as experts in their fields with past experience in integrated STEM curriculum.

Linstone and Turoff (2002) specified the size of the expert group may vary, but often a small group of individuals can produce the desired results needed in a Delphi study. Furthermore, Brockoff (1975) reported that the performance of an expert panel in a Delphi study, using forecasting questions, might benefit from the use of smaller groups for more well-defined results.

Research Design

A three-round methodology was used in this modified Delphi study. The round one survey contained ten open-ended response questions (see Appendix D). These questions emerged from discrepancies between the current STEM literature and the goals and outcomes of commercially-available STEM curricula. A comprehensive set of standards for integrated STEM education did not exist (NRC, 2011), and defining the characteristics required to develop

curricula is a current need for educators. The Delphi panel's individual responses to the round one questionnaire established a categorical data set for the survey questions used in later rounds. These questions focused on defining the major characteristics, or *big ideas*, that were essential in the process of developing integrated STEM curriculum.

Before administering the first round questionnaire to the expert panel, a small group of STEM educators reviewed the questions and recommended changes to ensure the validity of each question. The responses from the open-ended questions were "reviewed and categorized to create a valid and reliable list of structured and Likert-type closed-ended questionnaire items to be used for the second round of the Delphi study" (Sema & Kasim, 2012, p. 3).

In round two, the participants were asked to rank and comment on the big ideas as "strongly disagree," "disagree," "neither agree or disagree," "agree," or "strongly agree" based on the questionnaire items developed from the individual's responses from round one. The survey also allowed the panel of experts to comment on each of the survey questions. The participants' responses were then reviewed and analyzed to create a comprehensive account of the expert panels' consensus on the big ideas that are essential in the process of developing an integrated STEM curriculum. Based on descriptive statistics, responses were analyzed and the group means and standard deviations were established. The findings from round two were used to develop a final questionnaire, including descriptive statistics and participant comments.

The third round questionnaire provided the expert panel an opportunity to analyze the descriptive statistic results, review comments from round two from all participants, and make comments as necessary on the defining characteristics of integrated STEM curriculum. The panel reviewed the questions, along with the provided descriptive statistics of the group's responses, and was asked to rank each of the survey statements in which there was a consensus as

“important” or “essential.” The questions for which a consensus was not established asked the participants to rank each of the survey statements as “important” or “nonessential.” Participants were also given the opportunity to make further comments as deemed necessary.

After the surveys were completed and returned, the responses of “nonessential,” “important,” and “essential” were recorded and assigned numerical values of 0, 1, and 2 respectively. This allowed the researcher to calculate the frequency and percentage of responses for each statement to determine the agreement levels from the participants. Finally, the responses for each question and statement were analyzed to determine if significant differences exist in agreement levels based on the individual’s disciplinary groundings in science, technology and engineering, and/or mathematics.

Data Collection

Communication with the individual participants selected for the expert panel was established by means of telephone and email correspondence. Each participant was initially contacted by telephone to personalize the invitation to participate. If the telephone contact was unsuccessful, email correspondence was then initiated to secure the participants. Additionally, chain or snowball sampling, a form of sampling appropriate for identifying potential participants with specific skills, knowledge, and other characteristics, was used in the study (Cavana, Delehay, & Sekaran, 2001). The individuals initially identified to participate were asked to recommend a colleague in integrated STEM education that they believed would be a good choice to join the expert panel. Once the panel members committed to participate in the study, all further correspondence was conducted through email and telephone.

A Google Drive® Survey was utilized in the first round of the study. The form was sent to the participants via an email link. When the survey was completed, the responses were

returned automatically to the researcher in Google Drive® in the form of an Excel® spreadsheet, which was then included in analyses.

The surveys for rounds two and three were sent to the participants as a Word® document questionnaire. The responses from the final two rounds were collected in a Word® document and then exported to Microsoft Excel® for review and analysis.

Data Analysis

The open-ended responses from round one were collected, categorized, and combined to create a structured, closed-ended questionnaire (Sema & Kasim, 2012) for use in round two. The round two survey asked the participants to rank each item on the questionnaire using a five-point Likert scale with the following rankings: (1) strongly disagree, (2) disagree, (3) neither agree or disagree, (4) agree, and (5) strongly agree. These data were analyzed to find the mean, median, mode, and standard deviation of the responses. Although conclusive procedures for consensus are not specified in the literature (Hsu & Standford, 2007), the researcher determined that consensus occurred when the mean was ≥ 4 (agreement) or ≤ 2 (disagreement). The response means falling outside of this range were deemed as areas of non-agreement or non-consensus.

The descriptive statistics from round two were then used to develop the questionnaire and summary provided to the participants during round three. In the third round survey, the participants were given the mean, standard deviation, and individual comments for each question. The participants ranked each item on the questionnaire as (0) nonessential, (1) important, or (2) essential and were given the opportunity to add additional comments. Once the participants returned their responses from round three, the results were analyzed using Microsoft Excel® software. The group consensus was calculated using the percentage of the ratings for the panel as a whole and separately by disciplinary background.

Summary

The study emerged from the inconsistencies between goals and outcomes that exist in the current STEM literature and commercially available STEM curricula. This study used a modified Delphi research method to identify the defining characteristics of integrated STEM curriculum. A panel of experts was chosen by the researcher based on their recognition in the field of integrated STEM education. Additional participants were selected through chain or snowball sampling. The surveys were administered electronically, and the data were collected through three rounds of surveys. The results of this study will be discussed in chapter four.

Chapter 4: Results

The purpose of this study was to obtain consensus concerning the defining characteristics of integrated STEM curriculum through the implementation of a modified Delphi study. A three-round modified Delphi research process was implemented to elicit the responses of a panel of STEM education experts to obtain consensus concerning the defining characteristics of integrated STEM curriculum. The study was designed to answer four research questions related to developing STEM curriculum, including:

1. What are the defining characteristics that set integrated STEM education curriculum apart from single-discipline curricula according to a panel of experts?
2. How might a set of categorical and defining curricular components be established for an integrated STEM education curriculum?
3. What defining components or characteristics can be used to gauge whether an initiative, project, or curriculum should be referred to as integrated STEM education?
4. Do significant differences exist from the defining characteristics based on disciplinary grounding in science, mathematics, or technology and engineering?

Delphi Study Participants

Every effort was made by the researcher to obtain a diverse panel of participants identified as experts in STEM education. These participants were experienced with current STEM integration initiatives and the literature on integrated STEM education. Eighteen participants originally agreed to participate in the study. Two participants voluntarily withdrew during round one, because they believed that they were not qualified to participate based on their knowledge of commercially available STEM curricula. Four other participants were

unresponsive and did not complete the round one survey by the due date. The reporting Delphi panel participant's demographic data is reported in Table 3.

Table 3

Delphi Panel Participants Demographic Descriptive Statistics (N=12)

Categories	<i>n</i>	%
Content Discipline		
Science	3	25
Mathematics	2	17
Technology & Engineering	7	58
Gender		
Female	1	8
Male	11	92
Highest Level of Education		
Masters	3	25
Ed. S.	2	17
Ed. D./Ph. D	7	58
Current Employment		
University Professor	5	42
Technical College Faculty	1	8
Administration	2	16
Director of a Public Engagement Office at a University	1	8
Curriculum Developer	3	25
Age Range		
31-40 years	4	33
41-50 years	2	17
51-60 years	4	33
61-70 years	2	17

Note. Total of percentages is not 100% because of rounding.

Of the 12 Delphi panel participants who completed the study, 5 were chosen based on their expertise in integrated STEM education, and were contacted to participate in the study. The initial participants were asked about colleagues whom they believed would be suitable for the Delphi panel. The additional 7 members of the expert panel were identified through the use of chain or snowball sampling.

Data Collection Results

A three-round modified Delphi study was conducted to obtain consensus concerning the defining characteristics of integrated STEM curriculum. Twelve individuals completed the Delphi study ($n = 12$).

Round One

The Delphi panel participants anonymously answered 10 open-ended survey questions focused on K-12 integrated STEM education. These open-ended questions allowed each of the participants an opportunity to suggest possible considerations or solutions in developing STEM curricula (Kalaian & Kasim, 2012). The first Delphi round was implemented through a Google Drive® Survey/Form link provided as a link in an e-mail to the participants (see Appendix D). Table 4 contains the 10 open-ended questions elicited in round one.

Table 4

Round One Survey Questions

Question Number	Probe Question	Link to Research Question
1	What are essential curriculum components of integrated K-12 STEM Education?	1 - 2
2	What are items that differentiate a single discipline from an integrated STEM curriculum?	1 - 2 - 4

Table 4 (continued)

3	Ideally, must all STEM lessons or activities be problem-based? Why or why not?	3
4	Should STEM curriculum be based primarily upon the disciplinary background of the instructor? Why or why not?	4
5	If a STEM lesson fails to include one or more disciplines, should it be referred to as STEM education? Why or why not?	3
6	What are barriers to implementing a STEM curriculum into all grades K-12?	1
7	Of all of the commercially available STEM curricula, what percentage do you feel are truly integrated? Please explain.	2 - 3
8	Of the commercially available STEM curricula, which do you feel best represents integrated STEM? Please explain.	3
9	In your opinion, how might a curriculum designer assure that a curriculum is truly integrated?	1
10	In your opinion, what is the driving force behind most commercially available STEM curriculum?	3

Round One Analyses

The responses from round one were collected through a Google Drive® Survey/Form, exported to Microsoft Excel®, and then analyzed to establish a categorical data set of big ideas that are essential in the process of developing integrated STEM. The responses to questions 1, 2, and 9 contained a diverse data set that could only be minimally categorized (see Tables 5, 6, and 7), but were essential for developing the round two survey.

Table 5

Delphi Panel Participants Responses to Question - 1 - What are essential curriculum components of integrated K-12 STEM education?

Participant	Response
1	Must clearly address educational standards/content of each individual discipline, but in a manner that does not isolate it to only one discipline. For example, elementary students must learn fractions. Integrated STEM teaches fractions through their applications in science, engineering, and technology.

Table 5 (continued)

2	Curricula features include standards-based alignment that is appropriate for a consistent learner level. For example, the technology competencies are for grades 9-12 while the mathematics competencies are grade 4. Also, technology and engineering process/content is utilized to approach science and/or math competencies.
3	Instruction in Life Sciences, Physical Sciences, Earth and Space Sciences, and Mathematics
4	Project-based work with sufficient time for students to engage in designing, making, testing, reflecting and documenting
5	Reading, Writing, Logical reasoning, Science, Mathematics, Computer skills
6	Engineering Design embedded throughout the curriculum. Appropriate grade-level mathematics; applicable to solving technical problems. Physical science, technological knowledge, skills, and processes.
7	A blending of appropriate content from each of the areas depending on the content or problem posed. The integrated K-12 STEM curriculum would be specific content sections or pieces students would need to know and understand in order to address the problem. Skill development would be involved and integrated.
8	A well-rounded science perspective including life science physical science and math, but also components of critical thinking and problem solving to facilitate the development of tools or technology.
9	Content should be based on science (including computer science and engineering) with mathematics woven throughout. Teacher professional development would have to be intense and optimize a professional learning community.
10	Authentic, real-world project/problem based with equal instructional and assessment emphasis placed on both the technical content and the essential embedded academics of ELA, Math and science
11	Flexible working condition with staff, time to peruse each other's curriculum to see where commonalities lie, support from administration and from math department and stem department
12	Curriculum must be centered around a project that places all the learning into context. Planning is essential to assure that the project is authentic, that the learning is controlled by the students and that a presentation be made to an authentic audience.

Table 6

Delphi Panel Participants Responses to Question 2 - What are items that differentiate a single discipline from an integrated STEM curriculum?

Participant	Response
1	Integrated STEM teaches content from other disciplines. A single discipline can mention applications of concepts, particularly in the context of a story problem, but not necessarily teach content other than their own. A truly integrated STEM curriculum specifically teaches content identified by multiple disciplines as being critical.

Table 6 (continued)

- 2 Natural intersections of learning are further utilized to bridge associated study and application of combined conceptual knowledge
 - 3 Single-discipline instruction focuses on that discipline. However, the idea of a 'single discipline' is too rigid in US schools and curricula, as it limits application and exploration of real-world problems. These should be the basis for teaching. Said another way, we often give young children opportunities for exploration and knowledge-building; we don't tell THEM that it's physics, or earth science. Instead, we give them practical stuff to explore, requiring them to think and reason. We should do more of this in the HS.
 - 4 A single discipline could be rote or narrowly focused work in almost anything; integrated STEM implies project-based work on open-ended problems.
 - 5 No discipline can stand independent of another discipline. All disciplines are integrated. Presenting a discipline in isolation of related disciplines handicaps one's ability to make mental connections to pre-existing knowledge. Isolation of a discipline also limits real world applications. Basically, if one would examine any one real life experience, they would note the presence of a blend of many disciplines.
 - 6 A single discipline focuses on a certain subject area, i.e., algebra, while an integrated discipline takes on a meta-discipline approach, where ideally, no single subject or discipline defines the curriculum.
 - 7 A single discipline covers much of the content with appropriate labs that reinforce content knowledge. The course is usually designed to transmit an identified body of knowledge.
 - 8 Integrated stem curriculum delivers crosscutting concepts such as critical thinking and problem solving. It also supports the interdisciplinary view of science. A biology student can't fully understand the importance of water without diving into the chemical properties of water with the physics of water in motion. By breaking down these barriers between this abundance students are able to get a more realistic view of what science is and how we use it to better understand the world around us.
 - 9 What differentiates the single-discipline approach is the question of purpose. In a physics class, the mathematics, the technology, the chemistry, the design, are all for the sake of learning the physics. Only the physics is assessed. In a mathematics class, the other STEM areas are always encountered as peripheral to learning the underlying mathematics. In an integrated approach, a larger question would be the focus. It would have to be rich enough to engage multiple topics and there would have to be time and personnel to make sure that it is successful. In short, a school would have to go all-in on integrated. Not have integrated science with traditional math. I can't imagine many schools moving to that model.
 - 10 A STEM curriculum is a truly integrated teaching and learning tool and not teaching and learning that is organized in silos
 - 11 Different curriculums, different standards, different plan times
 - 12 A single discipline is constructed around a single set of standards. The learning is done in a vacuum and there is usually an assessment based on the standards. There is usually little in depth work and real world tie ins are limited. Integrated STEM is the opposite. It is designed around several sets of standards. The problem solving process is more important than a standardized test. There is less sage on the stage and more student ownership of the learning.
-

Table 7

Delphi Panel Participants Responses to Question 9 - In your opinion, how might a curriculum designer assure that a curriculum is truly integrated?

Participant	Response
1	Can teachers in each discipline find their educational content/standards in the curriculum? Do the teachers say "yes, that is a very good way to teach my stuff?" Is the STEM way more efficient in time and materials than the traditional individual methods?
2	Truly integrative STEM education curricula feature intentional alignment of technology and engineering concepts, processes, and approaches with appropriate and logically occurring concepts and processes of mathematics and/or science.
3	Curriculum is in 2 parts: 1. What you design - texts, supporting materials, websites, etc. This you can control. 2. What's delivered in the classroom - this you can't control.
4	Ask the students, "What subjects was this?" If they don't know or disagree, it was probably integrated!
5	Curriculum should be developed by a team of experts representing a wide span of discipline. The curriculum team should include representation from academia and industry.
6	Apply the curriculum to integrated curriculum models to see if they align.
7	Product testing. Ensure the outcomes match the goals/objectives. Does the evidence, either products or student behavior, match the STEM ideology?
8	Revision to by an interdisciplinary panel.
9	Assuming integration is the goal, one should search for the richest possible problems. For a student-centered approach, I would use themes such as "the cell" or "water" or "motion" and derive approaches from these huge areas. I would work with teams of teachers at a special, laboratory school to refine them.
10	Is aligned to the state's current and future workforce needs; Prepares all students for both further education/training and career entry and advancement; Instructs students in the essential academic content standards of reading, writing, mathematics and science through a thoughtful integration with CTE content standards; Assesses student course achievement through end-of-course exams that are half CTE content and half applied academics in reading, writing, mathematics and science; and Is designed using the appropriate application of activities, projects, and problems as the hierarchy of contextual learning.
11	Try to develop something that is balanced across different curriculums
12	Project based learning is the only effective way I have been able to do it. A project based in reality will require the application of subject matter from a variety of disciplines. The designer must define the learning as the first step in the design. Once the desired standards are selected (and there should not be many of them) the project and supporting activities can be designed.

The researcher concluded that each of these responses was diverse; and therefore, further investigation would be needed to establish an agreement by the Delphi panel in the second round of the study. The open-ended responses from the remaining questions were analyzed based on the frequency of each response. These responses were summarized in Table 8 below.

Table 8

Delphi Panel Participants Responses to Questions 3, 4, 5, 6, 7, 8, and 10

Question	%	Responses
3. Ideally, should all STEM lessons or activities be problem-based?	42	Yes
	42	Yes, but
	0	No
	17	No, but
4. Should STEM curriculum be based primarily upon the disciplinary background of the instructor?	8	Yes
	33	No
	58	Maybe
5. If a STEM lesson fails to include one or more disciplines, should it be referred to as STEM education?	17	Yes
	50	No
	25	Indefinite
	8	It is impossible
6. What are barriers to implementing a STEM curriculum into all grades K-12?	58	Structure of Schools
	25	Standardized Testing
	58	Teacher Preparation
	25	Parents and the Community
7. Of all of the commercially available STEM curricula what percentage do you feel are truly integrated?	8	None
	17	Very few
	8	<5%
	33	< 10%
	8	<20%
	25	Cannot answer

Table 8 (continued)

8. Of the commercially available STEM curricula, which do you feel best represents integrated STEM?	25	The Integrated Mathematics, Science, and Technology (IMaST)
	8	City Technology
	8	INcreasing Student Participation, Interest and Recruitment in Engineering and Science (INSPIRES)
	17	Project Lead the Way (PLTW)
	8	Engineering is Elementary (EiE)
	8	Math Trailblazers
	8	The SIMMS Integrated Mathematics
	17	Preparation for Tomorrow (PFT)
	1	Fischertechnik STEM Labs
	1	STEM 101
10. In your opinion, what is the driving force behind most commercially available STEM curriculum?	1	The Infinity Project
	67	Money
	17	National standards
	17	Professional organizations
	33	Attention at the state and national levels

Note. Total of percentages is not 100% because of duplicate responses.

Each of the open-ended responses established the framework of closed-ended questions to be used in round two of the Delphi. Based on Kalaian and Kasim (2012), the researcher, as the facilitator of the study, compiled each of these open-ended survey responses into a list of 85 Likert-type questionnaire items to be used in the second round of the Delphi study (see Appendix F).

Round Two

The same panel of experts was asked to continue participation in the study to identify the defining characteristics of integrated STEM curriculum through an e-mail letter (see Appendix E). Each of the panel members were provided with a closed-ended survey developed from the responses from the first round survey. The round two Delphi survey provided summary statistics from the round one responses, and the participants were asked to rank each of the 85 statements

provided in questionnaire using a five-point anchored Likert scale with the following rankings: (1) strongly disagree, (2) disagree, (3) neither agree or disagree, (4) agree, and (5) strongly agree (see Appendix G). The participants were also invited to comment on each of the statements from the panel members that were presented in the survey.

Round Two Analyses

The survey responses from round two were reviewed and analyzed by the researcher to find the mean and standard deviation of the responses. Although conclusive procedures for consensus are not apparent in the literature (Hsu & Standford, 2007; Kennedy, 2002), the researcher determined that consensus occurred when the central tendency or mean was ≥ 4 (agreement) or ≤ 2 (disagreement). The mean, standard deviation, and consensus determination for each of the questions and statements are provided in Table 9.

Table 9

Delphi Panel Participants Responses to Round Two Survey (N=12 unless otherwise noted)

Questions & Statements	<i>M</i>	<i>SD</i>	Consensus
Question 1			
What are essential curriculum components of integrated K-12 STEM Education?			
1. The curriculum clearly addresses the appropriate grade-level educational standards/content of each individual discipline without isolating it to one discipline.	3.75	1.01	No
2. Instruction in reading, writing, and numeracy are used to enable effective communication in problem-solving.	3.92	.76	No
3. Real-world problem-solving and application including creative design, testing, and evaluation of solutions are used to utilize students' base knowledge of science and mathematics.	4.33	.94	Yes
4. The curriculum is comprised of project-based work with sufficient time for students to engage in designing, making, testing, reflecting and documenting.	4.50	.87	Yes

Table 9 (continued)

5. Skill development, including logical reasoning and computer skills are interwoven.	4.17	.55	Yes
6. Curriculum must be centered around a project that places all the learning into context. Planning is essential to assure that the project is authentic, that the learning is controlled by the students and that a presentation be made to an authentic audience.	4.50	.65	Yes

Question 2

What are items that differentiate a single discipline from an integrated STEM curriculum?

1. Engages students in content from multiple disciplines.	4.58	.49	Yes
2. Natural intersections of learning are utilized to bridge the study and application of combined conceptual knowledge.	4.50	.50	Yes
3. Includes the application and exploration of real-world problems requiring students to think and reason.	4.33	.62	Yes
4. Includes project-based work on open-ended problems.	4.17	.55	Yes
5. Utilizes a meta-discipline approach, where ideally, no single subject or discipline defines the curriculum.	3.67	1.11	No
6. Delivers crosscutting concepts such as critical thinking and problem solving to support the interdisciplinary views of science and mathematics to better understand the world around us.	4.17	.69	Yes
7. Designed around several sets of national standards (such as CCSS, NGSS, ITEEA, etc.)	3.80	1.10	No

Question 3

Ideally, must all STEM lessons or activities be problem-based? Why or why not?

1. Problem-based instruction requires a shift in student expectations and engagement.	4.20	.60	Yes
2. Some educators would argue that some content simply cannot be taught through a problem-based approach.	3.00	1.50	No
3. This is a question of what is the most effective teaching strategy for that particular topic.	3.20	1.00	No
4. Background and cognitive knowledge must be established before students are ready for problem-based experiences.	2.50	1.26	No

Table 9 (continued)

5. Some projects may include elements that are not problem-based (i.e., vocabulary, math instruction, etc.). These elements are essential in supporting student learning within problem-based lessons.	4.00	.71	Yes
6. Problem-based STEM lessons prepare a learner to effectively apply curriculum learned to real-life problems and support the development of logical reasoning skills.	4.33	.75	Yes
7. Authentic problems are essential for an integrated approach because problems are rarely, if ever, answered by using knowledge and skill from one discipline alone.	4.42	.64	Yes
8. Problem-based STEM lessons do not have to be product based, but should include the development of a hypothesis development and a defense.	3.25	1.01	No
9. STEM lessons should be problem-based to support critical thinking and problem solving in the real-world.	4.42	.49	Yes
10. Problem-based learning supports students with authentic, meaningful learning experiences.	4.42	.64	Yes
11. Problems are real world issues that students must tackle. There are no existing answers and the students have to design the entire approach to the solution. Solutions to a problem are not by nature related to the solutions arrived at by others.	3.42	1.19	No

Question 4

Should STEM curriculum be based primarily upon the disciplinary background of the instructor? Why or why not?

1. It is important that teachers do not have a discipline-specific identity.	2.25	.72	No
2. Disciplinary knowledge is a must.	4.17	.69	Yes
3. Current staffing models in secondary schools make it difficult to develop integrated curriculum.	4.25	.92	Yes
4. Any educator can teach integrated STEM.	2.00	1.15	Yes
5. It is easier to integrate STEM learning in the elementary grades, where teachers are generalists.	2.58	1.04	No
6. STEM curriculum should be developed and standardized.	3.50	1.04	No
7. The instructor should be selected based on his/her qualifications to adequately teach the curriculum.	3.92	.49	No

Table 9 (continued)

8. Integrated STEM curriculum should not be determined by the instructor's ability.	3.67	1.37	No
9. If properly prepared, a STEM teacher would understand where his/her shortcomings are and complete professional development to strengthen his/her skills.	4.17	1.28	Yes
10. It is nearly impossible for one to be proficient in all of the STEM disciplines, but one can become an effective STEM teacher by just understanding the pedagogical content knowledge.	3.92	.64	No
11. The background of the instructor enables the instructor to provide students with personal examples from experience that help build student interest and learning.	4.33	.62	Yes
12. STEM teacher training should be provided through professional development which allows teachers to demonstrate their ability to teach the curriculum.	4.25	.72	Yes
13. It is important that integrated STEM curriculum rotate the main content emphasis of projects to encourage student interest and participation.	3.75	.92	No

Question 5

If a STEM lesson fails to include one or more disciplines, should it be referred to as STEM education? Why or why not?

1. It is nearly impossible to address all four disciplines in every lesson, particularly to the same depth and degree; but, it is important that all STEM content is included throughout the course.	3.75	1.16	No
2. If a lesson fails to include more than one, it should not be called education, let alone STEM education.	2.33	1.03	No
3. Most STEM lessons include all of the disciplines, but it is often easy to identify the disciplinary background of the curriculum writer based on the depth of content.	3.25	1.16	No
4. Not all problems will require the use of all STEM disciplines.	3.92	.86	No
5. It is important that a student address the problem creatively using appropriate content or skills from all four STEM areas.	3.33	.85	No
6. It is important that students have an understanding of 'technology' in STEM beyond the use of computers as a tool to solve problems.	4.83	.37	Yes

Table 9 (continued)

7. The understanding of the term STEM comes from the disciplinary components of the acronym and should not be redefined to include areas outside of science, technology, engineering, or mathematics, although STEM education may contain other disciplinary components.	3.5	1.1	No
8. STEM lessons should include as many of the four disciplines as possible.	4.42	.76	Yes
9. STEM is more than a lesson label and one project might include a heavier emphasis and in one area than another as well as topic areas outside of the STEM fields.	4.27	.75	Yes

Question 6

What are barriers to implementing a STEM curriculum into all grades K-12?

1. The infrastructure of middle school, high school, and college coursework is based on individual disciplines.	4.75	.43	Yes
2. The time required for problem and project-based learning is an issue.	3.25	1.16	No
3. The staffing of schools relies on discipline-specific instructors.	3.83	.69	No
4. The expectations and culture of teachers, administrators, and parents are an issue.	4.20	.90	Yes
5. Many secondary schools lack the appropriate materials and resources necessary to implement integrated STEM education.	3.70	1.20	No
6. Many elementary schools lack the appropriate materials and resources necessary to implement integrated STEM education.	3.33	1.25	No
7. It is difficult for schools to find qualified staff to implement STEM.	4.00	.90	Yes
8. There are few barriers to implementing integrated STEM learning in grades K-5.	2.40	1.00	No
9. Elementary teachers are very comfortable teaching reading, but not as much in STEM areas.	4.20	.60	Yes
10. Teacher preparation programs are too narrowly focused.	4.33	.75	Yes
11. K-8 teachers should be subject prepared similar to 9-12 teachers.	2.58	1.12	No
12. Many teachers are uncomfortable teaching technology and engineering.	4.50	.50	Yes

Table 9 (continued)

13. Teachers need to have the prerequisite skillsets used for design-based learning approaches.	3.92	.76	No
14. State mandated tests limit the ability to integrate learning.	3.58	1.23	No
15. There is broad societal acceptance of the model that specialization occurs as a student progresses in school.	3.67	1.11	No
16. Parents do not understand the expectations of integrated STEM education.	3.67	.75	No
17. The community does not have a clear understanding of STEM education.	3.83	.90	No

Question 7

Of all of the commercially available STEM curricula, what percentage do you feel are truly integrated? Please explain.

1. The market for STEM curricula is not mainstream.	3.25	1.64	No
2. The majority of STEM curricula is discipline specific; therefore the STEM curricula developed by science experts varies greatly from the STEM curricula written by math experts.	3.83	.80	No
3. Very few of the available integrated STEM curricula are learner level appropriate across all content areas.	3.08	.95	No
4. Commercial developers have traditionally not focused their work on sound pedagogical practices, but rather cool activities.	3.58	.64	No
5. Integrated STEM places an equal emphasis on the teaching and assessing—both technical and academic content.	4.08	.64	Yes
6. Many STEM programs have a narrow educational focus that includes a collection of activities and specific products.	3.50	.87	No

Question 8 ($n = 10$)

Of the commercially available STEM curricula, which do you feel best represents integrated STEM? Please explain.

The Integrated Mathematics, Science, and Technology (IMaST)	3.70	.78	No
City Technology	3.50	.67	No
INcreasing Student Participation, Interest and Recruitment in Engineering and Science (INSPIRES)	3.50	.81	No
Project Lead the Way (PLTW)	3.30	1.19	No
Engineering is Elementary (EiE)	3.50	1.02	No

Table 9 (continued)

Math Trailblazers	2.90	.94	No
The SIMMS Integrated Mathematics	2.70	.90	No
Preparation for Tomorrow (PFT)	3.90	.83	No
Fischertechnik STEM Labs	3.20	.98	No
STEM 101	3.40	.49	No
The Infinity Project	2.90	.94	No

Question 9

In your opinion, how might a curriculum designer assure that a curriculum is truly integrated?

1. The classroom teachers should be able to easily identify individual content standards within the curriculum.	3.92	.76	No
2. Traditional teaching methods are more efficient in time and materials than integrated STEM methods.	1.80	.70	No
3. STEM curriculum should include the alignment of technology and engineering concepts, processes, and approaches with grade-appropriate science and mathematics.	4.40	.50	Yes
4. When asked about an “integrated” lesson, students either cannot identify a specific discipline area or disagree on the discipline area covered in the lesson.	3.17	.80	No
5. Curriculum should be developed by a team of experts representing a wide span of disciplines including academia and industry.	3.80	1.00	No
6. Integrated STEM curriculum must align with the current goals and objectives of a school.	3.50	1.00	No
7. Review of STEM curricula by an interdisciplinary panel is essential.	4.20	.70	Yes
8. Curriculum must include a student-centered approach to solving real-world challenges.	4.50	.50	Yes
9. The curriculum must be aligned to current and future workforce needs.	4.00	.58	Yes
10. STEM curriculum requires the application of subject matter from a variety of disciplines.	4.42	.64	Yes

Question 10

In your opinion, what is the driving force behind most commercially available STEM curriculum?

1. Curriculum writers and textbook publishers see the potential market of STEM education.	4.08	1.04	Yes
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Table 9 (continued)

2.	A great deal of federal and private grant money designated to address these needs of STEM is available to schools.	3.33	1.18	No
3.	Businesses and schools are pressured by the interest in STEM, despite understanding or not understanding the meaning of STEM.	4.08	.95	Yes
4.	National standards affect curricula development and state adoption.	4.25	.83	Yes
5.	Professional organizations support the development of STEM curriculum because the future workforce depends on the younger generation.	4.00	.91	Yes
6.	National attention on STEM issues and the need for STEM graduates effect the development of curricula.	4.17	.55	Yes

The results of the round two survey provided a foundation for the round three survey. Although the mean alone was used to determine consensus, it was interesting to note that there was a wide range of disagreement on many of the statements as evident by reviewing the standard deviations ($SD > 1.00$) in Table 9. For example, Question 8, which asked the participants to rank the commercially-available STEM curricula that were identified by the participants in the first round, was removed from the third round survey. A consensus was not reached on any of the identified curricula during third round of the Delphi. In addition, two of the participants did not respond to the curricula, and another responded “neither agree nor disagree” on each of the items. All three commented on their lack of familiarity with these STEM curricula.

Round Three

The round three survey used the 85 statements regarding curricular characteristics in an integrated STEM education curriculum that were used to determine consensus in round two. The same panel of experts was asked to continue participation in the study to further define these characteristics of integrated STEM curriculum through an e-mail letter (see Appendix G).

Participants in round two were asked to rank each statement where a consensus was reached with a descriptor of “essential” or “important” (see Appendix H). The statements in which a consensus could not be reached were given a descriptor of “important” or “nonessential.”

Round Three Analyses

Once the participants returned their responses from round three, the results were analyzed using Microsoft Excel® software. The researcher determined a percentage $\geq .75$ would provide the understanding of a necessary and sufficient condition (Braumoeller & Goertz, 2000) for determining consensus for each of the statements as “essential,” “important,” and “nonessential” items. These numbers were calculated as (0) nonessential, (1) important, or (2) essential. The results from the round three survey are provided in Table 10.

Table 10

Delphi Panel Participants Responses to Round Three Survey (N=12 unless otherwise noted)

Question 1 - What are essential curriculum components of integrated K-12 STEM Education?						
	2 nd Round Consensus	Science Panelists (n = 3)	Technology & Engineering & Panelists (n = 7)	Mathematics Panelists (n = 2)	Delphi Panel	Necessary & Sufficient Condition (≥ .75)
Q1-1 - The curriculum clearly addresses the appropriate grade-level educational standards/content of each individual discipline without isolating it to one discipline.	No	3 - Important	3 – Important 4 – Nonessential	2 - Nonessential	83% - Important 17% - Nonessential	Important
Q1-2 - Instruction in reading, writing, and numeracy are used to enable effective communication in problem-solving.	No	3 - Important	7 - Important	1 – Important 1 – Nonessential	92% - Important 8% - Nonessential	Important
Q1-3 - Real-world problem-solving and application including creative design, testing, and evaluation of solutions are used to utilize students’ base knowledge of science and mathematics.	Yes	2 - Essential 1 - Important	4 - Essential 3 - Important	1 - Essential 1 - Important	58% - Essential 42% - Important	No

Table 10 (continued)

Q1-4 - The curriculum is comprised of project-based work with sufficient time for students to engage in designing, making, testing, reflecting and documenting.	Yes	2 - Essential 1 - Important	5 - Essential 2 - Important	1 - Essential	75% - Essential 25% - Important	Essential
Q1-5 - Skill development, including logical reasoning and computer skills are interwoven. <i>n = 11</i>	Yes	2 - Essential 1 - Important	2 - Essential 4 - Important	1 - Essential 1 - Important	36% - Essential 64% - Important	No
Q1-6 - Curriculum must be centered around a project that places all the learning into context. Planning is essential to assure that the project is authentic, that the learning is controlled by the students and that a presentation be made to an authentic audience.	Yes	3 - Important	3 - Essential 4 - Important	2 - Essential	50% - Essential 50% - Important	No

Question 2 - What are items that differentiate a single discipline from an integrated STEM curriculum?

	2 nd Round Consensus	Science Panelists	Technology & Engineering Panelists	Mathematics Panelists	Delphi Panel	Necessary & Sufficient Condition
Q2-1 - Engages students in content from multiple disciplines.	Yes	2 - Essential 1 - Important	6 - Essential 1 - Important	2 - Important	67% - Essential 33% - Important	No

Table 10 (continued)

Q2-2 - Natural intersections of learning are utilized to bridge the study and application of combined conceptual knowledge.	Yes	2 - Essential 1 – Important	4 - Essential 3 – Important	1- Essential 1 – Important	67% - Essential 33% - Important	No
Q2-3 - Includes the application and exploration of real-world problems requiring students to think and reason.	Yes	2 - Essential 1 – Important	7 - Essential	2 - Essential	92% - Essential 8% - Important	Essential
Q2-4 - Includes project-based work on open-ended problems.	Yes	2 - Essential	5 - Essential 2 – Important	2 - Essential	83% - Essential 17% - Important	Essential
Q2–5 - Utilizes a meta-discipline approach, where ideally, no single subject or discipline defines the curriculum.	No	1 – Important 2 – Nonessential	6 – Important 1 – Nonessential	2 - Nonessential	58% - Important 42% - Nonessential	No
Q2-6 - Delivers crosscutting concepts such as critical thinking and problem solving to support the interdisciplinary views of science and mathematics to better understand the world around us.	Yes	2 - Essential 1 – Important	5 - Essential 2 – Important	1 - Essential 1 – Important	67% - Essential 33% - Important	No
Q2 –7 - Designed around several sets of national standards (such as CCSS, NGSS, ITEEA, etc.)	No	2 – Important 1 – Nonessential	6 – Important 1 – Nonessential	2 - Important	83% - Important 17% - Nonessential	Important

Table 10 (continued)

Question 3 - Ideally, must all STEM lessons or activities be problem-based? Why or why not?						
	2 nd Round Consensus	Science Panelists	Technology & Engineering Panelists	Mathematics Panelists	Delphi Panel	Necessary & Sufficient Condition
Q3-1 - Problem-based instruction requires a shift in student expectations and engagement.	Yes	3 - Essential	4 - Essential 3 - Important	2 - Essential	75% - Essential 25% - Important	Essential
Q3-2 - Some educators would argue that some content simply cannot be taught through a problem-based approach. <i>n</i> = 10	No	2 – Important 1 – Nonessential	4 – Important 1 – Nonessential	2 - Non-Essential	30% - Important 70% - Nonessential	No
Q3-3 - This is a question of what is the most effective teaching strategy for that particular topic. <i>n</i> = 10	No	3 - Important	3 – Important 2 – Nonessential	2 - Non-Essential	60% - Important 40% - Nonessential	No
Q3-4 - Background and cognitive knowledge must be established before students are ready for problem-based experiences.	No	3 - Non-Essential	4 – Important 3 – Nonessential	2 - Non-Essential	33% - Important 67% - Nonessential	No
Q3-5 - Some projects may include elements that are not problem-based (i.e., vocabulary, math instruction, etc.). These elements are essential in supporting student learning within problem-based lessons. <i>n</i> = 11	Yes	1- Essential 2 - Important	5- Essential 1 - Important	1- Essential 1 - Important	64% - Essential 36% - Important	No

Table 10 (continued)

Q3-6 - Problem-based STEM lessons prepare a learner to effectively apply curriculum learned to real-life problems and support the development of logical reasoning skills.	Yes	3 - Essential	5- Essential 2 - Important	1- Essential 1 - Important	75% - Essential 25% - Important	Essential
Q3-7 - Authentic problems are essential for an integrated approach because problems are rarely, if ever, answered by using knowledge and skill from one discipline alone.	Yes	3 - Essential	7 - Essential	2 - Essential	100% - Essential 0% - Important	Essential
Q3-8 - Problem-based STEM lessons do not have to be product based, but should include the development of a hypothesis development and a defense.	No	3 - Important	4 – Important 3 – Nonessential	2 - Important	75% - Important 25% - Nonessential	Important
Q3-9 - STEM lessons should be problem-based to support critical thinking and problem solving in the real-world.	Yes	3 - Essential	4 – Essential 3- Important	1 – Essential 1 - Important	67% - Essential 33% - Important	No
Q3-10 - Problem-based learning supports students with authentic, meaningful learning experiences.	Yes	3 - Essential	6 - Essential 1 - Important	1 – Essential 1 - Important	83% - Essential 17% - Important	Essential

Table 10 (continued)

Q3-11 - Problems are real world issues that students must tackle. There are no existing answers and the students have to design the entire approach to the solution. Solutions to a problem are not by nature related to the solutions arrived at by others. <i>n</i> = 11	No	1 – Important 2 – Nonessential	2 – Important 4 – Nonessential	1 – Important 1– Nonessential	36% - Important 64% - Nonessential	No
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Question 4 - Should STEM curriculum be based primarily upon the disciplinary background of the instructor? Why or why not?

	2 nd Round Consensus	Science Panelists	Technology & Engineering Panelists	Mathematics Panelists	Delphi Panel	Necessary & Sufficient Condition
Q4-1 - It is important that teachers do not have a discipline-specific identity. <i>n</i> = 11	No	3 - Nonessential	2 - Important 4 - Nonessential	1 - Important 1 - Nonessential	27% - Important 73% - Nonessential	No
Q4-2 - Disciplinary knowledge is a must. <i>n</i> = 11	Yes	2 – Essential 1- Important	3 – Essential 3- Important	1 – Essential 1- Important	54% - Essential 45% - Important	No
Q4-3 - Current staffing models in secondary schools make it difficult to develop integrated curriculum. <i>n</i> = 11	Yes	3- Important	3 – Essential 3- Important	1 – Essential 1- Important	45% - Essential 54% - Important	No
Q4-4 - Any educator can teach integrated STEM. <i>n</i> = 10	Yes	1 - Important 2 - Nonessential	1 - Important 4 - Nonessential	2 - Nonessential	20% - Important 80% - Nonessential	Nonessential

Table 10 (continued)

Q4-5 - It is easier to integrate STEM learning in the elementary grades, where teachers are generalists.	No	3 - Nonessential	5 - Important 2 - Nonessential	2 - Nonessential	27% - Important 58% - Nonessential	No
Q4-6 - STEM curriculum should be developed and standardized.	No	2 - Important 1 - Nonessential	5 - Important 2 - Nonessential	1 - Important 1 - Nonessential	67% - Important 33% - Nonessential	No
Q4-7 - The instructor should be selected based on his/her qualifications to adequately teach the curriculum.	No	3 - Important	7 - Important 0 - Nonessential	2 - Important	100% - Important 0% - Nonessential	Important
Q4-8 - Integrated STEM curriculum should not be determined by the instructor's ability. <i>n</i> = 11	No	3 - Nonessential	5 - Important 1 - Nonessential	2 - Nonessential	45% - Important 54% - Nonessential	No
Q4-9 - If properly prepared, a STEM teacher would understand where his/her shortcomings are and complete professional development to strengthen his/her skills. <i>n</i> = 11	Yes	3 - Important	5 - Essential 1 - Important	1 - Essential 1 - Important	82% - Essential 18% - Important	Essential
Q4-10 - It is nearly impossible for one to be proficient in all of the STEM disciplines, but one can become an effective STEM teacher by just understanding the pedagogical content knowledge.	No	2 - Important 1 - Nonessential	6 - Important 1 - Nonessential	2 - Important	83% - Important 17% - Nonessential	Important

Table 10 (continued)

Q4-11 - The background of the instructor enables the instructor to provide students with personal examples from experience that help build student interest and learning.	Yes	2 - Essential 1 - Important	4 - Essential 3 - Important	1 - Essential 1 - Important	50% - Essential 50% - Important	No
Q4-12 - STEM teacher training should be provided through professional development which allows teachers to demonstrate their ability to teach the curriculum. <i>n</i> = 11	Yes	2 - Essential 1 - Important	5 - Essential 1 - Important	1 - Essential 1 - Important	73% - Essential 27% - Important	No
Q4-13 - It is important that integrated STEM curriculum rotate the main content emphasis of projects to encourage student interest and participation.	No	2 - Important 1 - Nonessential	3 - Important 4 - Nonessential	1 - Important 1 - Nonessential	50% - Important 50% - Nonessential	No

Table 10 (continued)

Question 5 - If a STEM lesson fails to include one or more disciplines, should it be referred to as STEM education? Why or why not?

	2 nd Round Consensus	Science Panelists	Technology & Engineering Panelists	Mathematics Panelists	Delphi Panel	Necessary & Sufficient Condition
Q5-1 - It is nearly impossible to address all four disciplines in every lesson, particularly to the same depth and degree; but, it is important that all STEM content is included throughout the course.	No	2 - Important 1 - Nonessential	4 - Important 3 - Nonessential	1 - Important 1 - Nonessential	58% - Important 42% - Nonessential	No
Q5-2 - If a lesson fails to include more than one, it should not be called education, let alone STEM education.	No	1 - Important 2 - Nonessential	2 - Important 5 - Nonessential	2 - Nonessential	25% - Important 75% - Nonessential	Nonessential
Q5-3 - Most STEM lessons include all of the disciplines, but it is often easy to identify the disciplinary background of the curriculum writer based on the depth of content.	No	1 - Important 2 - Nonessential	3 - Important 4 - Nonessential	1 - Important 1 - Nonessential	42% - Important 58% - Nonessential	No
Q5-4 - Not all problems will require the use of all STEM disciplines. $n = 11$	No	3 - Important	6 - Important	2 - Important	100% - Important 0% - Nonessential	Important

Table 10 (continued)

Q5-5 - It is important that a student address the problem creatively using appropriate content or skills from all four STEM areas.	No	1 - Important 2 - Nonessential	3 - Important 4 - Nonessential	1 - Important 1 - Nonessential	50% - Important 50% - Nonessential	No
Q5-6 - It is important that students have an understanding of 'technology' in STEM beyond the use of computers as a tool to solve problems.	Yes	2 - Essential 1 - Important	6 - Essential 1 - Important	1 - Essential 1 - Important	75% - Essential 25% - Important	Essential
Q5-7 - The understanding of the term STEM comes from the disciplinary components of the acronym and should not be redefined to include areas outside of science, technology, engineering, or mathematics, although STEM education may contain other disciplinary components.	No	1 - Important 2 - Nonessential	2 - Important 5 - Nonessential	2 - Nonessential	25% - Important 75% - Nonessential	Nonessential
Q5-8 - STEM lessons should include as many of the four disciplines as possible.	Yes	3 - Essential	4 - Essential 3 - Important	1 - Essential 1 - Important	67% - Essential 33% - Important	No
Q5-9 - STEM is more than a lesson label and one project might include a heavier emphasis in one area than another as well as topic areas outside of the STEM fields.	Yes	1 - Essential 2 - Important	5 - Essential 2 - Important	2 - Essential	67% - Essential 33% - Important	No

Table 10 (continued)

Question 6 - What are barriers to implementing a STEM curriculum into all grades K-12?						
	2 nd Round Consensus	Science Panelists	Technology & Engineering Panelists	Mathematics Panelists	Delphi Panel	Necessary & Sufficient Condition
Q6-1 - The infrastructure of middle school, high school, and college coursework is based on individual disciplines.	Yes	3 - Essential	4 - Essential 3 - Important	2 - Important	58% - Essential 42% - Important	No
Q6-2 - The time required for problem and project-based learning is an issue.	No	3- Important	6 - Important 1 - Nonessential	2- Important	92% - Important 8% - Nonessential	Important
Q6-3 - The staffing of schools relies on discipline-specific instructors.	No	3- Important	5 - Important 2 - Nonessential	2- Important	83% - Important 17% - Nonessential	Important
Q6-4 - The expectations and culture of teachers, administrators, and parents are an issue.	Yes	3 - Essential	4 - Essential 3 - Important	3 - Essential	75% - Essential 25% - Important	Essential
Q6-5 - Many secondary schools lack the appropriate materials and resources necessary to implement integrated STEM education. <i>n</i> = 11	No	3- Important	5 - Important 1 - Nonessential	2- Important	90% - Important 10% - Nonessential	Important
Q6-6 - Many elementary schools lack the appropriate materials and resources necessary to implement integrated STEM education. <i>n</i> = 11	No	3- Important	4 - Important 2 - Nonessential	2- Important	82% - Important 18% - Nonessential	Important

Table 10 (continued)

Q6-7 - It is difficult for schools to find qualified staff to implement STEM.	Yes	1 - Essential 2 - Important	4 - Essential 3 - Important	2 - Essential	58% - Essential 42% - Important	No
Q6-8 - There are few barriers to implementing integrated STEM learning in grades K-5. <i>n</i> = 11	No	1 - Important 2 - Nonessential	5 - Important 1 - Nonessential	2 - Nonessential	55% - Important 45% - Nonessential	No
Q6-9 - Elementary teachers are very comfortable teaching reading, but not as much in STEM areas. <i>n</i> = 11	Yes	2 - Essential 1 - Important	4 - Essential 2 - Important	1 - Essential 1 - Important	55% - Essential 45% - Important	No
Q6-10 - Teacher preparation programs are too narrowly focused. <i>n</i> = 11	Yes	2 - Essential 1 - Important	5 - Essential 1 - Important	2 - Essential	82% - Essential 18% - Important	Essential
Q6-11 - K-8 teachers should be subject prepared similar to 9-12 teachers.	No	3 - Nonessential	3 - Important 4 - Nonessential	1 - Important 1 - Nonessential	33% - Important 67% - Nonessential	No
Q6-12 - Many teachers are uncomfortable teaching technology and engineering. <i>n</i> = 11	Yes	2 - Essential 1 - Important	5 - Essential 1 - Important	2 - Essential	82% - Essential 18% - Important	Essential
Q6-13 - Teachers need to have the prerequisite skillsets used for design-based learning approaches.	No	3- Important	7 - Important	2- Important	100% - Important 0% - Nonessential	Important
Q6-14 - State mandated tests limit the ability to integrate learning.	No	2 - Important 1 - Nonessential	6 - Important 1 - Nonessential	2- Important	83% - Important 17% - Nonessential	Important

Table 10 (continued)

Q6-15 - There is broad societal acceptance of the model that specialization occurs as a student progresses in school.	No	1 - Important	5 - Important 2 - Nonessential	1 - Important 1 - Nonessential	75% - Important 25% - Nonessential	Important
Q6-16 - Parents do not understand the expectations of integrated STEM education.	No	1 - Important	6 - Important 1 - Nonessential	1 - Important	92% - Important 8% - Nonessential	Important
Q6-17 - The community does not have a clear understanding of STEM education.	No	1 - Important	6 - Important 1 - Nonessential	1 - Important	92% - Important 8% - Nonessential	Important

Question 7 - Of all of the commercially available STEM curricula, what percentage do you feel are truly integrated? Please explain.

	2 nd Round Consensus	Science Panelists	Technology & Engineering Panelists	Mathematics Panelists	Delphi Panel	Necessary & Sufficient Condition
Q7-1 - The market for STEM curricula is not mainstream.	No	1 - Important 2 - Nonessential	3 - Important 4 - Nonessential	2 - Important	50% - Important 50% - Nonessential	No
Q7-2 - The majority of STEM curricula is discipline specific; therefore the STEM curricula developed by science experts varies greatly from the STEM curricula written by math experts. <i>n</i> = 11	No	2 - Important 1 - Nonessential	5 - Important 1 - Nonessential	2 - Important	82% - Important 18% - Nonessential	Important
Q7-3 - Very few of the available integrated STEM curricula are learner level appropriate across all content areas. <i>n</i> = 11	No	1 - Important 2 - Nonessential	4 - Important 2 - Nonessential	1 - Important 1 - Nonessential	55% - Important 45% - Nonessential	No

Table 10 (continued)

Q7-4 - Commercial developers have traditionally not focused their work on sound pedagogical practices, but rather cool activities.	No	2 - Important 1 - Nonessential	7 - Important	2 - Important	92% - Important 8% - Nonessential	Important
Q7-5 - Integrated STEM places an equal emphasis on the teaching and assessing—both technical and academic content. <i>n</i> = 11	Yes	2 - Essential 1 - Important	4 - Essential 2 - Important	1 - Essential 1 - Important	64% - Essential 36% - Important	No
Q7-6 - Many STEM programs have a narrow educational focus that includes a collection of activities and specific products.	No	2 - Important 1 - Nonessential	6 - Important 1 - Nonessential	2 - Important	83% - Important 17% - Nonessential	Important

Question 9 - In your opinion, how might a curriculum designer assure that a curriculum is truly integrated?

	2 nd Round Consensus	Science Panelists	Technology & Engineering Panelists	Mathematics Panelists	Delphi Panel	Necessary & Sufficient Condition
Q9-1 - The classroom teachers should be able to easily identify individual content standards within the curriculum.	No	3 - Important	6- Important 1- Nonessential	2 - Nonessential	75% - Important 25% - Nonessential	Important
Q9-2 - Traditional teaching methods are more efficient in time and materials than integrated STEM methods. <i>n</i> = 10	Yes	1 - Essential 2 - Important	1 - Essential 4 - Important	2 - Essential	40% - Essential 60% - Important	No

Table 10 (continued)

Q9-3 - STEM curriculum should include the alignment of technology and engineering concepts, processes, and approaches with grade-appropriate science and mathematics.	Yes	2 - Essential 1 - Important	5 - Essential 2 - Important	2 - Essential	75% - Essential 25% - Important	Essential
Q9-4 - When asked about an “integrated” lesson, students either cannot identify a specific discipline area or disagree on the discipline area covered in the lesson.	No	2 - Important 1 - Nonessential	4 - Important 3- Nonessential	1 - Important 3 - Nonessential	58% - Important 42% - Nonessential	No
Q9-5 - Curriculum should be developed by a team of experts representing a wide span of disciplines including academia and industry.	No	2 - Important 1 - Nonessential	6 - Important 1 - Nonessential	2 - Important	83% - Important 17% - Nonessential	Important
Q9-6 - Integrated STEM curriculum must align with the current goals and objectives of a school.	No	3 - Important	4 - Important 3- Nonessential	1 - Important 1 - Nonessential	67% - Important 33% - Nonessential	No
Q9-7 - Review of STEM curricula by an interdisciplinary panel is essential.	Yes	2 - Essential 1 - Important	7 - Essential	2 - Essential	8% - Essential 92% - Important	Important
Q9-8 - Curriculum must include a student-centered approach to solving real-world challenges.	Yes	3 - Essential	5 - Essential 2 - Important	2 - Essential	17% - Essential 83% - Important	Important

Table 10 (continued)

Q9-9 - The curriculum must be aligned to current and future workforce needs. <i>n</i> = 11	Yes	3 - Essential	3 - Essential 3 - Important	1 - Essential 1 - Important	40% - Essential 60% - Important	No
Q9-10 - STEM curriculum requires the application of subject matter from a variety of disciplines.	Yes	3 - Essential	7 - Essential	2 - Essential	100% - Essential 0% - Important	Essential

Question 10 - In your opinion, what is the driving force behind most commercially available STEM curriculum?

	2 nd Round Consensus	Science Panelists	Technology & Engineering Panelists	Mathematics Panelists	Delphi Panel	Necessary & Sufficient Condition
Q10-1 - Curriculum writers and textbook publishers see the potential market of STEM education. <i>n</i> = 11	Yes	1 - Essential 2 - Important	4 - Essential 2 - Important	2 - Essential	64% - Essential 36% - Important	No
Q10-2 - A great deal of federal and private grant money designated to address these needs of STEM is available to schools. <i>n</i> = 10	No	3 - Important	4 - Important 1 - Nonessential	1 - Important 1 - Nonessential	80% - Important 20% - Nonessential	Important
Q10-3 - Businesses and schools are pressured by the interest in STEM, despite understanding or not understanding the meaning of STEM. <i>n</i> = 10	Yes	3 - Essential	2 - Essential 4 - Important	2 - Essential	60% - Essential 40% - Important	No
Q10-4 - National standards affect curricula development and state adoption. <i>n</i> = 11	Yes	3 - Essential	4 - Essential 2 - Important	1 - Essential 1 - Important	73% - Essential 37% - Important	Essential

Table 10 (continued)

Q10-5 - Professional organizations support the development of STEM curriculum because the future workforce depends on the younger generation. <i>n</i> = 11	Yes	2 - Essential 1 - Important	6 - Essential	2 - Essential	91% - Essential 9% - Important	Essential
Q10-6 - National attention on STEM issues and the need for STEM graduates effect the development of curricula.	Yes	2 - Essential 1 - Important	6 - Essential 1 - Important	2 - Essential	83% - Essential 17% - Important	Essential

Note. Total of percentages is not 100% because of rounding and because of duplicate responses from participants.

In round three of the study the Delphi panel was given the descriptive statistical results and comments from round two participants. The panel reviewed the statements and ranked each in which there was a consensus in round two as (1) important or (2) essential. The statements in which a consensus was not established, prompted the participants to provide a ranking of (1) important or (2) nonessential. The responses from round three were analyzed using Microsoft Excel® software. Of the 85 statements concerning the defining characteristics of integrated STEM education, 17 were identified as essential, 23 as important, and 3 as nonessential. The consensus statements that did not achieve a necessary and sufficient condition of $\geq .75$ were considered to be important, but not essential. Additionally, statements in which a consensus was not achieved in round two, and in which a necessary and sufficient condition of $\geq .75$ was not achieved, are noted in Table 10. The researcher recommends that these statements, initially suggested by the expert panel as defining characteristics, are of value and will be discussed further in Chapter 5. The responses from round three that achieved a necessary and sufficient condition with an agreement level of $\geq .75$ can be seen in Table 11.

Table 11

Round Three Survey Responses with a Necessary and Sufficient Condition for Agreement (N=12 unless otherwise noted)

17 Essential Characteristics	Science Panelists (n = 3)	Technology & Engineering Panelists (n = 7)	Mathematics Panelists (n = 2)	Delphi Panel	Necessary & Sufficient Condition (≥ .75)
Q1-4 - The curriculum is comprised of project-based work with sufficient time for students to engage in designing, making, testing, reflecting and documenting.	2 - Essential 1 - Important	5 - Essential 2 - Important	1 - Essential	75% - Essential 25% - Important	Essential
Q2-3 - Includes the application and exploration of real-world problems requiring students to think and reason.	2 - Essential 1 - Important	7 - Essential	2 - Essential	92% - Essential 8% - Important	Essential
Q2-4 - Includes project-based work on open-ended problems.	2 - Essential	5 - Essential 2 - Important	2 - Essential	83% - Essential 17% - Important	Essential
Q3-1 - Problem-based instruction requires a shift in student expectations and engagement.	3 - Essential	4 - Essential 3 - Important	2 - Essential	75% - Essential 25% - Important	Essential
Q3-6 - Problem-based STEM lessons prepare a learner to effectively apply curriculum learned to real-life problems and support the development of logical reasoning skills.	3 - Essential	5 - Essential 2 - Important	1 - Essential 1 - Important	75% - Essential 25% - Important	Essential
Q3-7 - Authentic problems are essential for an integrated approach because problems are rarely, if ever, answered by using knowledge and skill from one discipline alone.	3 - Essential	7 - Essential	2 - Essential	100% - Essential 0% - Important	Essential

Table 11 (continued)

Q3-10 - Problem-based learning supports students with authentic, meaningful learning experiences.	3 - Essential	6 - Essential 1 - Important	1 - Essential 1 - Important	83% - Essential 17% - Important	Essential
Q4-9 - If properly prepared, a STEM teacher would understand where his/her shortcomings are and complete professional development to strengthen his/her skills. <i>n</i> = 11	3 - Important	5 - Essential 1 - Important	1 - Essential 1 - Important	82% - Essential 18% - Important	Essential
Q5-6 - It is important that students have an understanding of ‘technology’ in STEM beyond the use of computers as a tool to solve problems.	2 - Essential 1 - Important	6 - Essential 1 - Important	1 - Essential 1 - Important	75% - Essential 25% - Important	Essential
Q6-4 - The expectations and culture of teachers, administrators, and parents are an issue.	3 - Essential	4 - Essential 3 - Important	3 - Essential	75% - Essential 25% - Important	Essential
Q6-10 - Teacher preparation programs are too narrowly focused. <i>n</i> = 11	2 - Essential 1 - Important	5 - Essential 1 - Important	2 - Essential	82% - Essential 18% - Important	Essential
Q6-12 - Many teachers are uncomfortable teaching technology and engineering. <i>n</i> = 11	2 - Essential 1 - Important	5 - Essential 1 - Important	2 - Essential	82% - Essential 18% - Important	Essential
Q9-3 - STEM curriculum should include the alignment of technology and engineering concepts, processes, and approaches with grade-appropriate science and mathematics.	2 - Essential 1 - Important	5 - Essential 2 - Important	2 - Essential	75% - Essential 25% - Important	Essential
Q9-10 - STEM curriculum requires the application of subject matter from a variety of disciplines.	3 - Essential	7 - Essential	2 - Essential	100% - Essential 0% - Important	Essential
Q10-4 - National standards affect curricula development and state adoption. <i>n</i> = 11	3 - Essential	4 - Essential 2 - Important	1 - Essential 1 - Important	73% - Essential 37% - Important	Essential

Table 11 (continued)

Q10-5 - Professional organizations support the development of STEM curriculum because the future workforce depends on the younger generation. <i>n</i> = 11	2 - Essential 1 - Important	6 - Essential	2 - Essential	91% - Essential 9% - Important	Essential
Q10-6 - National attention on STEM issues and the need for STEM graduates effect the development of curricula.	2 - Essential 1 - Important	6 - Essential 1 - Important	2 - Essential	83% - Essential 17% - Important	Essential
23 Important Characteristics	Science Panelists (<i>n</i> = 3)	Technology & Engineering Panelists (<i>n</i> = 7)	Mathematics Panelists (<i>n</i> = 2)	Delphi Panel	Necessary & Sufficient Condition ($\geq .75$)
Q1-1 - The curriculum clearly addresses the appropriate grade-level educational standards/content of each individual discipline without isolating it to one discipline.	3 - Important	3 – Important 4 – Nonessential	2 - Nonessential	83% - Important 17% - Nonessential	Important
Q1-2 - Instruction in reading, writing, and numeracy are used to enable effective communication in problem-solving.	3 - Important	7 - Important	1 – Important 1 – Nonessential	92% - Important 8% - Nonessential	Important
Q2 –7 - Designed around several sets of national standards (such as CCSS, NGSS, ITEEA, etc.)	2 – Important 1 – Nonessential	6 – Important 1 – Nonessential	2 - Important	83% - Important 17% - Nonessential	Important
Q3-8 - Problem-based STEM lessons do not have to be product based, but should include the development of a hypothesis development and a defense.	3 - Important	4 – Important 3 – Nonessential	2 - Important	75% - Important 25% - Nonessential	Important

Table 11 (continued)

Q4-7 - The instructor should be selected based on his/her qualifications to adequately teach the curriculum.	3 - Important	7 - Important 0 - Nonessential	2 - Important	100% - Important 0% - Nonessential	Important
Q4-10 - It is nearly impossible for one to be proficient in all of the STEM disciplines, but one can become an effective STEM teacher by just understanding the pedagogical content knowledge.	2 - Important 1 - Nonessential	6 - Important 1 - Nonessential	2 - Important	83% - Important 17% - Nonessential	Important
Q5-4 - Not all problems will require the use of all STEM disciplines. $n = 11$	3 - Important	6 - Important	2 - Important	100% - Important 0% - Nonessential	Important
Q6-2 - The time required for problem and project-based learning is an issue.	3- Important	6 - Important 1 - Nonessential	2- Important	92% - Important 8% - Nonessential	Important
Q6-3 - The staffing of schools relies on discipline-specific instructors.	3- Important	5 - Important 2 - Nonessential	2- Important	83% - Important 17% - Nonessential	Important
Q6-5 - Many secondary schools lack the appropriate materials and resources necessary to implement integrated STEM education. $n = 11$	3- Important	5 - Important 1 - Nonessential	2- Important	90% - Important 10% - Nonessential	Important
Q6-6 - Many elementary schools lack the appropriate materials and resources necessary to implement integrated STEM education. $n = 11$	3- Important	4 - Important 2 - Nonessential	2- Important	82% - Important 18% - Nonessential	Important
Q6-13 - Teachers need to have the prerequisite skillsets used for design-based learning approaches.	3- Important	7 - Important	2- Important	100% - Important 0% - Nonessential	Important
Q6-14 - State mandated tests limit the ability to integrate learning.	2 - Important 1 - Nonessential	6 - Important 1 - Nonessential	2- Important	83% - Important 17% - Nonessential	Important

Table 11 (continued)

Q6-15 - There is broad societal acceptance of the model that specialization occurs as a student progresses in school.	1 - Important	5 - Important 2 - Nonessential	1 - Important 1 - Nonessential	75% - Important 25% - Nonessential	Important
Q6-16 - Parents do not understand the expectations of integrated STEM education.	1 - Important	6 - Important 1 - Nonessential	1 - Important	92% - Important 8% - Nonessential	Important
Q6-17 - The community does not have a clear understanding of STEM education.	1 - Important	6 - Important 1 - Nonessential	1 - Important	92% - Important 8% - Nonessential	Important
Q7-2 - The majority of STEM curricula is discipline specific; therefore the STEM curricula developed by science experts varies greatly from the STEM curricula written by math experts. <i>n</i> = 11	2 - Important 1 - Nonessential	5 - Important 1 - Nonessential	2 - Important	82% - Important 18% - Nonessential	Important
Q7-4 - Commercial developers have traditionally not focused their work on sound pedagogical practices, but rather cool activities.	2 - Important 1 - Nonessential	7 - Important	2 - Important	92% - Important 8% - Nonessential	Important
Q7-6 - Many STEM programs have a narrow educational focus that includes a collection of activities and specific products.	2 - Important 1 - Nonessential	6 - Important 1 - Nonessential	2 - Important	83% - Important 17% - Nonessential	Important
Q9-1 - The classroom teachers should be able to easily identify individual content standards within the curriculum.	3 - Important	6- Important 1- Nonessential	2 - Nonessential	75% - Important 25% - Nonessential	Important
Q9-5 - Curriculum should be developed by a team of experts representing a wide span of disciplines including academia and industry.	2 - Important 1 - Nonessential	6 - Important 1 - Nonessential	2 - Important	83% - Important 17% - Nonessential	Important

Table 11 (continued)

Q9-7 - Review of STEM curricula by an interdisciplinary panel is essential.	2 - Essential 1 - Important	7 - Essential	2 - Essential	8% - Essential 92% - Important	Important
Q9-8 - Curriculum must include a student-centered approach to solving real-world challenges.	3 - Essential	5 - Essential 2 - Important	2 - Essential	17% - Essential 83% - Important	Important
Q10-2 - A great deal of federal and private grant money designated to address these needs of STEM is available to schools. <i>n</i> = 10	3 - Important	4 - Important 1 - Nonessential	1 - Important 1 - Nonessential	80% - Important 20% - Nonessential	Important
3 Nonessential Characteristics	Science Panelists (<i>n</i> = 3)	Technology & Engineering Panelists (<i>n</i> = 7)	Mathematics Panelists (<i>n</i> = 2)	Delphi Panel	Necessary & Sufficient Condition (≥ .75)
Q4-4 - Any educator can teach integrated STEM. <i>n</i> = 10	1 - Important 2 - Nonessential	1 - Important 4 - Nonessential	2 - Nonessential	20% - Important 80% - Nonessential	Nonessential
Q5-2 - If a lesson fails to include more than one, it should not be called education, let alone STEM education.	1 - Important 2 - Nonessential	2 - Important 5 - Nonessential	2 - Nonessential	25% - Important 75% - Nonessential	Nonessential
Q5-7 - The understanding of the term STEM comes from the disciplinary components of the acronym and should not be redefined to include areas outside of science, technology, engineering, or mathematics, although STEM education may contain other disciplinary components.	1 - Important 2 - Nonessential	2 - Important 5 - Nonessential	2 - Nonessential	25% - Important 75% - Nonessential	Nonessential

Note. Total of percentages is not 100% because of rounding and because of duplicate responses from participants.

Summary

This study used a modified Delphi research method to address the inconsistencies in the goals and outcomes that existed between current STEM literature and commercially available STEM curricula. The results identified defining characteristics that set integrated STEM education curriculum apart from single discipline curricula. The data provided a set of categorical and defining curricular components that may be used to gauge whether an initiative, project, or curriculum should be referred to as integrated STEM education. The results in relation to each of the research questions were discussed in detail in Chapter 5.

Chapter 5: Summary, Findings, Limitations, and Recommendations

The National Academies report *Successful K-12 STEM Education* (2011) highlighted that our nation's current and future accomplishments in science, technology, engineering, and mathematics (STEM) begin in the K-12 classroom, and that understanding the need for integrated STEM education had become a priority for educators and policymakers. The characteristics of what comprises an integrated STEM curriculum were a struggle for educators because the interpretation of STEM education's objectives and results were not well defined. Many programs and initiatives routinely use the term STEM to describe their intended purposes or goals; yet, a definitive integrated model for K-12 STEM education curriculum, as well as a clear definition of what makes a curriculum STEM, could not be located by this researcher.

Understanding the urgency to gain an understanding of the defining characteristics of integrated STEM curriculum, this study solicited the expertise of science, technology and engineering, and mathematics educators to determine these characteristics and to establish a set of categorical and defining curricular components necessary for developing integrated STEM curriculum.

Summary of the Study

The purpose of this study was to obtain consensus concerning the defining characteristics of integrated STEM (Science, Technology, Engineering, and Mathematics) curriculum through the implementation of a modified Delphi study. The Delphi method, used in developing program structure, needs assessment, and resources (Meyer & Booker, 1990), was implemented to seek out the expert views of those involved in integrated STEM education. The ultimate goal of the study was to pursue the defining characteristics that set integrated STEM education curriculum apart from single discipline curricula and establish a set of categorical and defining curricular

components that must be used to gauge whether an initiative, project, or curriculum should be referred to as integrated STEM education. Additionally, this study examined whether significant differences in the agreement levels of the identified defining characteristics ranked as nonessential, important, or essential exist based on the participants disciplinary grounding in science, technology and engineering, or mathematics education.

Findings

A three-round Delphi study was designed to answer four research questions related to developing integrated STEM education curriculum, including:

1. What are the defining characteristics that set integrated STEM education curriculum apart from single-discipline curricula according to a panel of experts?
2. How might a set of categorical and defining curricular components be established for an integrated STEM education curriculum?
3. What defining components or characteristics can be used to gauge whether an initiative, project, or curriculum should be referred to as integrated STEM education?
4. Do significant differences exist from the defining characteristics based on disciplinary grounding in science, mathematics, or technology and engineering?

The first round of the study asked the participants to respond to 10 open-ended questions. These responses were used to develop the instrument employed in the second and third rounds. The second round survey invited the participants to rank each of the initial statements created by each of the participants when responding to the 10 open-ended questions in round one as “strongly disagree,” “disagree,” “neither agree or disagree,” “agree,” or “strongly agree.” The third round survey requested the participants to rank each of the survey statements in which there was a consensus as “important” or “essential,” and as “important” or “nonessential” for

statements in which a consensus was not established. The following is a summary of the results based on each research question.

Research Question 1: What are the defining characteristics that set integrated STEM education curriculum apart from single-discipline curricula according to a panel of experts?

The data to respond to research question 1 came from the first round survey question 1, which asked the participants to identify the essential curriculum components of integrated K-12 STEM education, and survey question 2, which asked the participants to define the items that differentiate a single discipline from an integrated STEM curriculum. These statements were further defined by consensus levels in round two, and necessary and sufficient condition for receiving a rank of “important,” “essential,” or “nonessential” characteristics.

Survey question 1, provided the essential component that must be included in an integrated STEM education curriculum: *project-based work with sufficient time for students to engage in learning*. The panel also defined additional important components, including that *the curriculum clearly addresses the appropriate grade-level educational standards/content of each individual discipline without isolating it to one discipline*, and that *instruction in reading, writing, and numeracy are used to enable effective communication in problem-solving*. Although a necessary and sufficient condition was not found by the Delphi panel due to the participants being divided on important versus essential, the results suggested that *curriculum must be centered around a project that places all the learning into context*. The research also proposed that *planning is essential to assure that the project is authentic, that learning should be controlled by the students*, and that the learning process should include *a final presentation to an authentic audience*. In addition, 58% of the participants suggested that an essential component was that the curriculum *includes real-world problem-solving application, including creative*

design, testing, and evaluation of solutions that utilize students' base knowledge of science and mathematics. Furthermore, 64% of the participants advocated that an important component was *skill development, including logical reasoning and computer skills that are interwoven throughout the curriculum.*

Survey question 2, acknowledged that the two essential characteristics that set integrated STEM education curriculum apart from single discipline curricula are 1) *the application and exploration of real-world problems requiring students to think and reason*, and 2) *the inclusion of project-based work on open-ended problems.* The panel also recognized that an important characteristic of integrated STEM curricula are *designed around several sets of national standards, such as CCSS, NGSS, NCTM, and ITEEA.* Although a necessary and sufficient condition was not established, the majority of participants determined it is essential that integrated STEM curricula *engage students in content from multiple disciplines* and those natural intersections *of learning should be utilized to bridge the study and application of combined conceptual knowledge.* Along with this result, 58% of the participants suggested it was important that integrated STEM curricula *utilize a meta-discipline approach, where ideally, no single subject or discipline defines the curriculum.* Additionally, 67% recommended that *crosscutting concepts such as critical thinking and problem solving should be used to support the interdisciplinary views of science and mathematics to better understand the world around us.*

Two of the issues that emerged in the literature on the barriers to implementing integrated learning are a lack of content knowledge and a misunderstanding of what it means to truly integrate learning (Stinson, Harkness, Meyer, & Stallworth, 2009; Wang, Moore, Roehri, & Park, 2011). Survey question 6, asked the participants to pinpoint the barriers to implementing a K-12 STEM curriculum. The responses from round one were organized by the researcher into

four distinct STEM implementation barriers: structure of schools (58%), teacher preparation (58%), standardized testing (25%), and parents and the community (25%). The responses from round one were put into statements, further defined by consensus levels in round two, and determined as necessary and sufficient in round three. The Delphi panel responded that it was essential to consider: 1) *the expectations and culture of teachers, administrators, and parents*, 2) *that teacher preparation programs may be too narrowly focused*, and 3) *that many teachers are uncomfortable teaching technology and engineering*. The panel unanimously agreed that it was important that *teachers need to have the prerequisite skillsets used for design-based learning approaches*. Ninety-two percent of the participants identified that additional barriers included: *the time required for problem and project-based learning*, *that parents do not understand the expectations of integrated STEM education*, and *that the community does not have a clear understanding of STEM education*. Ninety percent of the participants responded that it was important to consider that *many schools lack the appropriate materials and resources necessary to implement integrated STEM education*. In addition, 83% reported that implementing STEM education could be difficult because *the staffing of schools relies on discipline-specific instructors* and *state mandated tests may limit the ability to integrate learning*. One of the panelists commented that the key elements for integration were the “willingness of math, science, and engineering teachers to work together to promote support for all students in each of the content areas. Planning time would be the ultimate component. It is very hard to plan projects when you do not have time to collaborate.”

Survey question 9, asked the Delphi panel to provide suggestions on how a curriculum designer might assure that a curriculum is truly integrated. The responses from round one were put into statements which were further defined by consensus levels in round two and necessary

and sufficient condition for receiving a rank of “important,” “essential,” or “nonessential.” The Delphi panel unanimously responded that it was essential that *STEM curricula require the application of subject matter from a variety of disciplines and include the alignment of technology and engineering concepts, processes, and approaches with grade-appropriate science and mathematics*. The Delphi panel agreed that it was important to consider that *STEM curricula be reviewed by an interdisciplinary panel, be designed around a student-centered approach to solving real-world challenges, and that classroom teachers should be able to easily identify individual content standards within the curriculum*. Another important recommendation was that *curricula be developed by a team of experts representing a wide span of disciplines, including academia and industry*. Although a necessary and sufficient condition was not found, the majority of participants agreed that *integrated STEM curricula must align with the current goals and objectives of a school and be aligned to current and future workforce needs*. It was also interesting to note that the panel agreed in the second round that *traditional teaching methods may be more efficient in time and materials than integrated STEM methods*.

Participants commented that, “I completely disagree with this statement,” “efficiency is not meaningful in this context,” and that “they may be more efficient in time, but that does not mean they are superior in quality.” Another interesting comment suggested that views about integrated learning would change as states progress in their understanding of integration through the application of the Common Core State Standards and Next Generation Science Standards.

According to the results, these are the essential curriculum components of integrated K-12 STEM education. These components may be used to differentiate integrated STEM from single-discipline learning. Additionally the barriers to implementation and suggestions on

developing integrated curricula might be applied in the development of integrated STEM curricula.

Research Question 2: How might a set of categorical and defining curricular components be established for an integrated STEM education curriculum?

The data to respond to research question 2 came from the first round survey question 1, which asked the participants to list the essential curriculum components of integrated K-12 STEM education; survey question 2, which asked the participants to define the items that differentiate a single discipline from an integrated STEM curriculum; and survey question 7, which asked the participants to estimate the percentage of commercially available STEM curricula that were truly integrated. These statements were further defined by consensus level in round two and necessary and sufficient condition for receiving a rank of “important,” “essential,” or “nonessential” characteristics in round three. The results from survey questions 1 and 2, discussed above relating to the defining characteristics that set integrated STEM education curriculum apart from single-discipline curricula, also fit into the categorical and defining curricular components needed for an integrated STEM education curriculum.

In round one survey question 7, participants responded to the percentage of commercially available curricula that they feel are truly integrated. The responses from round one indicated that the panel believed that very few, if any, of the available curricula are truly integrated. The responses from round one were put into statements that were further defined by consensus level in round two and necessary and sufficient condition for receiving a rank of “important,” “essential,” or “nonessential.” The Delphi panel did not rank any of the statements created from the first round comments as essential. However, the panel suggested that important considerations included that *the majority of STEM curricula is discipline specific, that many*

STEM programs have a narrow educational focus that includes a collection of activities and specific products, and that commercial developers have traditionally not focused their work on sound pedagogical practices, but rather cool activities. Furthermore, 64% agreed that it was important that *integrated STEM place an equal emphasis on the teaching and assessing—both technical and academic content.* In addition, 55% responded that it was important to consider that *very few of the available integrated STEM curricula are learner level appropriate across all content areas.* Participant comments regarding truly integrated curricula were: “It is true that the available curricula are heavy in one area or another” and “most of the available STEM curricula places a heavy emphasis on engineering.” Another participant remarked that, “it is important that pedagogy become focused on integration ... correlated with the Common Core State Standards and Next Generation Science Standards.”

The panel agreed that very few of the commercially-available STEM curricula provide learners with a truly integrated learning experience. According to the results, these were the categorical and defining curricular components for an integrated STEM education curriculum. Each of these findings might also be applied in the development of integrated STEM curricula.

Research Question 3: What defining components or characteristics can be used to gauge whether an initiative, project, or curriculum should be referred to as integrated STEM education?

The data to respond to research question 3 came from the first round survey question 3 which asked if STEM lessons or activities must be problem-based; survey question 5, which asked the participants if a STEM lesson fails to include one or more disciplines, should it be referred to as STEM education; survey question 7, which asked about the percentage of commercially available STEM curricula that is truly integrated; and survey question 10, which questioned the driving forces behind these curricula. In addition, an attempt was made by the

researcher to determine which of the commercially-available STEM curricula, suggested by the Delphi panel, best represents integrated STEM in survey question 8. However, the participants did not reach a consensus in round two, and this question was removed from the round three survey. The suggested curricula from the first round survey can be found in Chapter 4 (see Table 8). Additionally, the responses from survey question 7, discussing the percentage of commercially-available STEM curricula that was truly integrated, was used above as defining curricular components of integrated STEM education curriculum, but may also be used as a gauge to determine if an initiative, project, or curriculum should be referred to as integrated STEM education.

In the first round survey question 3, which asked if all STEM lessons or activities should be problem-based, the responses are as follows. Forty-two percent of the participants responded “yes,” 42% responded “yes, but...” and 17% responded “yes, but...” in regard to whether all STEM lessons or activities should be problem based. The responses from round one were put into statements which were further defined by consensus level in round two and necessary and sufficient condition for receiving a rank of “important,” “essential,” or “nonessential” characteristics. The Delphi panel unanimously responded that it was essential to recognize that *authentic problems must be used in an integrated approach because problems are rarely, if ever, answered by using knowledge and skill from one discipline alone.* It was also essential that it be understood that *problem-based instruction requires a shift in student expectations and engagement* and that *problem-based learning supports students with authentic, meaningful learning experiences.* In addition, the panel determined that it was essential to understand that *problem-based STEM lessons prepare a learner to effectively apply curriculum learned to real-life problems and support the development of logical reasoning skills.*

The panel also identified that an important consideration of problem-based learning was that not all lessons *have to be product based, but should include the development of a hypothesis development and a defense*. Although a necessary and sufficient condition was not found by the Delphi panel, 64% of the panel agreed that it was important to realize that *some projects may include elements that are not problem-based (i.e., vocabulary, math instruction, etc.) and that these elements are essential in supporting student learning within problem-based lessons*. Additionally, 67% agreed that it was important that *STEM lessons should be problem-based to support critical thinking and problem solving in the real world* and 73% suggested that *these problems should allow students to design the entire approach to the solution*. It was interesting to note that although a consensus was not reached in the second round for the statement that *some content simply cannot be taught through a problem-based approach*, 60% of the panel agreed that *the most effective teaching strategy should be used for a particular topic*.

In the round one survey question 5, the participants were asked if a STEM lesson fails to include one or more disciplines should it be referred to as STEM education. Seventeen percent of the participants responded “yes,” 50% responded “no,” 25% did not give a definitive response, and 8% said that it was “impossible” for a curriculum to consistently include all four STEM disciplines. The responses from round one were placed into statements further defined by consensus level in round two and necessary and sufficient condition for receiving a rank of “important,” “essential,” or “nonessential” characteristics. The Delphi panel identified that it was essential *that students have an understanding of ‘technology’ in STEM beyond the use of computers as a tool to solve problems*. The panel unanimously reported that it was important to understand that *not all problems will require the use of all STEM disciplines*. Although a necessary and sufficient condition was not found, 67% of the participants suggested that it was

important that *STEM lessons should include as many of the four disciplines as possible* and that *STEM is more than a lesson label, for instance one project might include a heavier emphasis and in one area than another as well as topic areas outside of the STEM fields*. 58 percent of the participants agreed that *it is nearly impossible to address all four disciplines in every lesson, particularly to the same depth and degree; but, it is important that all STEM content is included throughout a course*.

In the round one survey question 10, the participants were asked about their beliefs concerning the driving forces behind commercially available STEM curricula. The driving forces defined in the participant responses from round one were organized by the researcher into four distinct groups: money (67%), national standards (17%), professional organizations (17%), and the attention at the state and national levels (33%). The responses from round one were put into statements which were further defined by consensus level in round two and necessary and sufficient condition for receiving a rank of “important,” “essential,” or “nonessential.” The Delphi panel responded that it was essential to consider that *professional organizations support the development of STEM curriculum because the future workforce depends on the younger generation* and that *national attention on STEM issues and the need for STEM graduates affect the development of curricula*. The Delphi panel also responded that an important, driving force was the amount of *federal and private grant money designated to address these needs of STEM that is available to schools*. Although a necessary and sufficient condition was not found, 73% of the participants indicated that it was essential to consider that *national standards affect curricula development and state adoption*. Finally, 64% agreed that it was essential to consider that *curriculum writers and textbook publishers see the potential market of STEM education*, and

the understanding that *businesses and schools are pressured by the interest in STEM, despite understanding, or not understanding, the meaning of STEM* is important.

According to the results, these components or characteristics can be used to gauge whether an initiative, project, or curriculum should be referred to as integrated STEM education. It was essential that STEM education be problem- or project-based, but other considerations are essential in providing learners with the most authentic learning experiences. Additionally, the driving forces behind most commercially-available driving forces must be considered in the development, selection, and implementation of integrated STEM curricula.

Research Question 4: Do significant differences exist from the defining characteristics based on disciplinary grounding in science, technology and engineering, or mathematics education?

The data to respond to question 4 came from the first round survey question 1, which requested the participants to pinpoint the essential curriculum components of integrated K-12 STEM; survey question 2, which identified the items that differentiate a single discipline from an integrated STEM curriculum; and survey question 4, which asked if STEM curriculum should be based primarily upon the disciplinary background of the instructor. Again, these statements were further defined by consensus levels in round two and necessary and sufficient condition for receiving a rank of “important,” “essential,” or “nonessential” characteristics in round three. The responses to survey questions 1, 2, and 4 were sorted by the participants’ disciplinary grounding in science, technology and engineering, and mathematics education. The defining characteristics in which there was total agreement by discipline are shown in Tables 12, 13, and 14.

Table 12

Defining Characteristics in Which a Total Agreement was Reached by Disciplinary Members

Defining Characteristic	Disciplinary Grounding			
	Science Panelists	Technology & Engineering Panelists	Mathematics Panelists	Delphi Panel
The curriculum clearly addresses the appropriate grade-level educational standards/content of each individual discipline without isolating it to one discipline.	3 - Important	3 – Important 4 – Nonessential	2 - Nonessential	83% - Important 17% - Nonessential
Instruction in reading, writing, and numeracy are used to enable effective communication in problem-solving.	3 - Important	7 - Important	1 – Important 1 – Nonessential	92% - Important 8% - Nonessential
The curriculum is comprised of project-based work with sufficient time for students to engage in designing, making, testing, reflecting and documenting.	2 – Essential 1 - Important	5 – Essential 2 - Important	2 - Essential	75% - Essential 25% - Important
Curriculum must be centered around a project that places all the learning into context. Planning is essential to assure that the project is authentic, that the learning is controlled by the students and that a presentation be made to an authentic audience.	3 - Important	4 – Essential 3 – Important	2 - Essential	50% - Essential 50% - Important

Four of the defining characteristics had total agreement levels within the three groups of science, technology and engineering, and mathematics education. Science educators ($n = 3$) unanimously supported the importance that the *curriculum clearly addresses the appropriate grade-level educational standards/content of each individual discipline without isolating it to one discipline*. Again, this was consistent with the panel's 83% necessary and sufficient condition for agreement as an important characteristic. Additionally, both science and technology and engineering ($n = 7$) educators' total agreement levels were consistent with the 92% necessary and sufficient condition for agreement on the characteristic that *instruction in reading, writing, and numeracy are used to enable effective communication in problem-solving*.

Mathematics educators ($n = 2$) were in total agreement that an essential characteristic was that *the STEM curriculum is comprised of project-based work with sufficient time for students to engage in designing, making, testing, reflecting, and documenting*. This belief aligned with the Delphi panels' necessary and sufficient condition ($\geq 75\%$) of an essential characteristic. The characteristic that *curriculum must be centered around a project that places all the learning into context* was viewed as important by science educators and as essential to mathematics educators. A necessary and sufficient condition for agreement was not reached (50% - important, 50% - essential) by the Delphi panel.

Table 13

Items That Differentiate Integrated STEM Curriculum in Which a Total Agreement was Reached by Disciplinary Members

Defining Characteristic	Disciplinary Grounding			
	Science Panelists	Technology & Engineering Panelists	Mathematics Panelists	Delphi Panel
Engages students in content from multiple disciplines.	2 – Essential 1 - Important	6 – Essential 1 - Important	2 - Important	67% - Essential 33% - Important
Includes the application and exploration of real-world problems requiring students to think and reason.	2 – Essential 1 - Important	7 - Essential	2 - Essential	92% - Essential 8% - Important
Includes project-based work on open-ended problems.	3 -Essential	5 – Essential 2 - Important	2 - Essential	83% - Essential 17% - Important
Utilizes a meta-discipline approach, where ideally, no single subject or discipline defines the curriculum.	1 – Important 2 – Nonessential	6 – Important 1 – Nonessential	2 - Nonessential	58% - Important 42% - Nonessential
Designed around several sets of national standards (such as CCSS, NGSS, ITEEA, etc.)	2 – Important 1 – Nonessential	6 – Important 1 – Nonessential	2 - Important	83% -- Important 17% - Nonessential

Five of the items that differentiate a single discipline from an integrated STEM curriculum had total agreement levels within the three groups of science, technology and engineering, and mathematics education. Mathematics educators ($n = 2$) were in 100% agreement that the items should *include the application and exploration of real-world problems*

requiring students to think and reason and project-based work on open-ended problems. This belief aligned with the Delphi panels' necessary and sufficient condition (75%) of about items that differentiate a single discipline from an integrated STEM curriculum. The item that curriculum should *engage students in content from multiple disciplines and be designed around several sets of national standards* were determined to be important by math educators. A necessary and sufficient condition for agreement was reached on the item concerning national standards, but was not reached for the item about engaging students in multiple disciplines. Technology and engineering educators ($n = 7$) also agreed that an essential item was that STEM curriculum *include the application and exploration of real-world problems requiring students to think and reason*, while science educators ($n = 3$) unanimously agreed that *project-based work on open-ended problems* is an essential item.

Two of the issues that arose from the literature on the currently operating models of integrated STEM education were that of teacher preparation and certification, and that many of the curricula reflect the disciplinary background of the curriculum developer. Survey question 4, questioned if STEM curriculum should be based primarily upon the disciplinary background of the instructor. In round one 8% of the participants responded "yes," 33% responded "no," and 58% responded "maybe." The responses from round one were put into statements that were further defined by consensus level in round two and necessary and sufficient condition for receiving a rank of "important," "essential," or "nonessential." In round 2, the panel disagreed on the statement that any educator can teach integrated STEM. Two of the technology and engineering education participants did not choose to rank this statement as an important or nonessential consideration. One of these participants commented that "this really depends." The other commented they "don't know how the choices apply to a factual or counterfactual

response.” Another panelist that ranked this as a nonessential consideration commenting that “I do not agree with this statement.” The Delphi panel did agree that it is essential to consider the statements *if properly prepared, a STEM teacher would understand where his/her shortcomings are and complete professional development to strengthen his/her skills*. The panel unanimously agreed that it is important that *the instructor should be selected based on his/her qualifications to adequately teach the curriculum*.

Although a necessary and sufficient condition was not found due by the Delphi panel, 83% of the panel agreed that *it is nearly impossible for one to be proficient in all of the STEM disciplines, but one can become an effective STEM teacher by just understanding the pedagogical content knowledge*. Sixty-seven percent of the panel agreed that it was important that *STEM curriculum be developed and standardized*. Furthermore, the panel agreement was split on determining if *it is important that integrated STEM curriculum rotate the main content emphasis of projects to encourage student interest and participation*.

Table 14 below displays the statements in which there was total agreement by discipline when asked if STEM curriculum should be based primarily upon the disciplinary background of the instructor.

Table 14

Items on the Disciplinary Background of the Instructor in Which a Total Agreement was Reached by Disciplinary Members

Defining Characteristic	Disciplinary Grounding			
	Science Panelists	Technology & Engineering Panelists	Mathematics Panelists	Delphi Panel
It is important that teachers do not have a discipline-specific identity. <i>n</i> = 11	3 - Nonessential	2 – Important 4 – Nonessential	1 – Important 1 – Nonessential	27% - Important 73% - Nonessential
Current staffing models in secondary schools make it difficult to develop integrated curriculum. <i>n</i> = 11	3 - Important	3 – Essential 3 – Important	1 – Essential 1 – Important	45% - Essential 54% - Important
Any educator can teach integrated STEM. <i>n</i> = 10	1 – Important 2 – Nonessential	1 – Important 4 – Nonessential	2 - Nonessential	20% - Important 80% - Nonessential
It is easier to integrate STEM learning in the elementary grades, where teachers are generalists.	3 - Nonessential	5 – Important 2 – Nonessential	2 - Nonessential	42% -- Important 58% - Nonessential
The instructor should be selected based on his/her qualifications to adequately teach the curriculum.	3 - Important	7 - Important	2 - Important	100% -- Important 0% - Nonessential
Integrated STEM curriculum should not be determined by the instructor's ability. <i>n</i> = 11	3 - Nonessential	5 – Important 1 – Nonessential	2 - Nonessential	45% -- Important 54% - Nonessential

Table 14 (continued)

If properly prepared, a STEM teacher would understand where his/her shortcomings are and complete professional development to strengthen his/her skills. $n = 11$	3 - Essential	5 – Essential 1 – Important	1 – Essential 1 – Important	82% - Essential 18% - Important
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Note. Total of percentages is not 100% because of rounding and duplicate participant responses.

Seven of the items regarding if a STEM curriculum should be based primarily upon the disciplinary background of the instructor had total agreement levels within the three groups of science, technology and engineering, and mathematics education. Science educators ($n = 3$) were in total agreement that an essential consideration was that *if properly prepared, a STEM teacher would understand where his/her shortcomings are and complete professional development to strengthen his/her skills*. This finding supports the Delphi panels' necessary and sufficient condition (75%) for the consideration in regards to the disciplinary background of the STEM instructor. All three groups were in agreement that an important consideration was that *the instructor should be selected based on his/her qualifications to adequately teach integrated STEM curriculum*. Science educators all agreed that an important consideration was that *current staffing models in secondary schools make it difficult to develop integrated curriculum*. A necessary and sufficient condition for agreement was not reached (54% - important, 45% - essential) by the Delphi panel.

Science educators all agreed that a nonessential consideration was the consideration *that STEM teachers do not have a discipline-specific identity*. This item did not reach a necessary and sufficient condition (75%); however, 73% of the participants agreed that this was nonessential.

Mathematics educators ($n=2$) were in 100% agreement that the consideration that *any educator can teach integrated STEM*, which did have a necessary and sufficient condition by the panel. Both science and mathematics educators were in total agreement that the consideration that *integrated STEM curriculum should not be determined by the instructor's ability and that it is easier to integrate STEM learning in the elementary grades, where teachers are generalists*. This did stand out against the technology and engineering educators responses that these were important consideration with agreements of 83% ($n = 6$) and 71% ($n = 7$) respectively. Two of the technology and engineering educators did not respond to multiple questions throughout the round three survey, including items concerning the disciplinary background of the instructor. Additionally, the larger number of technology and engineering panelists compared to science and mathematics may have affected the ability of the group to reach total consensus throughout round three.

The purpose of this study was to obtain consensus concerning the defining characteristics of integrated STEM curriculum through the implementation of a modified Delphi study. The results of this study show total agreement on two essential characteristics. The results also indicated that very few, if any, of the commercially-available STEM curricula provided a truly integrated learning experience. This was counter to the findings of the study that reveals that integrated STEM education requires the application of subject matter from a variety of disciplines. Furthermore, the study indicated that authentic problems were essential for an integrated approach because problems are rarely, if ever, answered by using knowledge and skill from one discipline alone.

Conclusions for Practice

Eighty-five initial statements concerning the defining characteristics of integrated STEM education were proposed by an expert panel made up of individuals representing science, technology and engineering, and mathematics education. The data identified 17 of these characteristics as essential and 23 as important. These defining curricular components were recommended for use to determine whether an initiative, project, or curriculum should be referred to as integrated STEM education.

According to Bybee (2010), the purpose of STEM education should include the “conceptual understandings, procedural skills, and abilities” needed to solve problems related to the “personal, social, and global issues” involving the integration of “interrelated” and “complementary components” of science, technology, engineering, and mathematics (p. 31). The researcher recommended that the curricular components, goals and outcomes, and items related to teacher preparation and certification displayed in Table 15 be used in the development, preparation, and implementation of integrated STEM education.

Table 15

Recommendations for Integrated STEM Education Practice

Curricular Components

- ✓ Curricula are developed using sound pedagogical practices, including a student-centered approach to solving real world challenges through project-based work on open-ended problems.
- ✓ Curricula are designed around several sets of national standards (such as CCSS, NGSS, ITEEA, etc.).
- ✓ Curricula includes the alignment of technology and engineering concepts, processes, and approaches the addresses the appropriate grade-level educational standards/content of each individual discipline without isolating it to one discipline.
- ✓ Curricula are developed by a team of experts representing a wide span of disciplines including academia and industry and reviewed by an interdisciplinary panel.

Table 15 (continued)

Goals and Outcomes
<ul style="list-style-type: none"> ✓ The application of subject matter from a variety of disciplines through problem and project-based learning. ✓ The understanding that problems are rarely, if ever, answered by using knowledge and skill from one discipline alone. ✓ The engagement of students in authentic, meaningful learning experiences that include designing, making, testing, reflecting and documenting. ✓ The application and exploration of real-world problems requiring students to think and reason. ✓ The understanding of ‘technology’ beyond the use of computers as a tool to solve problems. ✓ Clear communication of the expectations of integrated STEM education.
Teacher Preparation and Certification
<ul style="list-style-type: none"> ✓ The instructor should be selected based on his/her qualifications to adequately teach the curriculum. ✓ Teachers need to have the prerequisite skillsets used for design-based learning approaches including problem and project-based learning. ✓ Teacher preparation programs are too narrowly focused. ✓ Many teachers are uncomfortable teaching technology and engineering, and proper teacher preparation must include instruction in technology and engineering. ✓ Teachers must have an understanding of the pedagogical content knowledge of all STEM disciplines. ✓ Professional development must be available to STEM teachers to strengthen his/her skills, including a true understanding of the importance of professional organizations. ✓ Integrated STEM instruction requires a shift in student expectations and engagement. ✓ The understanding and expectations of teachers, administrators, parents, and the community regarding integrated STEM education must be clearly communicated. ✓ Understanding of national standards and state adoption is essential. ✓ Understanding of how to access federal and private grant money designated to address the lack the appropriate materials and resources necessary to implement K-12 integrated STEM education.

Converging on Bybee’s (2010) purpose of STEM education, along with the curricular components, goals and outcomes, and items related to teacher preparation and certification listed

in Table 15, these considerations may assist educators involved in integrated STEM education. Teacher preparation programs must provide pre-service teachers with a deep understanding of problem- and project-based instructional strategies. These preparation programs must also include instruction on design-based learning including the approaches taught in technology and engineering education. The researcher also suggested that, although not specifically mentioned by the expert panelists in this study, integrated STEM curriculum must provide learners with the ability to collaborate with others when addressing a problem and proposing solutions (Wagner, 2008).

Study Limitations

A number of limitations existed within this study. These limitations include the Delphi methodology used and the limited number of participants, particularly in science and mathematics. These limitations prohibit the ability to generalize the results of this study. It was difficult for the researcher to identify science and mathematics educators involved in truly integrated STEM education, beyond those who have only placed a 'STEM' label on traditional science and mathematics curricula.

This study was also limited by the perspectives of the Delphi panelists. The round three survey responses indicated that two of the participants failed to respond to some of the statements with a rank of "essential," "important," and "nonessential." They commented that they could not adequately respond to the statements with the available descriptors. Several attempts were made to contact these participants by telephone. Unfortunately, they were unavailable during the time frame of the study.

Recommendations for Future Research

The researcher recommended that a more traditional Delphi study with a larger sample of those involved in developing and implementing integrated STEM curricula be conducted. Furthermore, the researcher specifically suggested that the panelists be asked “how they would have modified this statement in order to be able to agree” rather than employing an “additional comments” section along with the statement.

The definition of integrated STEM education requires that it be more clearly and thoroughly defined. One of the participants continually referred to the STEM teacher, as if STEM represented a specific discipline or class. Although, a precise definition based on the literature was provided to participants, the researcher believed that there is a division on the general understanding and meaning of what comprised integrated STEM education.

The definition of project-based learning needed to be more clearly defined and differentiated from problem-based learning. Although research supported the uniqueness of these two approaches, it seemed that there was confusion on the interpretive use of these terms. One of the participants commented, “I think there are many questions around project-based learning. What a project is? How students learn? What the results should be? It’s not just a question of what the most effective method of teaching is, but the most general context of learning and transfer.” This issue, as well as the integration of content, should be addressed through future research. This was especially true as the Next Generation Science Standards (which place a heavy emphasis on technology and engineering) and the Common Core State Standards both call for student performance expectations across disciplinary boundaries.

Summary

The results of this study answered four research questions related to developing integrated STEM education curriculum, and add to the literature on the definitive attributes of what embodies STEM education. The panel agreed that the majority of STEM curricula were not integrated, but discipline specific curricula, as well as many STEM programs, have a narrow educational focus that includes a collection of activities and specific products that may not be developed using sound pedagogical practices.

The Delphi panel agreed that essential characteristics of integrated STEM education should include project-based work on open-ended problems, appropriate grade-level educational standards/content of each STEM discipline (without isolating it to one discipline), and instruction in reading, writing, and numeracy to enable effective communication in problem-solving. Also, integrated STEM education curriculum should include the application and exploration of real-world problems requiring students to think and reason and be designed around several sets of national standards (such as CCSS, NGSS, NCTM, and ITEEA).

Additional considerations when developing and implementing integrated STEM curricula include clarifying the expectations of students, teachers, administrators, parents, and the community. The panel also suggested that many schools lack the appropriate materials and resources necessary to implement integrated STEM education.

The structure of our school systems, including the time required for problem- and project-based learning, and the fact that the staffing of schools currently relies on discipline-specific instructors, might to be explored. It was also acknowledged that many teachers were uncomfortable teaching technology and engineering and perhaps teacher preparation programs were too narrowly focused. Educators must have the prerequisite skillsets needed for 21st

century design-based learning approaches. Recognizing the need and taking steps toward bringing integrated STEM education into our nation's schools will continue to be a top priority for educators.

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Appendix A: IRB Approval

January 14, 2013

MEMORANDUM

TO: Vinson Carter
Michael Daugherty

FROM: Ro Windwalker
IRB Coordinator

RE: New Protocol Approval

IRB Protocol #: 12-09-129

Protocol Title: *Defining Characteristics of an Integrated STEM Education Curriculum*

Review Type: EXEMPT EXPEDITED FULL IRB

Approved Project Period: Start Date: 01/14/2013 Expiration Date: 01/13/2014

Your protocol has been approved by the IRB for the first phase of the survey. Future surveys must be submitted to and approved by the IRB as modifications to this protocol before implementation. Protocols are approved for a maximum period of one year. If you wish to continue the project past the approved project period (see above), you must submit a request, using the form *Continuing Review for IRB Approved Projects*, prior to the expiration date. This form is available from the IRB Coordinator or on the Research Compliance website (<http://vpred.uark.edu/210.php>). As a courtesy, you will be sent a reminder two months in advance of that date. However, failure to receive a reminder does not negate your obligation to make the request in sufficient time for review and approval. Federal regulations prohibit retroactive approval of continuation. Failure to receive approval to continue the project prior to the expiration date will result in Termination of the protocol approval. The IRB Coordinator can give you guidance on submission times.

This protocol has been approved for 25 participants. If you wish to make *any* modifications in the approved protocol, including enrolling more than this number, you must seek approval *prior to* implementing those changes. All modifications should be requested in writing (email is acceptable) and must provide sufficient detail to assess the impact of the change.

If you have questions or need any assistance from the IRB, please contact me at 210Administration Building, 5-2208, or irb@uark.edu.

Appendix B: Prospective Letter to Participants



314 Peabody Hall ♦ Fayetteville, Arkansas 72701 ♦ (479) 575-3076 ♦ (479) 575-6676 (Fax)
 Department of Curriculum & Instruction, College of Education & Health Professions

Integrated STEM Education Study

Hello Dr. _____,

My name is Vinson Carter and I am an instructor of technology and engineering education at the University of Arkansas. I am currently working on my dissertation research under the direction of Dr. Michael Daugherty. I am looking for a panel of experts in integrated STEM education, and I invite you to read the following paragraphs about my study. Thank you in advance for your consideration.

To assist those who practice research, teach, and develop curriculum in integrated STEM education, I am undertaking a study to determine the defining characteristics of integrated STEM education curricula. Ultimately, my goal is to provide STEM educators with research based information to guide the development and implementation of integrated K-12 STEM education. The results of the study are important to the field of STEM education and will provide invaluable insight into the defining characteristics that comprise integrated K-12 STEM education.

You are invited to participate in this study because of your involvement in STEM Education. The study will be a three round Delphi method. If you elect to participate, I will send a separate mailing inviting you to list and explain several key topics that you believe should receive the profession's highest priority in developing and implementing integrated STEM education. I will then build on these topics with the goal of reaching consensus and a rank ordered list throughout the following surveys.

Would you be willing to be part of my expert panel? Additionally, if you have a colleague in integrated STEM education that you feel would be a good fit for this study I would greatly appreciate it if you would recommend them to me by providing me with their contact information.

Sincerely,

Vinson Carter

University of Arkansas

Department of Curriculum and Instruction

Appendix C: Round One Letter to Participants



314 Peabody Hall ♦ Fayetteville, Arkansas 72701 ♦ (479) 575-3076 ♦ (479) 575-6676 (Fax)
Department of Curriculum & Instruction, College of Education & Health Professions

February 1, 2013

To: Prospective Research Participants
From: Vinson Carter
Reference: Integrated STEM Education

I need your valuable insight. I am conducting research to determine the defining characteristics of integrated STEM education curriculum. The *Determining the Defining Characteristics of an Integrated STEM Education Curriculum Round One Study* is available at the following link:

[Click here for the survey.](#)

Please take a few minutes to complete the first of three on-line surveys and submit it no later than February 15. Your honest and professional responses are needed so that an accurate analysis can be made concerning the defining characteristics that are essential in developing integrated STEM education curriculum. Your participation will involve completing three on-line surveys and should take no more than 20-30 minutes for each survey. Your involvement in the study is voluntary, and you may choose not to participate or to stop at any time without penalty. Be assured that your responses will be kept confidential to the extent allowed by law and University policy; only group results of this research will be reported. The results of the research study may be published, but your name will not be used. The published results will be presented in summary form only, and your identity will not be associated with your responses in any published format.

The findings from this project may provide STEM educators with research based information to guide the development and implementation of integrated K-12 STEM education. The results of the study are important to the field of STEM education and will provide invaluable insight into

the defining characteristics that comprise integrated K-12 STEM education. There are no known risks or discomforts associated with this research.

Please note that Internet communications are insecure and there is a limit of confidentiality that can be guaranteed due to the technology itself. If you are not comfortable with the level of confidentiality provided by the Internet, please feel free to print out a copy of each survey as they become available, fill them out by hand, and mail it to me at the address on the survey, with no return on the envelope.

If you have questions or concerns about this study, you may contact me, Vinson Carter, at _____ or by e-mail at _____, or Michael K. Daugherty at _____ or by e-mail at _____. For questions or concerns about your rights as a research participant, please contact Ro Windwalker, the University's IRB Coordinator, at (479) 575-2208 or by e-mail at irb@uark.edu.

Thank you in advance for your prompt return of the first survey and commitment for the additional 2 that will follow. Be assured that your input is providing a valuable service to the profession of STEM education. We will be pleased to send you a summary of the survey results if you desire. By completing and returning this survey, you are agreeing to participate in the above described research project. Please keep this letter for your records. Thank you very much for your cooperation on this project.

Sincerely,

Vinson Carter
University of Arkansas
Department of Curriculum and Instruction

Appendix D: Round One Instrument

DEFINING CHARACTERISTICS OF AN INTEGRATED STEM CURRICULUM IN K-12 EDUCATION

Your honest and professional responses are needed so that an accurate analysis can be made concerning the defining characteristics that are essential in developing integrated STEM education curriculum. Be assured that your responses will be kept confidential to the extent allowed by law and University of Arkansas policy; only group results of this research will be reported. The results of the research study may be published, but your name will not be used. The published results will be presented in summary form only, and your identity will not be associated with your responses in any published format.

The findings from this project may provide STEM educators with research based information to guide the development and implementation of integrated K-12 STEM education. The results of the study are important to the field of STEM education and will provide invaluable insight into the defining characteristics that comprise integrated K-12 STEM education.

* Required

What is your primary discipline? *

- Science Education
- Technology and/or Engineering Education
- Mathematics Education
- Other:

What is your gender? *

- Female
- Male

What is your age range? *

- 20-30 years
- 31-40 years
- 41-50 years
- 51-60 years
- 61-70 years
- 71 years or older
- I prefer not to provide my age

Highest Level of Education Completed *

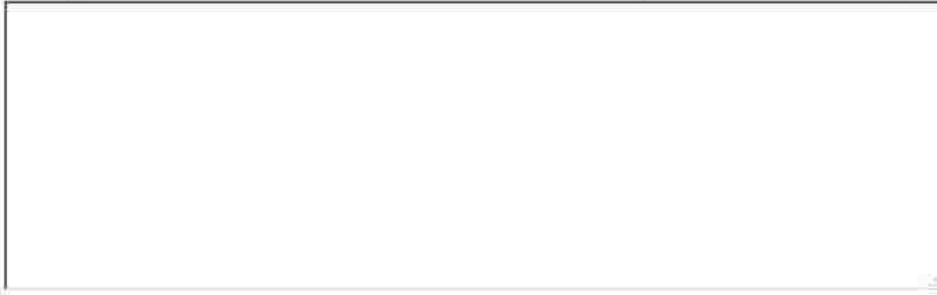
- Bachelors
- Masters
- Ed.S.
- Ed. D./Ph. D
- Other:

Current Employment Status *

- K-6 Teacher
- 7-12 Teacher
- University Professor
- Administration
- Other:

What are essential curriculum components of integrated K-12 STEM Education? ***What are items that differentiate a single discipline from an integrated STEM curriculum? ***

Ideally, should all STEM lessons or activities be problem-based? Why or why not? *



Should STEM curriculum be based primarily upon the disciplinary background of the instructor? Why or why not? *



If a STEM lesson fails to include one or more disciplines, should it be referred to as STEM education? Why or why not? *




What are barriers to implementing a STEM curriculum into all grades K-12? *



In your opinion, what is the driving force behind most commercially available STEM curriculum? *

A large, empty rectangular text box with a thin black border, intended for the respondent to provide their answer to the question above.

In your opinion, how might a curriculum designer assure that a curriculum is truly integrated? *

A large, empty rectangular text box with a thin black border, intended for the respondent to provide their answer to the question above.

Of all of the commercially available STEM curricula, what percentage do you feel are truly integrated? Please explain. *

A large, empty rectangular text box with a thin black border, intended for the respondent to provide their answer to the question above.

Of the commercially available STEM curricula, which do you feel best represents integrated STEM? Please explain. *

Submit

Appendix E: Round Two Letter to Participants

314 Peabody Hall ♦ Fayetteville, Arkansas 72701 ♦ (479) 575-3076 ♦ (479) 575-6676 (Fax)
Department of Curriculum & Instruction, College of Education & Health Professions

**Round 2 - Integrated STEM Education
Delphi Study**

Dear _____,

Thank you very much for agreeing to be a participant in my study to determine the defining characteristics of an integrated STEM education curriculum, and for your continued support. As you will recall, the purpose of Round 1 of this Delphi study was to identify the defining characteristics of an integrated STEM education curriculum.

Round 2 of this study will seek to draw consensus on the topics that you believe are important to establish a better knowledge base for integrated STEM education. The responses from the open-ended questions in Round 1 have been “reviewed and categorized to create a valid and reliable list of structured and Likert-type closed-ended questionnaire items to be used for the second round of the Delphi study” (Sema & Kasim, 2012, p. 3).

Please complete the attached survey, save the Word® document as Round 2, and forward it to me, Vinson Carter at _____. Your responses will remain confidential. **Please return your response by Monday, March 24, 2013.**

Sincerely,

Vinson Carter

University of Arkansas
Department of Curriculum and Instruction

Appendix F: Round Two Instrument

DEFINING CHARACTERISTICS OF AN INTEGRATED STEM

CURRICULUM IN K-12 EDUCATION

Q1 - Based on the collective Delphi panel's responses to identify the essential curriculum components of integrated K-12 STEM Education, I have developed the following statements. Please identify the degree to which you agree or disagree with the following statements. If you have comments about a particular statement, please add that to the "comments section" at the end of Q1.

1. The curriculum clearly addresses the appropriate grade-level educational standards/content of each individual discipline without isolating it to one discipline.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

2. Instruction in reading, writing, and numeracy are used to enable effective communication in problem-solving.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

3. Real-world problem-solving and application including creative design, testing, and evaluation of solutions are used to utilize students' base knowledge of science and mathematics.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

4. The curriculum is comprised of project-based work with sufficient time for students to engage in designing, making, testing, reflecting and documenting.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

5. Skill development, including logical reasoning and computer skills are interwoven.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

6. Curriculum must be centered around a project that places all the learning into context. Planning is essential to assure that the project is authentic, that the learning is controlled by the students and that a presentation be made to an authentic audience.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

Q1 - Comments, if any:

Q2 - Based on the collective Delphi panel's responses to identify items that differentiate a single discipline from an integrated STEM curriculum, I have developed the following statements. Please identify the degree to which you agree or disagree with the following statements. If you have comments about a particular statement, please add that to the "comments section" at the end of Q2.

1. Engages students in content from multiple disciplines.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

2. Natural intersections of learning are utilized to bridge the study and application of combined conceptual knowledge.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

3. Includes the application and exploration of real-world problems requiring students to think and reason.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

4. Includes project-based work on open-ended problems.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

5. Utilizes a meta-discipline approach, where ideally, no single subject or discipline defines the curriculum.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

6. Delivers crosscutting concepts such as critical thinking and problem solving to support the interdisciplinary views of science and mathematics to better understand the world around us.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

7. Designed around several sets of national standards (such as CCSS, NGSS, ITEEA, etc.)

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

Q2 - Comments, if any:

Q3 - Ideally, should all STEM lessons or activities be problem-based? Why or why not?

Delphi Panel Responses: Yes: n = 5 Yes, but ...: n = 5 No: n = 0 No, but ...: n = 2

I have developed the following statements based on the collective Delphi panel's responses to the above question. Please identify the degree to which you agree or disagree with the following statements. If you have comments about a particular statement, please add that to the "comments section" at the end of Q3.

1. Problem-based instruction requires a shift in student expectations and engagement.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

2. Some educators would argue that some content simply cannot be taught through a problem-based approach.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

3. This is a question of what is the most effective teaching strategy for that particular topic.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

4. Background and cognitive knowledge must be established before students are ready for problem-based experiences.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

5. Some projects may include elements that are not problem-based (i.e., vocabulary, math instruction, etc.). These elements are essential in supporting student learning within problem-based lessons.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

6. Problem-based STEM lessons prepare a learner to effectively apply curriculum learned to real-life problems and support the development of logical reasoning skills.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

7. Authentic problems are essential for an integrated approach because problems are rarely, if ever, answered by using knowledge and skill from one discipline alone.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

8. Problem-based STEM lessons do not have to be product based, but should include the development of a hypothesis development and a defense.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

9. STEM lessons should be problem-based to support critical thinking and problem solving in the real-world.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

10. Problem-based learning supports students with authentic, meaningful learning experiences.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

11. Problems are real world issues that students must tackle. There are no existing answers and the students have to design the entire approach to the solution. Solutions to a problem are not by nature related to the solutions arrived at by others.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

Q3 - Comments, if any:

Q4 - Should STEM curriculum be based primarily upon the disciplinary background of the instructor? Why or why not?

Delphi Panel Responses: Yes: n = 1 No: n = 4 Maybe: n = 7

I have developed the following statements based on the collective Delphi panel's responses to the above question. Please identify the degree to which you agree or disagree with the following statements. If you have comments about a particular statement, please add that to the "comments section" at the end of Q4.

1. It is important that teachers do not have a discipline-specific identity.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

2. Disciplinary knowledge is a must.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

3. Current staffing models in secondary schools make it difficult to develop integrated curriculum.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

4. Any educator can teach integrated STEM.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

5. It is easier to integrate STEM learning in the elementary grades, where teachers are generalists.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

6. STEM curriculum should be developed and standardized.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

7. The instructor should be selected based on his/her qualifications to adequately teach the curriculum.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

8. Integrated STEM curriculum should not be determined by the instructor's ability.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

9. If properly prepared, a STEM teacher would understand where his/her shortcomings are and complete professional development to strengthen his/her skills.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

10. It is nearly impossible for one to be proficient in all of the STEM disciplines, but one can become an effective STEM teacher by just understanding the pedagogical content knowledge.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

11. The background of the instructor enables the instructor to provide students with personal examples from experience that help build student interest and learning.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

12. STEM teacher training should be provided through professional development which allows teachers to demonstrate their ability to teach the curriculum.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

13. It is important that integrated STEM curriculum rotate the main content emphasis of projects to encourage student interest and participation.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

Q4 - Comments, if any:

Q5 - If a STEM lesson fails to include one or more disciplines, should it be referred to as STEM education? Why or why not?

Delphi Panel Responses: Yes: n = 2 No: n = 6 Indefinite: n = 3 It is impossible : n = 1

I have developed the following statements based on the collective Delphi panel's responses to the above question. Please identify the degree to which you agree or disagree with the following statements. If you have comments about a particular statement, please add that to the "comments section" at the end of Q5.

1. It is nearly impossible to address all four disciplines in every lesson, particularly to the same depth and degree; but, it is important that all STEM content is included throughout the course.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

2. If a lesson fails to include more than one, it should not be called education, let alone STEM education.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

3. Most STEM lessons include all of the disciplines, but it is often easy to identify the disciplinary background of the curriculum writer based on the depth of content.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

4. Not all problems will require the use of all STEM disciplines.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

5. It is important that a student address the problem creatively using appropriate content or skills from all four STEM areas.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

6. It is important that students have an understanding of 'technology' in STEM beyond the use of computers as a tool to solve problems.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

7. The understanding of the term STEM comes from the disciplinary components of the acronym and should not be redefined to include areas outside of science, technology, engineering, or mathematics, although STEM education may contain other disciplinary components.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

8. STEM lessons should include as many of the four disciplines as possible.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

9. STEM is more than a lesson label and one project might include a heavier emphasis and in one area than another as well as topic areas outside of the STEM fields.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

Q5- Comments, if any:

Q6 - Based on the collective Delphi panel's responses to identify the barriers to implementing an integrated STEM education curriculum into all grades K-12, the barriers identified can be categorized into four major themes: the structure of schools, standardized testing, teacher preparation, and parents and/or the community.

I have developed the following statements based on the responses to this question. Please identify the degree to which you agree or disagree with the following statements. If you have comments about a particular statement, please add that to the "comments section" at the end of Q6.

1. The infrastructure of middle school, high school, and college coursework is based on individual disciplines.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

2. The time required for problem and project-based learning is an issue.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

3. The staffing of schools relies on discipline-specific instructors.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

4. The expectations and culture of teachers, administrators, and parents are an issue.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

5. Many secondary schools lack the appropriate materials and resources necessary to implement integrated STEM education.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

6. Many elementary schools lack the appropriate materials and resources necessary to implement integrated STEM education.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

7. It is difficult for schools to find qualified staff to implement STEM.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

8. There are few barriers to implementing integrated STEM learning in grades K-5.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

9. Elementary teachers are very comfortable teaching reading, but not as much in STEM areas.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

10. Teacher preparation programs are too narrowly focused.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

11. K-8 teachers should be subject prepared similar to 9-12 teachers.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

12. Many teachers are uncomfortable teaching technology and engineering.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

13. Teachers need to have the prerequisite skillsets used for design-based learning approaches.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

14. State mandated tests limit the ability to integrate learning.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

15. There is broad societal acceptance of the model that specialization occurs as a student progresses in school.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

16. Parents do not understand the expectations of integrated STEM education.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

17. The community does not have a clear understanding of STEM education.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

Q6- Comments, if any:

Q7 - Of all of the commercially available STEM curricula what percentage do you feel are truly integrated?

Please explain.

Based on the collective Delphi panel's response to this question, very few, if any (less than 10%) of commercially available STEM curricula can be considered integrated. I have developed the following statements based on the responses to the above question. Please identify the degree to which you agree or disagree with the following statements. If you have comments about a particular statement, please add that to the "comments section" at the end of Q7.

1. The market for STEM curricula is not mainstream.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

3. The majority of STEM curricula is discipline specific; therefore the STEM curricula developed by science experts varies greatly from the STEM curricula written by math experts.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

4. Very few of the available integrated STEM curricula are learner level appropriate across all content areas.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

5. Commercial developers have traditionally not focused their work on sound pedagogical practices, but rather cool activities.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

6. Integrated STEM places an equal emphasis on the teaching and assessing—both technical and academic content.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

7. Many STEM programs have a narrow educational focus that includes a collection of activities and specific products.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

Q7- Comments, if any:

Q8 - Of the commercially available STEM curricula, which do you feel best represents integrated STEM? Please explain.

Based on the collective Delphi panel's response to identify the commercially available STEM curricula that best represent integrated STEM, the following have been suggested. I have also included a brief description about each. Please identify the degree to which you agree or disagree with the following responses from the panel. If you have comments about a particular statement, please add that to the "comments section" at the end of Q8.

1. *The Integrated Mathematics, Science, and Technology (IMaST)*

Developed by The Center for Mathematics, Science and Technology at Illinois State University's, the IMaST program is an integrated mathematics, science, and technology curriculum for 6-8 grades. IMaST was developed by funding from the NSF, Eisenhower funds from the Illinois State Board of Education, and Illinois State University. The IMaST curriculum consists of theme-based modules based benchmarks, national standards, and state frameworks in mathematics, science, and technology (IMaST; Center for Mathematics, Science and Technology, 2012).

Strongly disagree
 Disagree
 Neither agree nor disagree
 Agree
 Strongly agree

2. *City Technology*

City Technology was an outgrowth of a previous project called City Science, an NSF-funded professional development effort that engaged 75 public elementary teachers from Harlem and the South Bronx during 1992-1995. The theme of City Science was to use the urban environment as a source of material for elementary science. Components of the project were the Built Environment, the Natural Environment and the Human Environment. Currently, the, Physical Science Comes Alive, is an outgrowth of previous work on mechanisms and circuits, and consists of two sets of four curriculum units each, Force & Motion and Energy Systems, distributed over the grade bands K-1, 2-3 and 4-5. These units integrate engineering, science, math, literacy and art, in the context of children designing their own toys, cards and books (City Technology, The City College of New York, 2013).

Strongly disagree
 Disagree
 Neither agree nor disagree
 Agree
 Strongly agree

3. *INcreasing Student Participation, Interest and Recruitment in Engineering and Science (INSPIRES)*

INSPIRES is a collaborative project between the University of Maryland Baltimore County and University of Maryland School of Medicine and is funded through a grant from the National Science Foundation. The project is designed to target the core engineering skills and concepts that should be addressed at the high school level in order to better prepare students to pursue engineering and technology related careers (University of Maryland Baltimore County and University of Maryland School of Medicine, 2010).

Strongly disagree
 Disagree
 Neither agree nor disagree
 Agree
 Strongly agree

4. *Project Lead the Way (PLTW)*

PLTW was initially developed by New York's Shenendehowa Central School District and further expanded by SREB's High Schools That Work as a hands-on, project-based engineering and biomedical sciences curriculum for middle and high school students. The initiative is funded by Charitable Leadership Foundation (CLF), the Kern Family Foundation, NASA, affiliate universities, and industry partners (PLTW, 2012).

 Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

5. *Engineering is Elementary (EiE)*

Originally developed by the Boston Museum of Science, EiE is a research-based grades 1-5 STEM curriculum designed to focus on students' knowledge of science and engineering to design, create, and improve solutions. EiE is primarily funded by the NSF and matching funds from industry. The EiE curriculum is based on 20 units that are designed to meet the ITEEA Standards for Technological Literacy and the Massachusetts' science standards (EiE, 2013).

 Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

6. *Math Trailblazers*

Developed by the Teaching Integrated Mathematics and Science Project, Institute of Mathematics and Science Education, and the University of Illinois at Chicago, Math Trailblazers is a research-based K-5 mathematics program focuses on real problems are naturally interdisciplinary and is aligned to the Common Core State Standards and integrates math, science and language arts (Kendal Hunt Publishing, 2013, Education Development Center, Math Trailblazers, 2001).

 Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

7. *The SIMMS Integrated Mathematics*

Developed by the Montana Council of Teachers of Mathematics through a State Systemic Initiative Award from the National Science Foundation, The SIMMS Integrated Mathematics curriculum is a complete NCTM Standards-based mathematics program is designed to replace all grade 9-12 mathematics by involving students with real world contexts and incorporating a modeling approach using technology (Kendal Hunt Publishing, 2013).

 Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

8. *Preparation for Tomorrow (PFT)*

Preparation for Tomorrow is an initiative of the Southern Regional Education Board (SREB) and a consortium of states to create career pathway programs of study that prepare high school students for careers and meaningful credentials or postsecondary certificates or degrees. The initiative creates curricula for all students by blending learning experiences that advance students' literacy, math, science and technical knowledge and skills, and that strengthen the habits of behavior and mind for success. Understanding students' interests, abilities and potential career goals, and possible educational and training paths leads to students' deeper understanding of postsecondary education and workplace opportunities (SREB, 2013).

 Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

9. *Fischertechnik STEM Labs*

The Fischertechnik STEM Lab Programs are a standards-based curriculum involving inquiry, design and problem solving, especially developed for use with the Fischertechnik construction system. The program combines Middle School and High School curriculum with hands-on exploration and creation and consists of various theme projects for teachers to use with their students to enable them to explore and understand different essential STEM concepts areas (Fischertechnik STEM Lab, 2012).

 Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

10. *STEM 101*

Developed by The STEM Academy, the STEM 101 K-12 curriculum was collaboratively developed by K-12 teachers, school administrators, university educators, industry partners, engineering and biomedical professionals to improve rural and low-income student growth, close achievement gaps, decrease dropout rates, increase high school graduation rates and teacher effectiveness. The curriculum focuses on students applying real-world application of their STEM education with hands-on activities and maps to the Common Core, International Technology Engineering Education Association, Accreditation Board for Engineering and Technology, National Research Council (Science), and the National Council of Teachers of Mathematics (The STEM Academy, 2013).

 Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

11. *The Infinity Project*

Developed by the Caruth Institute for Engineering Education at Southern Methodist University, the Infinity Project is an engineering curriculum for grades 6-12 designed to focus on the preparation of educators and students future success in STEM fields. The project is funded by the DOE, NSF, Texas Instruments, and numerous other industry partners. The Infinity Project curriculum is in use by 37 states (Infinity Project, 2012).

 Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

Q8- Comments, if any:

Q9 - In your opinion, how might a curriculum designer assure that a curriculum is truly integrated?

Based on the collective Delphi panel's response to identify how a curriculum designer might assure that a curriculum is truly integrated, I have developed the following statements. Please identify the degree to which you agree or disagree with the following statements. If you have comments about a particular statement, please add that to the "comments section" at the end of Q9.

1. The classroom teachers should be able to easily identify individual content standards within the curriculum.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

2. Traditional teaching methods are more efficient in time and materials than integrated STEM methods.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

3. STEM curriculum should include the alignment of technology and engineering concepts, processes, and approaches with grade-appropriate science and mathematics.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

4. When asked about an "integrated" lesson, students either cannot identify a specific discipline area or disagree on the discipline area covered in the lesson.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

5. Curriculum should be developed by a team of experts representing a wide span of disciplines including academia and industry.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

6. Integrated STEM curriculum must align with the current goals and objectives of a school.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

7. Review of STEM curricula by an interdisciplinary panel is essential.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

8. Curriculum must include a student-centered approach to solving real-world challenges.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

9. The curriculum must be aligned to current and future workforce needs

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

10. STEM curriculum requires the application of subject matter from a variety of disciplines.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

Q9- Comments, if any:

Q10 – In your opinion, what is the driving force behind most commercially available STEM curriculum?

Based on the collective Delphi panel's responses to this question, money, national standards, professional organizations, and attention at the state and national levels are the driving forces behind most commercially available STEM curriculum. From the panel's responses I have developed the following statements. Please identify the degree to which you agree or disagree with the following statements. If you have comments about a particular statement, please add that to the "comments section" at the end of Q10.

1. Curriculum writers and textbook publishers see the potential market of STEM education.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

2. A great deal of federal and private grant money designated to address these needs of STEM is available to schools.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

3. Businesses and schools are pressured by the interest in STEM, despite understanding or not understanding the meaning of STEM.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

4. National standards affect curricula development and state adoption.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

5. Professional organizations support the development of STEM curriculum because the future workforce depends on the younger generation.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

6. National attention on STEM issues and the need for STEM graduates effect the development of curricula.

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

Q10- Comments, if any:

Thank you very much for completing the survey. Please save the Word® document as Round 2 and forward it to me, Vinson Carter at . Your responses will remain confidential. Please return your response by Monday, March 24, 2013.

Appendix G: Round Three Letter to Participants



314 Peabody Hall ♦ Fayetteville, Arkansas 72701 ♦ (479) 575-3076 ♦ (479) 575-6676 (Fax)
Department of Curriculum & Instruction, College of Education & Health Professions

Round 3 - Integrated STEM Education Delphi Study

Dear _____,

Thank you very much your continued support and participation in my study to determine the defining characteristics of an integrated STEM education curriculum. As you will recall, the purpose of Round 1 of this Delphi study was to identify the defining characteristics of an integrated STEM education curriculum. The purpose of Round 2 was to draw consensus on the topics that you believe are important to establish a better knowledge base for integrated STEM education.

The purpose of Round 3 is to establish a set of categorical and defining curricular components that must be included in an integrated STEM education curriculum based on the following descriptors: essential items, important items, and nonessential items. Although conclusive procedures for consensus are not apparent in the literature (Hsu & Standford, 2007; Kennedy, 2002), I have determined that consensus occurred when the central tendency or mean was ≥ 4 (agreement) or ≤ 2 (disagreement).

I apologize for the length of the survey; however, I really only need you to respond to the 85 Likert items. The items that need a response appear as **black text**, and the items that provide information appear as **blue text**. As always, comments are welcome, and will be included in the results of the study.

Please complete the attached survey, save the Word® document as Round 3, and forward it to me, Vinson Carter at _____ . Your responses will remain confidential. Please return your response by Friday, April 26, 2013.

Sincerely,

Vinson Carter

Appendix H: Round Three Instrument

Delphi Survey 3 - DEFINING CHARACTERISTICS OF AN INTEGRATED STEM CURRICULUM IN K-12 EDUCATION

Black – Responses Needed

Blue – Directions/Study Information/Previous Participant Comments

Q1 - What are essential curriculum components of integrated K-12 STEM Education?

Based on the collective Delphi panel's initial responses to identify the essential curriculum components of integrated K-12 STEM Education in the Round 1 Survey, a set of statements were created based on the essential components identified. In the Round 2 Survey panelists individually identified the degree to which they agree or disagree with these statements. A consensus did occur based on the mean responses (≥ 4 - agreement or ≤ 2 - disagreement) from the panel on the following statements. Because the items were originally identified as essential curriculum components of integrated K-12 STEM Education by members of the Delphi panel, please identify whether or not the following statements are important or essential.

1. Real-world problem-solving and application including creative design, testing, and evaluation of solutions are used to utilize students' base knowledge of science and mathematics. (Q1-3 - $n = 12$, Mean = 4.33, Standard Deviation = .94)

Important Essential

Previous participant comments:

- Confuses the issue of whether the real goal is to develop design & problem-solving or justify math & science learning, and it might not be possible to do both
- Statement is too ambiguous

Additional comments, if any:

2. The curriculum is comprised of project-based work with sufficient time for students to engage in designing, making, testing, reflecting and documenting. (Q1-4 - $n = 12$, Mean = 4.5, Standard Deviation = .87)

Important Essential

Additional comments, if any:

3. Skill development, including logical reasoning and computer skills are interwoven. (Q1-5 - $n = 12$, Mean = 4.17, Standard Deviation = .55)

Important Essential

Previous participant comments:

- Some skills may be pre-requisite, i.e. instruction is designed based on assumptions that students have a skill level that will be enhanced by instruction.
- The skills are not identified clearly, not is "logical reasoning" simply a "skill."

Additional comments, if any:

4. Curriculum must be centered around a project that places all the learning into context. Planning is essential to assure that the project is authentic, that the learning is controlled by the students and that a presentation be made to an authentic audience.

(Q1-6 - $n = 12$, Mean = 4.5, Standard Deviation = .65)

Important Essential

Previous participant comments:

- What are the appropriate number of days to be allocated for a project/unit? How often should units have a presentation made to an authentic audience? Is this specific to grade levels?

Additional comments, if any:

A consensus did not occur based on the mean responses (≥ 4 - agreement or ≤ 2 -disagreement) from the panel on the following statements. Because the items were originally identified as essential curriculum components of integrated K-12 STEM Education by members of the Delphi panel, and the panel agreed with these statements in the Round 2 Survey, please identify whether or not the following components are nonessential or important.

5. The curriculum clearly addresses the appropriate grade-level educational standards/content of each individual discipline without isolating it to one discipline. (Q1-1 - $n = 12$, Mean = 3.75, Standard Deviation = 1.01)

Nonessential Important

Previous participant comments:

- The answer to #1 would depend on which "content/standards" are addressed

Additional comments, if any:

6. Instruction in reading, writing, and numeracy are used to enable effective communication in problem-solving. (Q1-2 - $n = 12$, Mean = 3.92, Standard Deviation = .76)

Nonessential Important

Previous participant comments:

- I don't know what "effective communication in problem-solving" means, nor how instruction will be used to enable it

Additional comments, if any:

Q2 - What are items that differentiate a single discipline from an integrated STEM curriculum?

Based on the collective Delphi panel's initial responses to identify the items that differentiate a single discipline from an integrated STEM curriculum in the Round 1 Survey, a set of statements were created based on the items identified. In the Round 2 Survey panelists individually identified the degree to which they agree or disagree with these statements. **A consensus did occur based on the mean responses (≥ 4 - agreement or ≤ 2 - disagreement) from the panel on the following statements. Because the items were originally identified items that differentiate a single discipline from an integrated STEM curriculum by members of the Delphi panel, and**

the panel agreed with these statements in the Round 2 Survey, please identify whether or not the following items are important or essential.

1. Engages students in content from multiple disciplines. (Q2-1 - $n = 12$, Mean = 4.58, Standard Deviation = .49)

Important Essential

Additional comments, if any:

2. Natural intersections of learning are utilized to bridge the study and application of combined conceptual knowledge.

(Q2-2 - $n = 12$, Mean = 4.5, Standard Deviation = .50)

Important Essential

Previous participant comments:

- Not sure what 'natural intersections of learning' means.

Additional comments, if any:

3. Includes the application and exploration of real-world problems requiring students to think and reason.

(Q2-3 - $n = 12$, Mean = 4.33, Standard Deviation = .62)

Important Essential

Additional comments, if any:

4. Includes project-based work on open-ended problems. (Q2-4 - $n = 12$, Mean = 4.17, Standard Deviation = .55)

Important Essential

Additional comments, if any:

5. Delivers crosscutting concepts such as critical thinking and problem solving to support the interdisciplinary views of science and mathematics to better understand the world around us. (Q2-6 - $n = 12$, Mean = 4.17, Standard Deviation = .69)

Important Essential

Previous participant comments:

- I do not view critical thinking and problem solving as concepts that are delivered. I believe these are processes, and do not need to be named in the curriculum. Any good integrated STEM curriculum includes these processes.
- The context of the problem can be helpful for students to consider solutions. Creativity, however, should still be encouraged and supported.

Additional comments, if any:

A consensus did not occur based on the mean responses (≥ 4 - agreement or ≤ 2 -disagreement) from the panel on the following statements. Because the items were originally identified as items that differentiate a single discipline from an integrated STEM curriculum by members of the Delphi panel, and the panel agreed with these statements in the Round 2 Survey, please identify whether or not the following components are nonessential or important.

6. Utilizes a meta-discipline approach, where ideally, no single subject or discipline defines the curriculum.
(Q2-5 - $n = 12$, Mean = 3.67, Standard Deviation = 1.11)

Nonessential Important

Additional comments, if any:

7. Designed around several sets of national standards (such as CCSS, NGSS, ITEEA, etc.).
(Q2-7 - $n = 12$, Mean = 3.8, Standard Deviation = 1.1)

Nonessential Important

Previous participant comments:

- The areas that most concern me are content specificity and standards-based design. These are really the same issue. It is better to go deeply into one area than to be broad. However, best would be to go deeply into a multi-disciplinary, intellectually rich topic. This may mean that certain content standards are not "covered". However, the process standards would be.
- The technical content of the project is dominate; the academic subordinate- The use of the new Common Core Standards should be used by selecting only the most essential to the project - The technical content standards should be written specifically to the project

Additional comments, if any:

Q3 - Ideally, should all STEM lessons or activities be problem-based? Why or why not?

Round 1 Delphi Panel Responses to this question: Yes: $n = 5$ Yes, but ...: $n = 5$ No: $n = 0$ No, but ...: $n = 2$

Based on the collective Delphi panel's initial responses to identify if STEM lessons or activities should be problem-based in the Round 1 Survey, a set of statements were created by the responses to why or why not. In the Round 2 Survey panelists individually identified the degree to which they agree or disagree with these statements. A consensus did occur based on the mean responses (≥ 4 - agreement or ≤ 2 -disagreement) from the panel on the following statements. Please identify whether or not the following items are important or essential when considering if a STEM lesson or activity should be problem-based.

1. Problem-based instruction requires a shift in student expectations and engagement.
(Q3-1 - $n = 12$, Mean = 4.2, Standard Deviation = .60)

Important Essential

Additional comments, if any:

2. Some projects may include elements that are not problem-based (i.e., vocabulary, math instruction, etc.). These elements are essential in supporting student learning within problem-based lessons. (Q3-5 - $n = 12$, Mean = 4.0, Standard Deviation = .75)

Important _____ Essential

Previous participant comments:

- It's true that some educators think so, but I'm not one of them.

Additional comments, if any:

3. Problem-based STEM lessons prepare a learner to effectively apply curriculum learned to real-life problems and support the development of logical reasoning skills. (Q3-6 - $n = 12$, Mean = 4.33, Standard Deviation = .75)

Important _____ Essential

Previous participant comments:

- I think there are many questions around project-based learning. What a project is? How students learn? What the results should be? It's not just a question of what the most effective method of teaching is, but the most general context of learning and transfer.

Additional comments, if any:

4. Authentic problems are essential for an integrated approach because problems are rarely, if ever, answered by using knowledge and skill from one discipline alone. (Q3-7 - $n = 12$, Mean = 4.42, Standard Deviation = .64)

Important _____ Essential

Additional comments, if any:

5. STEM lessons should be problem-based to support critical thinking and problem solving in the real-world. (Q3-9 - $n = 12$, Mean = 4.42, Standard Deviation = .49)

Important _____ Essential

Additional comments, if any:

6. Problem-based learning supports students with authentic, meaningful learning experiences. (Q3-10 - $n = 12$, Mean = 4.42, Standard Deviation = .64)

Important _____ Essential

Additional comments, if any:

A consensus did not occur based on the mean responses (≥ 4 - agreement or ≤ 2 - disagreement) from the panel on the following statements. Please identify whether or not the following components are nonessential or important when considering if a STEM lesson or activity should be problem-based.

7. Some educators would argue that some content simply cannot be taught through a problem-based approach. (Q3-2 - $n = 12$, Mean = 3.0, Standard Deviation = 1.5)

Nonessential Important

Additional comments, if any:

8. This is a question of what is the most effective teaching strategy for that particular topic. (Q3-3 - $n = 12$, Mean = 3.2, Standard Deviation = 1)

Nonessential Important

Additional comments, if any:

9. Background and cognitive knowledge must be established before students are ready for problem-based experiences. (Q3-4 - $n = 12$, Mean = 2.5, Standard Deviation = 1.26)

Nonessential Important

Additional comments, if any:

10. Problem-based STEM lessons do not have to be product based, but should include the development of a hypothesis development and a defense. (Q3-8 - $n = 12$, Mean = 3.25, Standard Deviation = 1.01)

Nonessential Important

Previous participant comments:

- What is "product based"? I would consider the artifacts developed to provide for the defense of a hypothesis, a product.

Additional comments, if any:

11. Problems are real world issues that students must tackle. There are no existing answers and the students have to design the entire approach to the solution. Solutions to a problem are not by nature related to the solutions arrived at by others. (Q3-11 - $n = 12$, Mean = 3.42, Standard Deviation = 1.19)

Nonessential Important

Previous participant comments:

- Sometimes, using historical problems works. Answers can be known.

Additional comments, if any:

Q4 - Should STEM curriculum be based primarily upon the disciplinary background of the instructor? Why or why not?

Round 1 Delphi Panel Responses to this question: Yes: $n = 1$ No: $n = 4$ Maybe: $n = 7$

Based on the collective Delphi panel's initial responses to identify if STEM curriculum be based primarily upon the disciplinary background of the instructor in the Round 1 Survey, a set of statements were created by the responses to why or why not. In the Round 2 Survey panelists individually identified the degree to which they agree or disagree with these statements. A consensus did occur based on the mean responses (≥ 4 - agreement or ≤ 2 - disagreement) from the panel on the following statements. Please identify whether or not the following items are important or essential when considering if a STEM curriculum should be based primarily upon the disciplinary background of the instructor.

1. Disciplinary knowledge is a must. (Q4-2 - $n = 12$, Mean = 4.17, Standard Deviation = .69)

Important Essential

Previous participant comments:

- In each case, my answer would be "it depends."

Additional comments, if any:

2. Current staffing models in secondary schools make it difficult to develop integrated curriculum. (Q4-3 - $n = 12$, Mean = 4.25, Standard Deviation = .92)

Important Essential

Additional comments, if any:

3. If properly prepared, a STEM teacher would understand where his/her shortcomings are and complete professional development to strengthen his/her skills. (Q4-9 - $n = 12$, Mean = 4.17, Standard Deviation = 1.28)

Important Essential

Previous participant comments:

- The only intervention to improving education lies with curriculum and teacher PD, Teacher PD must rigorous taught by experts and reinforced through virtual ongoing PD

Additional comments, if any:

4. The background of the instructor enables the instructor to provide students with personal examples from experience that help build student interest and learning. (Q4-11 - $n = 12$, Mean = 4.33, Standard Deviation = .62)

Important Essential

Additional comments, if any:

5. STEM teacher training should be provided through professional development which allows teachers to demonstrate their ability to teach the curriculum. (Q4-12 - $n = 12$, Mean = 4.25, Standard Deviation = .72)

Important Essential

Previous participant comments:

- This is confusing. Not sure if you are asking for teachers to demonstrate a way to show mastery for completion or certification or for sharing ideas with other teachers as to how they would conduct a project.

Additional comments, if any:

A consensus did not occur based on the mean responses (≥ 4 - agreement or ≤ 2 - disagreement) from the panel on the following statements. Please identify whether or not the following components are nonessential or important when considering if a STEM curriculum should be based primarily upon the disciplinary background of the instructor.

6. Any educator can teach integrated STEM. (Q4-4 - $n = 12$, Mean = 2.0, Standard Deviation = 1.15)

Nonessential Important

Previous participant comments:

- In each case, my answer would be "it depends."

Additional comments, if any:

7. It is important that teachers do not have a discipline-specific identity. (Q4-1 - $n = 12$, Mean = 2.25, Standard Deviation = .72)

Nonessential Important

Previous participant comments:

- Teacher specialty areas will be one of the biggest challenges. Lots of piloting will be required.

Additional comments, if any:

8. It is easier to integrate STEM learning in the elementary grades, where teachers are generalists. (Q4-5 - $n = 12$, Mean = 2.58, Standard Deviation = 1.04)

Nonessential Important

Additional comments, if any:

9. STEM curriculum should be developed and standardized. (Q4-6 - $n = 12$, Mean = 3.5, Standard Deviation = 1.04)

Nonessential Important

Previous participant comments:

- In each case, my answer would be "it depends."

Additional comments, if any:

10. The instructor should be selected based on his/her qualifications to adequately teach the curriculum. (Q4-7 - $n = 12$, Mean = 3.92, Standard Deviation = .49)

Nonessential Important

Previous participant comments:

- In each case, my answer would be "it depends."

Additional comments, if any:

11. Integrated STEM curriculum should not be determined by the instructor's ability. (Q4-8 - $n = 12$, Mean = 3.67, Standard Deviation = 1.37)

Nonessential Important

Additional comments, if any:

12. It is nearly impossible for one to be proficient in all of the STEM disciplines, but one can become an effective STEM teacher by just understanding the pedagogical content knowledge. (Q4-10 - $n = 12$, Mean = 3.92, Standard Deviation = .64)

Nonessential Important

Additional comments, if any:

13. It is important that integrated STEM curriculum rotate the main content emphasis of projects to encourage student interest and participation. (Q4-13 - $n = 12$, Mean = 3.75, Standard Deviation = .92)

Nonessential Important

Previous participant comments:

- In each case, my answer would be "it depends."
- I am not sure that rotation of the main content will encourage student interest. Students get bored with repetition, but they also sense when a project is artificial and things are forced. Project cut across the disciplines and emphasis should be placed in different areas to help round out skill sets.

Additional comments, if any:

Q5 - If a STEM lesson fails to include one or more disciplines, should it be referred to as STEM education? Why or why not?

Round 1 Delphi Panel Responses to this question: Yes: $n = 2$ No: $n = 6$ Indefinite: $n = 3$ It is impossible: $n = 1$

Based on the collective Delphi panel's initial responses to identify whether a STEM lesson that fails to include one or more disciplines should be referred to as STEM education in the Round 1 Survey, a set of statements were created by the responses to why or why not. In the Round 2 Survey panelists individually identified the degree to which they agree or disagree with these statements. A consensus did occur based on the mean

responses (≥ 4 - agreement or ≤ 2 -disagreement) from the panel on the following statements. Please identify whether or not the following items are important or essential when considering whether a STEM lesson that fails to include one or more disciplines should be referred to as STEM education.

Previous participant comments:

- This depends on the particular curriculum, or are about how the term should be used, which depends on who's using it & why.
- Ben Franklin addressed this concept 260 years ago and the debate is on-going. STEM is a label and it is important to treat it as such. Good project based learning requires students to struggle and fail in the development of solutions. STEM subjects are inter-related and require a lot of effort to master, but taught in a vacuum they lose meaning.

1. It is important that students have an understanding of 'technology' in STEM beyond the use of computers as a tool to solve problems. (Q5-6 - $n = 12$, Mean = 4.83, Standard Deviation = .37)

Important Essential

Additional comments, if any:

2. STEM lessons should include as many of the four disciplines as possible. (Q5-8 - $n = 12$, Mean = 4.42, Standard Deviation = .76)

Important Essential

Additional comments, if any:

3. STEM is more than a lesson label and one project might include a heavier emphasis and in one area than another as well as topic areas outside of the STEM fields. (Q5-9 - $n = 12$, Mean = 4.27, Standard Deviation = .75)

Important Essential

Additional comments, if any:

A consensus did not occur based on the mean responses (≥ 4 - agreement or ≤ 2 -disagreement) from the panel on the following statements. Please identify whether or not the following components are nonessential or important when considering whether a STEM lesson that fails to include one or more disciplines should be referred to as STEM education.

4. It is nearly impossible to address all four disciplines in every lesson, particularly to the same depth and degree; but, it is important that all STEM content is included throughout the course. (Q5-1 - $n = 12$, Mean = 3.75, Standard Deviation = 1.16)

Nonessential Important

Additional comments, if any:

5. If a lesson fails to include more than one, it should not be called education, let alone STEM education. (Q5-2 - $n = 12$, Mean = 2.33, Standard Deviation = 1.03)

Nonessential Important

Additional comments, if any:

6. Most STEM lessons include all of the disciplines, but it is often easy to identify the disciplinary background of the curriculum writer based on the depth of content. (Q5-3 - $n = 12$, Mean = 3.25, Standard Deviation = 1.16)

Nonessential Important

Additional comments, if any:

7. Not all problems will require the use of all STEM disciplines. (Q5-4 - $n = 12$, Mean = 3.92, Standard Deviation = .86)

Nonessential Important

Additional comments, if any:

8. It is important that a student address the problem creatively using appropriate content or skills from all four STEM areas. (Q5-5 - $n = 12$, Mean = 3.33, Standard Deviation = .85)

Nonessential Important

Additional comments, if any:

9. The understanding of the term STEM comes from the disciplinary components of the acronym and should not be redefined to include areas outside of science, technology, engineering, or mathematics, although STEM education may contain other disciplinary components. (Q5-7 - $n = 12$, Mean = 3.50, Standard Deviation = 1.12)

Nonessential Important

Additional comments, if any:

Q6 - What are barriers to implementing a STEM curriculum into all grades K-12?

The collective Delphi panel's initial responses to identify the barriers to implementing an integrated STEM education curriculum into all grades K-12 emerged into four major themes: the structure of schools, standardized testing, teacher preparation, and parents and/or the community during the Round 1 Survey. A set of statements were created by these responses to identify these barriers. In the Round 2 Survey panelists individually identified the degree to which they agree or disagree with these statements. A consensus did occur based on the mean responses (≥ 4 - agreement or ≤ 2 -disagreement) from the panel on the following statements. Please identify whether or not the following items are important or essential when considering the barriers to implementing an integrated STEM education curriculum into all grades K-12.

1. The infrastructure of middle school, high school, and college coursework is based on individual disciplines. (Q6-1 - $n = 12$, Mean = 4.75, Standard Deviation = .43)

Important Essential

Previous participant comments:

- But this is not the most ideal situation it just is what it is.

Additional comments, if any:

2. The expectations and culture of teachers, administrators, and parents are an issue. (Q6-4 - $n = 12$, Mean = 4.17, Standard Deviation = .90)

Important Essential

Additional comments, if any:

3. It is difficult for schools to find qualified staff to implement STEM. (Q6-7 - $n = 12$, Mean = 4.00, Standard Deviation = .91)

Important Essential

Additional comments, if any:

4. Elementary teachers are very comfortable teaching reading, but not as much in STEM areas. (Q6-9 - $n = 12$, Mean = 4.17, Standard Deviation = .55)

Important Essential

Additional comments, if any:

5. Teacher preparation programs are too narrowly focused. (Q6-10 - $n = 12$, Mean = 4.33, Standard Deviation = .75)

Important Essential

Previous participant comments:

- Are we discussing undergraduate programs in general? If so, then yes.

Additional comments, if any:

6. Many teachers are uncomfortable teaching technology and engineering. (Q6-12 - $n = 12$, Mean = 4.50, Standard Deviation = .50)

Important Essential

Additional comments, if any:

A consensus did not occur based on the mean responses (≥ 4 - agreement or ≤ 2 - disagreement) from the panel on the following statements. Please identify whether or not the following components are nonessential or important when considering the barriers to implementing an integrated STEM education curriculum into all grades K-12.

7. The time required for problem and project-based learning is an issue. (Q6-2 - $n = 12$, Mean = 3.25, Standard Deviation = 1.16)

Nonessential Important

Additional comments, if any:

8. The staffing of schools relies on discipline-specific instructors. (Q6-3 - $n = 12$, Mean = 3.38, Standard Deviation = .69)

Nonessential Important

Additional comments, if any:

9. Many secondary schools lack the appropriate materials and resources necessary to implement integrated STEM education. (Q6-5 - $n = 12$, Mean = 3.70, Standard Deviation = 1.20)

Nonessential Important

Additional comments, if any:

10. Many elementary schools lack the appropriate materials and resources necessary to implement integrated STEM education. (Q6-6 - $n = 12$, Mean = 3.33, Standard Deviation = 1.25)

Nonessential Important

Additional comments, if any:

11. There are few barriers to implementing integrated STEM learning in grades K-5. (Q6-8 - $n = 12$, Mean = 2.42, Standard Deviation = 1.04)

Nonessential Important

Additional comments, if any:

12. K-8 teachers should be subject prepared similar to 9-12 teachers. (Q6-11 - $n = 12$, Mean = 2.56, Standard Deviation = 1.12)

Nonessential Important

Additional comments, if any:

13. Teachers need to have the prerequisite skillsets used for design-based learning approaches. (Q6-13 - $n = 12$, Mean = 3.92, Standard Deviation = .76)

Nonessential Important

Additional comments, if any:

14. State mandated tests limit the ability to integrate learning. (Q6-14 - $n = 12$, Mean = 3.58, Standard Deviation = 1.26)

Nonessential Important

Previous participant comments:

- Make the state tests standards based and the education system will change

Additional comments, if any:

15. There is broad societal acceptance of the model that specialization occurs as a student progresses in school. (Q6-15 - $n = 12$, Mean = 3.67, Standard Deviation = 1.11)

Nonessential Important

Additional comments, if any:

16. Parents do not understand the expectations of integrated STEM education. (Q6-16 - $n = 12$, Mean = 3.67, Standard Deviation = .75)

Nonessential Important

Additional comments, if any:

17. The community does not have a clear understanding of STEM education. (Q6-17 - $n = 12$, Mean = 3.83, Standard Deviation = .90)

Nonessential Important

Previous participant comments:

- The real impediments to STEM education come from the educational establishment not the community. There are many turf, seniority and union issues. Heavy focus on standardized testing required courses for graduation, and focus on low level memorization and history of science type education work against the implementation of project based education which values in-depth research vs. broad mile wide foot deep approaches.

Additional comments, if any:

**Q7 - Of all of the commercially available STEM curricula what percentage do you feel are truly integrated?
Please explain.**

In the Round 1 Survey the collective Delphi panel's initial responses to this question indicated that, very few, if any (less than 10%) of commercially available STEM curricula can be considered integrated. In the Round 2 Survey panelists individually identified the degree to which they agree or disagree with these statements based upon the panel's responses. A consensus did occur based on the mean responses (≥ 4 - agreement or ≤ 2 - disagreement) from the panel on the following statement. Please identify whether or not the following items are important or essential when considering if a STEM curricula is truly integrated.

1. Integrated STEM places an equal emphasis on the teaching and assessing —both technical and academic content.

(Q7-5 - $n = 12$, Mean = 4.08, Standard Deviation = .64)

Important Essential

Additional comments, if any:

A consensus did not occur based on the mean responses (≥ 4 - agreement or ≤ 2 -disagreement) from the panel on the following statements. Please identify whether or not the following components are nonessential or important when considering if a STEM curricula is truly integrated.

2. The market for STEM curricula is not mainstream. (Q7-1 - $n = 12$, Mean = 3.25, Standard Deviation = 1.16)

Nonessential Important

Additional comments, if any:

3. The majority of STEM curricula is discipline specific; therefore the STEM curricula developed by science experts varies greatly from the STEM curricula written by math experts. (Q7-2 - $n = 12$, Mean = 3.83, Standard Deviation = .80)

Nonessential Important

Additional comments, if any:

4. Very few of the available integrated STEM curricula are learner level appropriate across all content areas. (Q7-3 - $n = 12$, Mean = 3.08, Standard Deviation = .95)

Nonessential Important

Previous participant comments:

- I do not have a good command of commercially available STEM curricula.

Additional comments, if any:

5. Commercial developers have traditionally not focused their work on sound pedagogical practices, but rather cool activities.

(Q7-4 - $n = 12$, Mean = 3.58, Standard Deviation = .64)

Nonessential Important

Additional comments, if any:

6. Many STEM programs have a narrow educational focus that includes a collection of activities and specific products.

(Q7-6 - $n = 12$, Mean = 3.50, Standard Deviation = .87)

Nonessential Important

Previous participant comments:

- I do not have a good command of commercially available STEM curricula.
- I wasn't really sure how I was to respond to these different questions or descriptions. Also, I am not familiar with all of them, so it is hard to know or understand what each consists of or is comprised of regardless of who created and developed them.

Additional comments, if any:

Q8 - Of the commercially available STEM curricula, which do you feel best represents integrated STEM? Please explain.

The collective Delphi panel identified the commercially available curricula that best represent integrated STEM during the Round 1 Survey. In the Round 2 Survey panelists individually identified the degree to which they agree or disagree with the identified curricula. A consensus did not occur based on the mean responses (≥ 4 - agreement or ≤ 2 -disagreement) to identify the commercially available curricula that best represent integrated STEM. No further input is needed for this question.

Q9 - In your opinion, how might a curriculum designer assure that a curriculum is truly integrated?

Based on the collective Delphi panel's initial responses to how a curriculum designer might assure that a curriculum is truly integrated, a set of statements were created by the responses. In the Round 2 Survey panelists individually identified the degree to which they agree or disagree with these statements. A consensus did occur based on the mean responses (≥ 4 - agreement or ≤ 2 -disagreement) from the panel on the following statements. Please identify whether or not the following items are important or essential when considering how a curriculum designer might assure that a curriculum is truly integrated.

1. Traditional teaching methods are more efficient in time and materials than integrated STEM methods.

(Q9-2 - $n = 11$, Mean = 1.8, Standard Deviation = .70)

Important Essential

Additional comments, if any:

2. STEM curriculum should include the alignment of technology and engineering concepts, processes, and approaches with grade-appropriate science and mathematics. (Q9-3 - $n = 12$, Mean = 4.40, Standard Deviation = .50)

 _____ Important Essential _____

Additional comments, if any:

3. Review of STEM curricula by an interdisciplinary panel is essential. (Q9-7 - $n = 12$, Mean = 4.20, Standard Deviation = .70)

 _____ Important Essential _____

Previous participant comments:

- All reviews must include community stakeholders and not just school teachers and admin.

Additional comments, if any:

4. Curriculum must include a student-centered approach to solving real-world challenges. (Q9-8 - $n = 12$, Mean = 4.50, Standard Deviation = .50)

 _____ Important Essential _____

Additional comments, if any:

5. The curriculum must be aligned to current and future workforce needs. (Q9-9 - $n = 12$, Mean = 4.00, Standard Deviation = .58)

 _____ Important Essential _____

Additional comments, if any:

6. STEM curriculum requires the application of subject matter from a variety of disciplines. (Q9-10 - $n = 12$, Mean = 4.42, Standard Deviation = .64)

 _____ Important Essential _____

Additional comments, if any:

A consensus did not occur based on the mean responses (≥ 4 - agreement or ≤ 2 - disagreement) from the panel on the following statements. Please identify whether or not the following items are nonessential or important when considering how a curriculum designer might assure that a curriculum is truly integrated.

7. The classroom teachers should be able to easily identify individual content standards within the curriculum. (Q9-1 - $n = 11$, Mean = 3.92, Standard Deviation = .76)

 _____ Nonessential Important _____

Additional comments, if any:

8. When asked about an “integrated” lesson, students either cannot identify a specific discipline area or disagree on the discipline area covered in the lesson. (Q9-4 - $n = 12$, Mean = 3.17, Standard Deviation = .80)

Nonessential Important

Additional comments, if any:

9. Curriculum should be developed by a team of experts representing a wide span of disciplines including academia and industry.
(Q9-5 - $n = 12$, Mean = 3.80, Standard Deviation = 1.00)

Nonessential Important

Additional comments, if any:

10. Integrated STEM curriculum must align with the current goals and objectives of a school.
(Q9-6 - $n = 12$, Mean = 3.50, Standard Deviation = 1.00)

Nonessential Important

Additional comments, if any:

Q10 – In your opinion, what is the driving force behind most commercially available STEM curriculum?

The collective Delphi panel’s initial responses to this question that money, national standards, professional organizations, and attention at the state and national levels are the driving forces behind most commercially available STEM curriculum during the Round 1 Survey. A set of statements were created by these responses to identify these driving forces. In the Round 2 Survey panelists individually identified the degree to which they agree or disagree with these statements. A consensus did occur based on the mean responses (≥ 4 - agreement or ≤ 2 -disagreement) from the panel on the following statements. Please identify whether or not the following items are important or essential when considering the driving force behind most commercially available STEM curriculum.

1. Curriculum writers and textbook publishers see the potential market of STEM education.
(Q10-1 - $n = 12$, Mean = 4.08, Standard Deviation = 1.04)

Important Essential

Additional comments, if any:

2. Businesses and schools are pressured by the interest in STEM, despite understanding or not understanding the meaning of STEM. (Q10-3 - $n = 12$, Mean = 4.08, Standard Deviation = .95)

Important Essential

Additional comments, if any:

3. National standards affect curricula development and state adoption. (Q10-4 - $n = 12$, Mean = 4.25, Standard Deviation = .83)

Important Essential

Additional comments, if any:

4. Professional organizations support the development of STEM curriculum because the future workforce depends on the younger generation. (Q10-5 - $n = 12$, Mean = 4.00, Standard Deviation = .91)

Important Essential

Additional comments, if any:

5. National attention on STEM issues and the need for STEM graduates effect the development of curricula. (Q10-6 - $n = 12$, Mean = 4.12, Standard Deviation = .55)

Important Essential

Additional comments, if any:

A consensus did not occur based on the mean responses (≥ 4 - agreement or ≤ 2 -disagreement) from the panel on the following statement. Please identify whether or not the following items are nonessential or important when considering the driving force behind most commercially available STEM curriculum.

6. A great deal of federal and private grant money designated to address these needs of STEM is available to schools. (Q10-2 - $n = 12$, Mean = 3.33, Standard Deviation = 1.18)

Nonessential Important

Additional comments, if any:

Thank you very much for completing the survey. Please save the Word® document as Round 3 and forward it to me, Vinson Carter at . Your responses will remain confidential. Please return your response by Friday, April 26, 2013.